ORTHOPAEDIC REHABILITATION OF THE ATHLETE

GETTING BACK IN THE GAME





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Orthopaedic Rehabilitation of the Athlete

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PREFACE

Orthopaedic Rehabilitation of the Athlete was designed to be a comprehensive, extensively illustrated textbook about the rehabilitation of common musculoskeletal conditions that affect athletes—from the professional competitor to the occasional participant. The textbook is the first of its kind to bring together surgeons, therapists, and athletic trainers to address injuries from the cervical spine to the foot, and nearly everything in between.

Comprising 45 chapters and 242 internationally renowned authors, the content and organization of this work is unique. All chapters have between three and nine parts (separate sections) with additional authors and experts that tease out the most salient and clinically applicable features and scenarios for our patients. The fundamental issues in the care of each major injury are first introduced in separate chapters. Next, treatment regimens for nonoperative care are given, with guidelines describing the indications for surgical intervention. Each diagnostic section includes an operative portion that explains, in a highly illustrative manner, the surgical technique and intraoperative variations, so that the entire musculoskeletal care team can better understand how the details of surgery may affect the rehabilitative portion of the athlete's care.

For patients undergoing surgery, preoperative "pre-habilitation" and postoperative rehabilitation are described in great detail. All physicians, physical therapists, and athletic trainers who work with competitive athletes face the challenge of returning the athlete to competition as quickly, safely, and completely as possible. In compiling this book, we have emphasized the terminal and transitional phases of rehabilitation necessary to restore the athlete to competition. This includes many chapters with detailed rehabilitation plans customized for sports in which the injuries commonly occur. Many books that include rehabilitation do not emphasize this critical phase of the actual return to sport-specific training and competition. Often there seems to be a gap between traditional rehabilitation programs and the intense requirements of participation in specific sports. Much of this book is dedicated to this transitional phase of returning the athlete back to sports safely, using sport-specific rehabilitation programs and progressive return to training, participation, and competition. Detailed criteria are given to guide the clinician and facilitate the decision to discharge the athlete from rehabilitation and return him or her back to sports.

The textbook was formatted with a post-injury and recover timeline that will facilitate progression through a rehabilitation plan. This original feature is formatted in a timeline "ribbon" of rehabilitation progressions. Simply reviewing the ribbon will provide guidelines for the clinician to use when rehabilitating the patient following each specific injury. The timeline is designed with the "stoplight" concept: The red area of the timeline signifies that extreme caution is needed in the early stages, because of factors including pain, effusion, arthrogenic inhibition, soft tissue healing, and kinesophobia. In the yellow area of the timeline, a moderate degree of caution is still required in the progression of the patient. The green area of the timeline means that the patient can be accelerated and progress to the terminal and transitional phases of the rehabilitation program.

We hope that therapists, athletic trainers, surgeons, students, residents, and fellows, as well as others with an interest in the comprehensive care of the musculoskeletal system, will all find this book informative and useful for their education and practice. To enhance post-injury care, both the print and online versions have dedicated rehabilitation guidelines and exercise prescriptions that will enhance communication within musculoskeletal teams.

We are deeply indebted to our contributors. Without their incredible talent and expertise, this textbook would not have been possible. We are very fortunate to have authors who are leaders in their fields. We would also like to thank the Elsevier team of Ann Ruzycka Anderson, Don Scholz, and Jennifer Moore, who handled a complex and innovative publishing product with the highest level of dedication and professionalism.

Bruce Reider
George J. Davies
Matthew T. Provencher

Chapter 1



Anterior Shoulder Instability

INTRODUCTION

Ellen Shanley, PhD, PT, OCS, Charles A. Thigpen, PhD, PT, ATC, and Richard J. Hawkins, MD

Epidemiology

Overall Incidence

- Estimates of the initial incidence of anterior glenohumeral instability in the general population range from 8.2 occurrences per 100,000 person years[1] in the rural United States to as high as 24 occurrences per 100,000 person years in Scandinavian countries.[2,3]
- In NCAA athletes the instability incidence at the glenohumeral joint was calculated as 0.12 injuries per 1000 athletic exposures (AE).[4]
- The frequency of instability episodes in a military population over 1 year was calculated as 2.8%.[5]
- The overall injury rate, including both initial and recurrent episodes of shoulder instability, has been documented to significantly increase the total number of episodes.[1,4]

Age

- Owens et al. reported that 80% of shoulder dislocations occur in younger patients.[5] Forty seven percent of patients presenting to U.S. emergency departments with traumatic dislocations were between the age of 15 and 29.[6] A Scandinavian population study reported that the overall peak incidence of shoulder dislocations in males occurred between the ages 21 and 30 and in females between the ages of 61 and 80.[2] Recurrent instability has been reported at highest frequencies in patients younger than 20 years old (66% to 94%).[7,8]

Gender

- Male collegiate athletes (0.15/1000 AE) were 2.7 times more likely to sustain a shoulder instability episode than female (0.06/ 1000 AE) collegiate athletes.[4] In the military, male cadets had a slightly higher frequency of shoulder instability than their female counterparts with 2.9% and 2.5% documented over a 1-year study period, respectively.[5]

Sport

- In collegiate athletes, the rate of shoulder instability was greatest in Spring football at 0.40/1000 AE followed by wrestling (0.21/1000 AE), women's ice hockey (0.18/1000 AE) and fall football (0.18/1000 AEs).[4]
- In high school athletes, dislocations were reported to be higher in male sports (38%) than female sports (29%).[9] However, female basketball players sustained more shoulder dislocations than male basketball players (proportion ratio = 2.7).[9,10]
- Injuries were sustained more in games (0.31/1000 AE) than practices (0.09/1000 AE) and NCAA athletes were 3.5 times more likely to sustain an injury in games than in practice.[4]

Position

- In football, linebackers, wide receivers, and running backs most frequently sustained dislocations.[9]
- Outside hitters reported the highest percentage of shoulder dislocation amongst volleyball players [9]

Pathophysiology

Intrinsic Factors

- Several anatomic factors have been theorized to increase the potential for anterior instability of the

glenohumeral joint. Capsular redundancy, patulousness of the inferior glenohumeral capsule, variations in the capsular and ligament insertion to the glenoid, and laxity of the rotator interval have been identified as risk factors for initial and recurrent instability.[11,12] The glenoid labrum is a static stabilizer of the joint and disruption of this structure yields a decrease in the stability of approximately 10% in all directions.[13] Generalized joint hypermobility (Figure 1-1), as measured by the Beighton scale, has been associated with a 2.5 times increased risk of having reported an episode of glenohumeral instability.[14]

- The loss of osseous integrity by altered inclination or version, as well as bone loss on the glenoid or humeral side of the joint, may affect anterior and inferior joint stability. There is the concept of bone loss inferiorly which may suggest, if significant, a bone block operation rather than an arthroscopic Bankart type of repair.
  - Following failure of an arthroscopic procedure, an open procedure going through the subscapularis might be considered.
  - There may be associated pathology that requires attention such as a superior labrum anterior to posterior (SLAP) lesion. Most surgeons in doing a Bankart repair in the presence of a SLAP, also repair the SLAP for added stability.[15]
  - There is a relationship of the presence of SLAP tears and increased strain on the anterior inferior glenoid humeral ligament. Thus it is related to instability.
- Dynamic stability of the shoulder is dependent on concavity-compression.[16] This phenomenon is related to the centering forces produced by coordinated contraction of the rotator cuff musculature combined with proper position and stabilization of the scapula. [17] A lack of neuromuscular control secondary to interruption of descending neural input,[18-21] rotator cuff inhibition or decreased integrity,[13,22-25] or scapular dyskinesis can lead to shoulder instability.[26,27]

Extrinsic Factors

- The initial incidence of shoulder dislocation was greater in those involved in sport and recreational activities as compared with sedentary individuals in the general population.[2,6] Also, the frequency of recurrent dislocation was greater in athletes (> 80%) than the general population (33%).[7,28]
- Contact has been documented as the most common mechanism of shoulder dislocation.[9,29] In full to partial contact sports, contact with another participant was the most frequent cause of dislocation.[9] Another common mechanism for injury was player contact with equipment and playing surfaces.[9,10]
- In the general population, especially older women, falls on the outstretched arm have been theorized as a frequent cause of dislocation.[2]

Traumatic Factors

- Bankart described the mechanism for shoulder dislocation as a fall on the extended arm causing a forceful extension of the humerus resulting in anterior-inferior dislocation.[30]
- More recently, contact or externally applied energy to the distal upper extremity while the arm is abducted and externally rotated, forcing the shoulder beyond the limits of normal range of motion, has been documented in weight lifters and rugby players sustaining anterior shoulder dislocations.[31-33]

Classic Pathological Findings

- Intraarticular pathology, including disruption of the anterior inferior capsule and labrum associated with anterior dislocation has been classically documented by Perthes (Figure 1-2).[34] Bankart has been credited with describing a shearing disruption of the glenoid labrum naming this the "essential lesion" of any anterior glenohumeral dislocation (Figure 1-3).[30] Previously, Flower in 1861 and Caird in 1887, described the relationship of a defect in the head of the humerus as an associated injury suffered with anterior dislocation.[35]
- Bony injury to the glenoid has been documented as a frequent concomitant injury suffered during a high energy dislocation.[36] The presence of a bony Bankart lesion in association with a Hill-Sachs lesion (often termed an engaging Hill-Sachs lesion) is a risk factor for recurrent dislocation.

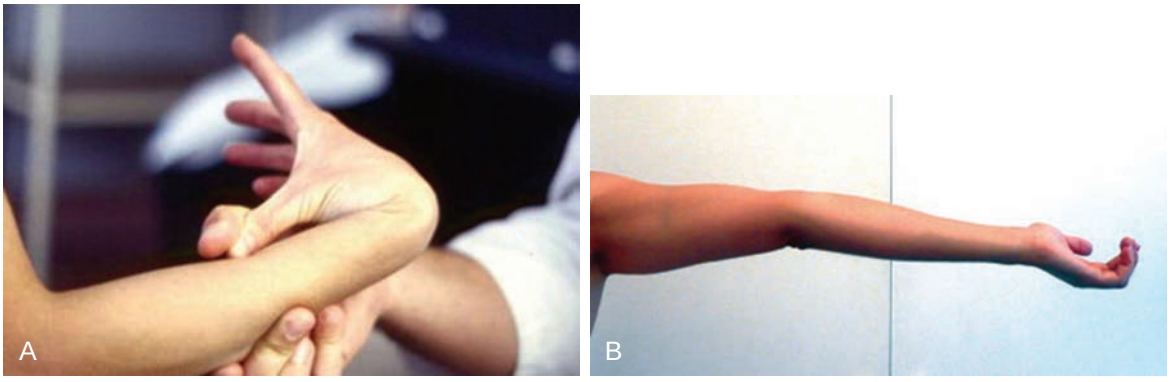

FIGURE 1-1. Hyperlaxity of the wrist (A) and elbow (B).*(Courtesy of Drs. Baujat and Finidori, Necker Hospital, Genetics Department and Pediatric Orthopaedic Surgery Department, Paris, France.) (From Provencher MT, Romeo AA, editors: Shoulder instability: a comprehensive approach. Philadelphia, 2011, Elsevier (Saunders), p. 481) Fig 42-10 and 42-11.*

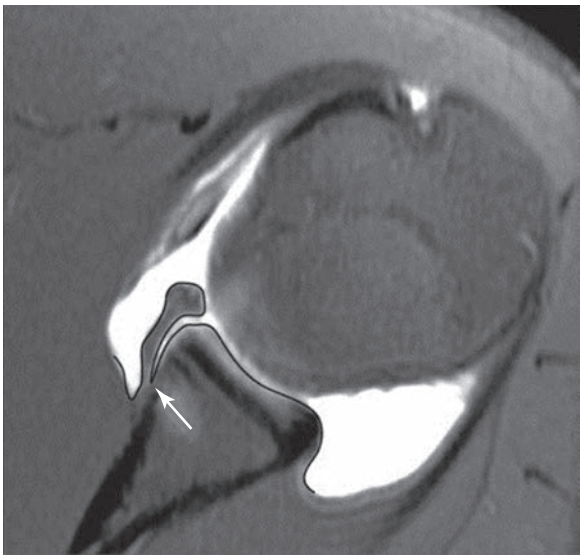

FIGURE 1-2. Axial MRI scan of a Perthes lesion: Incomplete tear of nondisplaced anteroinferior labrum that remains attached to the glenoid neck only through periosteal fibers *(arrow). (From Provencher MT, Romeo AA, editors: Shoulder instability: a comprehensive approach. Philadelphia, 2011, Elsevier (Saunders), p. 98.) Fig 8-10.*

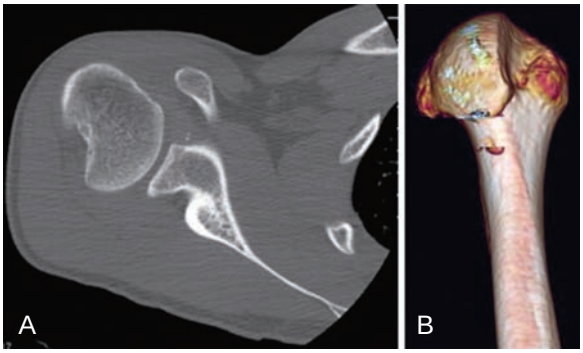

FIGURE 1-3. The axial CT image and associated 3-D reconstruction demonstrate a large Hill-Sachs lesion of the posterosuperolateral humeral head and evaluation of the anterior glenoid rim reveals loss of normal contour consistent with a compression type glenoid injury. *(From Provencher MT, Romeo AA, editors: Shoulder instability: a comprehensive approach. Philadelphia, 2011, Elsevier (Saunders), p. 251.) Fig 21-4.*



FIGURE 1-4. Axial MRA demonstrating an ALPSA lesion *(arrow). (From Provencher MT, Romeo AA, editors: Shoulder instability: a comprehensive approach. Philadelphia, 2011, Elsevier (Saunders), p. 72.) Fig 6-5A.*



FIGURE 1-5. Performance of the anterior apprehension test. An examination is positive when the patient expresses "apprehension" or the feeling of their shoulder slipping out of socket when in this abducted externally rotated position. *(From Provencher MT, Romeo AA, editors: Shoulder instability: a comprehensive approach. Philadelphia, 2011, Elsevier (Saunders), p. 26.) Fig 2-8A.*

- Researchers documenting the prevalence of specific tissue injury after primary and recurrent anterior dislocations reported anterior labrum periosteal sleeve avulsion (ALPSA) (Figure 1-4) lesions (27%) occurred with greater frequency than Bankart lesions (24%) during primary dislocation.[36]

Clinical Presentation

History

- Depending on the timing of presentation, patients presenting for evaluation often complain of pain after an initial episode of traumatic anterior instability. The pain and muscle spasm may accompany prolonged dislocation with a delay in reduction.
- The individual may report impaired sensation, loss of motion, and impaired strength.[37]
- Commonly, patients report feelings of apprehension and instability.[33]

Physical Examination

Abnormal Findings

- Positive anterior apprehension test (+/– relocation test) (Figure 1-5) is suggestive of anterior instability.[37] The relocation test (Figure 1-6) must not be confused with a positive relocation for reduction of pain which would be suggestive of internal impingement.
- Positive results for the combination of all three provocative (apprehension, relocation, and surprise) tests,



FIGURE 1-6. Performance of the anterior relocation test. The addition of a posteriorly directed force to the anterior proximal arm results in relief of patient apprehension in the abducted, externally rotated position. *(From Provencher MT, Romeo AA, editors: Shoulder instability: a comprehensive approach. Philadelphia, 2011, Elsevier (Saunders), p. 26.) Fig 2-10.*



FIGURE 1-7. True anteroposterior (Grashey) radiographic view demonstrating intact glenoid rim. *(From Provencher MT, Romeo AA, editors: Shoulder instability: a comprehensive approach. Philadelphia, 2011, Elsevier (Saunders), p. 90.) Fig 8-2C.*

was highly specific for the presence of anterior instability.[33]

- The athlete may complain of popping or clicking in the shoulder on movement.[38]
- Neurologic assessment including sensory and motor exam might demonstrate impaired sensation over the deltoid [38] and decreased strength for abduction and external rotation[38]. These symptoms are usually found in an individual requiring eduction of the dislocation. Symptoms may be related to neuropraxia and are usually transient axillary nerve injury.[38] There is rarely decreased strength related to a true persistent neurological injury.

Pertinent Normal Findings

- The patient with anterior instability will demonstrate normal to near normal single plane range of motion after an initial recovery.
- Strength will return after a brief period of recovery barring neurological involvement.
- The patient will resume participation at a high level of play with the exception of overhead activities and activities requiring the arm to extend behind the body or adopt a position of abduction and external rotation.
- The provocative position for anterior instability is the maximal cocking position for a thrower.

Imaging

- Radiographic studies routinely consist of a true AP (right angle to the scapula) (Figure 1-7), a lateral scapula, and an axillary view. They often demonstrate the presence of a Hill-Sachs lesion of the humeral head and may demonstrate a loss of bone at the anterior surface of the glenoid. *There can be specialized X-rays such as a west point view (Figure 1-8) to determine anterior glenoid bone involvement and specialized views to identify a Hill-Sachs lesion.*

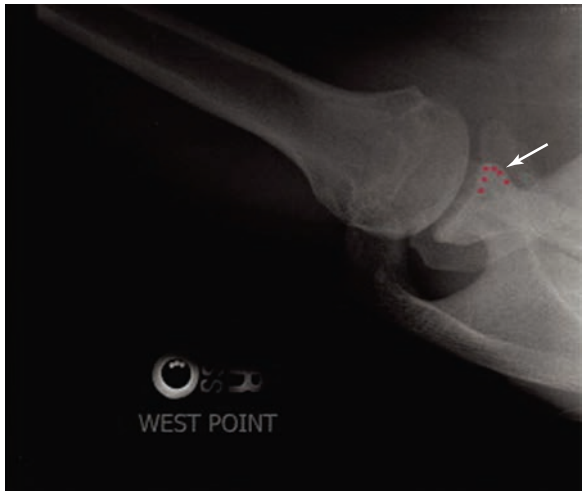

FIGURE 1-8. West Point view. Red dots outline glenoid bone loss (about 15%) *(white arrow). (From Provencher MT, Romeo AA, editors: Shoulder instability: a comprehensive approach. Philadelphia, 2011, Elsevier (Saunders), p. 173.) Fig 14-2B.*

- Magnetic resonance imaging (Figure 1-9) may demonstrate tearing of the anterior inferior glenoid labrum and with less frequency the anterior capsule and anterior aspect of the inferior glenohumeral ligament. Increased signals denoting structural deficits and tissue inflammation are noted on the T2-weighted images. The concomitant rotator cuff tear, in an older patient, can be diagnosed with an MRI.
- Commuted tomography (CT) is utilized to identify bone defects in two dimensions.
- CT reconstructions are three-dimensional studies (Figure 1-10) and are used to quantify bone defects on both the humeral and glenoid surfaces when standard X-ray images fail to specifically define the

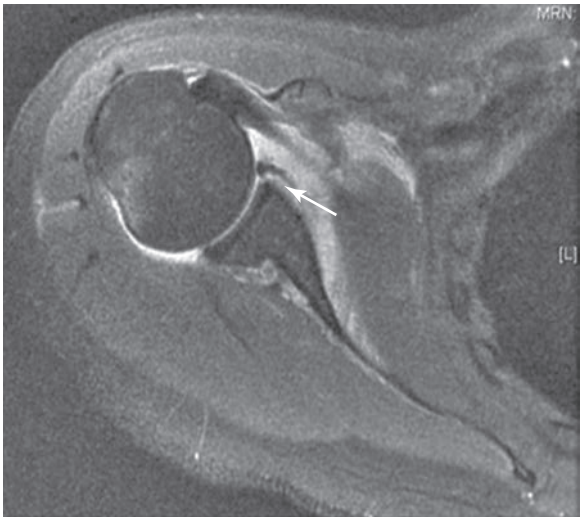

FIGURE 1-9. Axial MR arthrogram demonstrating an anterior labral tear. Note fluid interposed between anterior labrum and glenoid *(arrow). (From Provencher MT, Romeo AA, editors: Shoulder instability: a comprehensive approach. Philadelphia, 2011, Elsevier (Saunders), p. 71.) Fig 6-4A.*



FIGURE 1-11. Commercially available external rotation sling that can be used for immediate postreduction immobilization. *(From Provencher MT, Romeo AA, editors: Shoulder instability: a comprehensive approach. Philadelphia, 2011, Elsevier (Saunders), p. 103.) Fig 9-3.*



FIGURE 1-10. Three-dimensional CT: Arrow indicates the bone fragment detached from the anterior glenoid rim. *(From Provencher MT, Romeo AA, editors: Shoulder instability: a comprehensive approach. Philadelphia, 2011, Elsevier (Saunders), p. 96.) Fig 8-7A.*

lesion. These images are used sparingly as they deliver a fair amount of radiation exposure to the patient.

Differential Diagnosis

- Multidirectional instability of the glenohumeral joint may be confused with anterior glenohumeral joint instability. The differential diagnosis is made by history (chronic episodes of subluxation/dislocations and often laxity in multiple joints), unwanted translation in two or more directions (always inferior and either anterior, or posterior), and positive sulcus sign. Additionally, the athlete may present with decreased dynamic stability and poor muscle control in multiple planes of motion.
- Posterior instability may be misdiagnosed as anterior instability. Patients with decreased force couple/concavity compression, and altered positioning of the humeral head in the glenoid fossa can be misdiagnosed with anterior instability. These patients will appear to have increased anterior translation on examination if the humeral head is not centered prior to conducting the load shift test. The differential diagnosis begins with recognizing the presenting symptoms. The patient will often complain of an inability to bring their arm across their body especially when weight is applied to the distal portion of the upper extremity.
- Superior labrum from anterior to posterior (SLAP) lesions have been documented in patients complaining of anterior instability. Patients with complaints of anterior instability have been documented to present with a variety of labral and bony lesion (ALPSA).[15]

Treatment

Nonoperative Management

- Bracing: Itoi et al. have shown that traumatic anterior instability can be placed in a **sling** (Figure 1-11) with pillow at 45° to 60° of external rotation (ER) and the injury heals. However, compliance and long-term success seem to be problematic, based on follow-up studies.
- A criterion-based, progressive exercise program is thought to be effective for short-term management of traumatic anterior shoulder instability coupled with bracing when the athlete returns to sport. This program focuses on rotator cuff and scapular stability as well as maximizing shoulder proprioception/kinetic awareness in higher ranges of elevation and ER.

Guidelines for Choosing Among Nonoperative Treatments

- Patients with initial, unidirectional, capsular injuries may be appropriate for immediate bracing in slight abduction and ER.
- A progressive rehabilitation program works well for many patients to ensure success.

Surgical Indications

- Disability related to recurrent dislocations.
- First-time dislocations with combinations of specific pathologies (e.g., an older patient with combined dislocation and rotator cuff tear).
- Selected patients presenting with acute dislocation and combined bone loss (humeral and glenoid).

Aspects of History, Demographics, or Exam Findings that Affect Choice of Treatment

- Number of dislocations[39]
- Severity of dislocation
  - Was anesthesia required?
  - Was it a "locked" dislocation?
- Labral involvement
- Bony avulsion
- Percentage glenoid bone loss[39]
- Residual neurological or vascular symptoms
- Rotator cuff involvement
- Concomitant SLAP repair[15]

Aspects of Clinical Decision-Making When Surgery is Indicated

- Number of dislocations and the resultant disability are considered when planning for surgery.
- Patient age and overall health.
- Patients presenting with apprehension concerns are examined carefully to define the size and location of the lesion.
- Patients with engaging lesions require consideration to determine if the engagement occurs prior to attainment of the 90-90 positions.
- Patients presenting to the orthopedic surgeon reporting recurrent dislocations with difficult reduction.
- Sport and occupational requirements (i.e., position played, contact, ROM requirements).
- Associated complications (i.e., axillary nerve or rotator cuff involvement).
- Previous failed reconstruction.

Evidence

Arciero RA, Wheeler JH, Ryan JB, et al: Arthroscopic Bankart repair versus nonoperative treatment for acute, initial anterior shoulder dislocations. *Am J Sports Med* 22:589–594, 1994.

This is a prospective study evaluating the effectiveness of two treatment pathways for anterior dislocation of the shoulder in young athletes. Non-operative treatments verses arthroscopic Bankart suture repair for the dislocation was compared. Thirty-six athletes met the inclusion criteria: first time with a traumatic anterior dislocation, no history of impingement or subluxation, dislocation required manual reduction, and no neurological injury present. Of the two patient groups, Group 1 was immobilized for 1 month followed by rehabilitation and return to full activity at 4 months. Group 2 received arthroscopic Bankart repair before receiving similar rehabilitation as those athletes in Group 1. Twelve of the 15 nonoperative patients developed instability following return to full activity. Seven of these patients required open Bankart repair to correct instability. Eighty-six percent of the patients (18/21) in the arthroscopic Bankart repair group were deemed stabile and only one patient returned for an open procedure. It was determined that Bankart repair significantly reduced recurrent instability in anterior shoulder dislocation sustained in young athletes. (Level I evidence).

Bigliani LU, Kelkar R, Flatow EL, et al: Glenohumeral stability. Biomechanical properties of passive and active stabilizers. *Clin Orthop Relat Res* 330:13–30, 1996.

The article focuses on the stability of the glenohumeral joint. The anatomy of the joint is evaluated to analyze how osseous stability is achieved and the mechanics of arthrokinematic motion within the joint. The function of the joint capsule and ligaments are detailed regarding static and dynamic stability. The author recommends conducting studies to elucidate motion and biomechanics under abnormal conditions, such as rotator cuff pathology, and shoulder degeneration. (Level V evidence).

Buss DD, Lynch GP, Meyer CP, et al: Nonoperative management for in-season athletes with anterior shoulder instability. *Am J Sports Med* 32:1430–1433, 2004.

This is a prospective study of 30 athletes sustaining an episode of anterior shoulder instability. The athletes were treated conservatively without a sling and with physical therapy, if necessary, to restore range of motion and strength to symmetrical limits. The athletes were returned to full participation in their sport with a brace and were monitored for the number of recurrent instability episodes, additional injuries, and the ability to complete their season. (Level III evidence)

Cameron KL, Duffey ML, DeBerardino TM, et al: Association of generalized joint hypermobility with a history of glenohumeral joint instability. *J Athl Train* 45:253–258, 2010.

This study enrolled a cohort of 1050 incoming West Point freshman evaluated to identify risk factors for glenohumeral joint instability. The Beighton Scale was used to access generalized joint hypermobility. Those freshmen with a history of glenohumeral joint instability had higher total Beighton Scale scores than did those with no history of instability. Freshmen with a Beighton score greater than 2 were 2.5 times more likely to have an associated history of shoulder instability than those without a history of instability. (Level II evidence).

Griffith JF, Antonio GE, Yung PS, et al: Prevalence, pattern, and spectrum of glenoid bone loss in anterior shoulder dislocation: CT analysis of 218 patients. *AJR Am J Roentgenol* 190:1247–1254, 2008.

This cohort study quantified bone loss via CT scan in 218 patients to determine the prevalence and severity of glenoid bone loss in patients presenting after anterior dislocation. The CT scans were compared with 55 patients without a history of shoulder dislocation. The study determined that glenoid bone loss is common but generally mild. The severity of bone loss was maximally recorded at 33% of surface area. The

number of dislocations was only moderately correlated with the amount of glenoid bone loss. (Level II evidence).

Hantes ME, Venouziou AI, Liantsis AK, et al: Arthroscopic repair for chronic anterior shoulder instability: a comparative study between patients with Bankart lesions and patients with combined Bankart and superior labral anterior posterior lesions. *Am J Sports Med* 37:1093–1098, 2009.

Sixty-three patients with a diagnosis of chronic anterior shoulder instability were studied. Evaluation was performed to determine which of two groups each person should be assigned: Bankart/ALPSA lesion (n = 38), or a combined Bankart/ALPSA lesion and type II SLAP lesion (n = 25). Groups were matched for age, gender, activity level, apprehension and ROM. Arthroscopic examination, preparation, and repair of all injured tissues were performed for each patient. The patients received identical rehabilitation protocols. Patients in the second group displayed significantly more preoperative instability episodes and required on average an additional suture anchor for fixation. Similar results for postoperative success and function were documented between groups. (Level III evidence).

Kralinger FS, Golser K, Wischatta R, et al: Predicting recurrence after primary anterior shoulder dislocation. *Am J Sports Med* 30:116–120, 2002.

This study was a retrospective analysis of records and radiologic follow up of 241 patients treated after episodic anterior instability. Risk factors including: Rowe score, demographics, athletic activity, clinical (ROM, apprehension sign) and radiologic features (Hill-Sachs lesion, glenoid bone loss) were analyzed. The authors found that age (21 to 30) was the most accurate factor predicting recurrence of dislocation. The authors recommended that individuals in this age group participating in high levels of activity should undergo primary stabilization. (Level IV evidence).

Nelson BJ, Aciero RA: Arthroscopic management of glenohumeral Instability. *Am J Sports Med* 28:602–614, 2000.

Over the last 20 years there have been new developments in arthroscopic shoulder techniques, especially in the area of shoulder instability. The article discusses the various arthroscopic surgical techniques used to treat the unstable glenohumeral joint. The article looks at arthroscopic stabilization techniques for primary anterior glenohumeral instability, recurrent anterior instability, and multidirectional instability. The wide ranges of results are also discussed. (Level V evidence).

Owens BD, Duffey ML, Nelson BJ, et al: The incidence and characteristics of shoulder instability at the United States Military Academy. *Am J Sports Med* 35:1168–1173, 2007.

This is a prospective study, which looked at 4141 students at the United Military Academy to determine how many experienced a new traumatic shoulder instability event. Between September 1, 2004 and May 31, 2005; 117 students with a mean age of 20 experienced a traumatic shoulder instability event. Each instability event used the following methods to evaluate the injury: physical examination, plain radiographs, and magnetic resonance imaging. Subluxations where present in 85% of the instability events. Direction, chronicity, and whether it was a subluxation or dislocation were recorded. (Level II evidence).

Simonet WT, Melton LJ, 3rd, Cofield RH, et al: Incidence of anterior shoulder dislocation in Olmsted County, Minnesota. *Clin Orthop Relat Res* 186–191, 1984.

The study retrospectively analyzed the incidence of traumatic anterior shoulder dislocations among all Olmsted County, Minnesota residents during a 10 year period. The history of incidence was reviewed for the 124 patients who had been treated for an anterior dislocated shoulder. Of the 124, 116 had complete follow-up evaluation records. It was determined that the incidence rates were higher among men than women. According to the author, young males have the highest frequency of shoulder dislocations. No significant differences in incidence rates were found between urban and rural communities. (Level IV evidence).

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Multiple-Choice Questions

QUESTION 1. Overall in high school athletes, males are at a higher risk of sustaining at traumatic anterior shoulder dislocation when compared to females. However, when comparing which two sports females are at higher risk than males:

A. Boys' baseball to girls' softball
B. Boys' to girls' basketball
C. Boys' to girls' ice hockey
D. Boys' to girls' soccer

QUESTION 2. Generalized joint hypermobility, as measured by the Beighton scale, has been associated with a ____ times increased risk of having reported an episode of glenohumeral instability.

A. 1.5
B. 2.0
C. 2.5
D. 3.0

QUESTION 3. When documenting specific tissue injury after primary and recurrent anterior dislocations, researchers have reported:

A. ALPSA lesions occurred with greater frequency than Bankart lesions during primary dislocation
B. Concomitant intraarticular pathology occurs with increasing frequency with recurrent dislocations
C. Bony Bankart lesions occurred with greater frequency than Hill-Sachs lesions during recurrent dislocation
D. Glad lesions occurred with greater frequency than Bankart lesions during primary dislocation

QUESTION 4. Which of the following modalities is the best choice for an older patient presenting after initial dislocation episode presenting with complaints of weakness and inability to lift their arm overhead?

A. Computed tomography
B. Computed tomography with 3D reconstruction
C. Magnetic resonance imaging
D. Specialized radiographs (West Point view)

QUESTION 5. Neuropraxic symptoms in a patient presenting after anterior dislocation are most often related to:

A. Axillary nerve injury
B. Musculocutaneous nerve injury
C. Radial nerve injury
D. Suprascapular nerve injury

Answer Key

QUESTION 1. Correct answer: **B** (see Overall Incidence—Sport)

QUESTION 2. Correct answer: **C** (see Pathophysiology)

QUESTION 3. Correct answer: **A** (see Pathophysiology)

QUESTION 4. Correct answer: **C** (see Clinical Presentation)

QUESTION 5. Correct answer: **A** (see Clinical Presentation)

NONOPERATIVE REHABILITATION FOLLOWING ANTERIOR CAPSULOLABRAL INJURY

Charles A. Thigpen, PhD, PT, ATC, Ellen Shanley, PhD, PT, OCS, and Richard J. Hawkins, MD

Overview of Goals, Important Milestones, and Guidelines

- Conservative management of anterior shoulder instability is often considered for patients diagnosed with traumatic anterior shoulder instability.
- The rehabilitation process is not dependent on time as clearance for return to sport is not based on assumed tissue healing.
- The rate of recurrence following traumatic anterior shoulder instability is significant and should be considered during the counseling and rehabilitation process. In general, the younger the patient and the more tissues involved (capsule/ligament, labrum, glenoid), the greater the recurrence rate. Therefore, we recommend limiting the number of recurrent episodes as they may lead to increased incidence of intrarticular pathology and long-term complications.
- Rehabilitation following traumatic anterior instability is therefore based on criteria alone with a strong emphasis on maximizing dynamic stability about the shoulder girdle.
- The suggested treatment progressions should be constantly within the context of risk of reinjury based on age, sport, and involved pathology.

GUIDING PRINCIPLES OF NONOPERATIVE REHABILITATION

- Gradual, pain-free restoration of range of motion (ROM) avoiding the sensation of instability
- Muscle guarding/spasm must first be resolved before dynamic stability can be restored
- Correct application of manual techniques and therapeutic exercises to promote static balance in glenohumeral joint mobility and optimum dynamic stabilization from the rotator cuff and associated shoulder girdle muscles.
- Return to sport is not appropriate until the athlete demonstrates dynamic stability in the functional ROM in which they are expected to participate.

Phase I

Goals

- Educate the patient about restrictions, pain management, and activities of daily living (ADLs).
- Protect the anterior shoulder by avoiding positions/movements that are likely to increase stress on the anterior/inferior capsulolabral structures.
- Minimize shoulder pain to normalize muscle tone.
- Gradually restore frontal plane elevation, abduction, and external rotation (ER) above 45°, as suggested in Table 1-1.
- Restore scapular control.

Clinical Pearls

- Modalities and soft tissue mobilization are often helpful to decrease guarding and allow gradual increase in muscle function.
- Restore isometric, then positional, isometric muscle function before progressing to full ROM concentric activities

Protection

- We recommend initial sling use for dislocations with gradual progression to no sling based on pain, available ROM, muscle performance, and activity level.

Management of Pain and Swelling

- Oral pain medications as needed
- Electrical stimulation (Transcutaneous Electrical Neural Stimulation, TENS) is recommended to manage pain and muscle guarding.
- Intermittent cryotherapy for pain and inflammation reduction[1]

Table 1-1 Staged Range of Motion Goals Following Arthroscopic Anterior Capsulolabral Injury

	PFE	PER at 20° abd	PER at 90° abd	AFE
Phase I	90°	10°–30°	Contraindicated	NA
Phase II	155°	50°–65°	75°	145°
Phase III	WFL	WFL	WFL	WFL

AFE, Active forward elevation in the scapular plane; *NA*, not appropriate; *PER*, passive external rotation; *PFE*, passive forward elevation; *WFL*, within functional limits.

- Patient positioning: patients are encouraged to use pillows or bolsters to find a "position of comfort," usually slightly abducted (20° to 30°) in a neutral or slight internal rotation (IR), especially at night. This position is recommended to reduce stress on repaired structures as well as to "unload" the surrounding muscles.

Techniques for Progressive Increase in Range of Motion

- The initial phase is resolving pain, decreasing swelling, and allowing the acute, postinjury shoulder to recover.
- Supported Codman's pendulum exercises for gentle motion and joint distraction, supported forward elevation (FE) (<90°), and ER to 0° at the side (<20° abduction) can be performed immediately to maintain joint mobility but should not reproduce symptoms. We suggest all of these motions be performed with support to minimize rotator cuff activity due to incorrect technique.[2-4]

Manual Therapy Techniques

- Gentle joint distraction and grade I-II joint oscillations may be helpful before performing supervised passive/active assisted range of motion (P/AAROM) by the rehabilitation professional to decrease muscle guarding and prepare the joint for ROM exercise. We recommend these treatments to be performed in the scapular plane in approximately 30° of elevation, and neutral rotation to limit the stress on the capsulolabral injury.[5]

Soft Tissue Techniques

- Shortening, parallel techniques (such as positional release/strain-counterstrain) may be helpful to reduce protective guarding especially for the subscapularis, posterior rotator cuff, teres major, latissimus dorsi, and pectoralis major/minor.

Stretching/Flexibility Techniques for the Musculo-Tendinous Unit

- Stretching/flexibility exercises are not recommended at this time due the need to protect the repair. Cervicothoracic, elbow, hand, and wrist.

Other Therapeutic Exercises

- Lower extremity and cardiovascular exercises may begin immediately as long as there is no reproduction of instability symptoms. This is crucial especially for the in-season management with the goal to return to play in season.

Activation of Primary Muscles Involved

- Isometric exercises may begin day 1 as tolerated. We recommend performing these exercises in the "safe zone" of 20° to 30° abduction in the plane of the scapula in neutral rotation first with the elbow supported then gradually removing support.
- Gradual progression to positional isometrics can begin day 1.

Open and Closed Kinetic Chain Exercises

- Closed chain activities are often less painful and help to provide compression of the GH joint, thereby increasing the static stability of the joint (Figure 1-12).

Neuromuscular Dynamic Stability Exercises

- Exercises to emphasize rotator cuff balance and co-contraction should be emphasized during Phase I (Figure 1-13).

Milestones for Progression to the Next Phase

- Minimal to moderate pain (Numeric Pain Rating Scale [NPRS]: 2 to 4/10) with minimal pain at rest (2/10)



FIGURE 1-12. Closed kinetic chain perturbations in quadruped. Patient is positioned in quadruped loading affected arm as tolerated. Perturbations can then be applied manually or using an unstable surface.

TIMELINE 1-1: Nonoperative Rehabilitation Following Anterior Capsulolabral Injury

PHASE I	PHASE II	PHASE III
• Sling • PT modalities • ROM wk 3—forward elevation to 90° • ROM wk 3—external rotation to 10°–30° • TBS/TAS/TLS activities as recommended & tolerated • Scapular exercises • AAROM exercises within functional range • Wk 4—submaximal isometrics for GH joint muscles	• Sling • PT Modalities • ROM wk 3—forward elevation to 90° • ROM wk 3—external rotation to 10°–30° • TBS/TAS/TLS activities as recommended & tolerated • Scapular exercises • AAROM exercises within functional range • Wk 4—submaximal isometrics for GH joint muscles	• Sling • PT Modalities • ROM wk 3—forward elevation to 90° • ROM wk 3—external rotation to 10°–30° • TBS/TAS/TLS activities as recommended & tolerated • Scapular exercises • AAROM exercises within functional range • Wk 4—submaximal isometrics for GH joint muscles

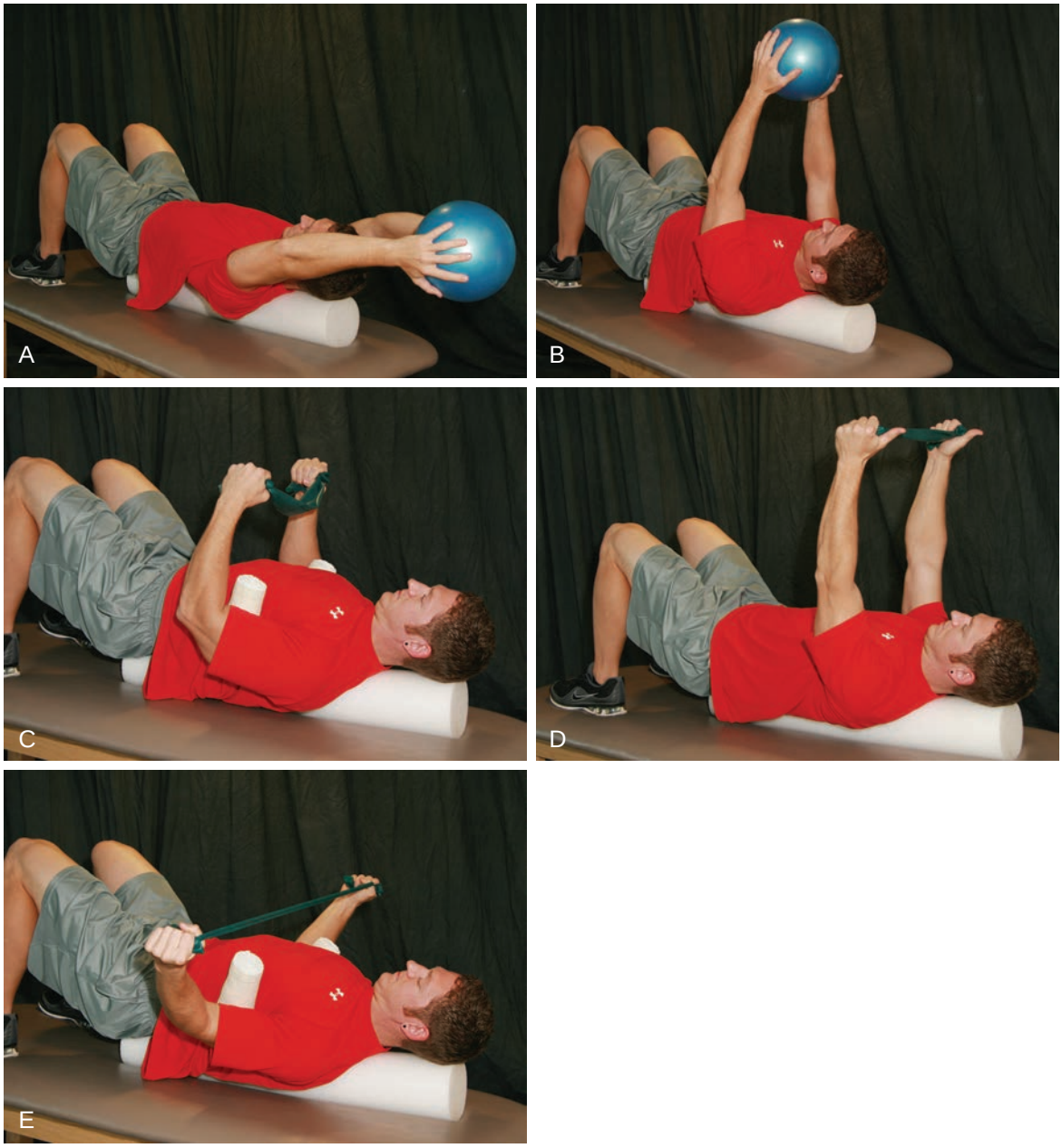

FIGURE 1-13. Cuff co-contraction during elevation: **A, B,** Patient squeezes ball into internal rotation/adduction while elevating arm as tolerated. **C-E,** Patient maintains ER while elevating arm as tolerated.

- Stage I ROM goals achieved but not significantly exceeded

Phase II

Goals

- Minimize shoulder pain (<2/10)
- Achieve staged ROM goals to normalize passive ROM and active ROM.
- Normalize rotator cuff guarding and neuromuscular control
- Normalize scapular position and control

Clinical Pearls

- Normalize subscapularis muscle function to provide dynamic stability for the anterior shoulder.
- Avoid scapular protraction with coronal plane shoulder motion to limit stress on the anterior capsulolabral structures.[6,7]
- Follow up soft tissue work with proprioceptive neuromuscular facilitation (PNF), positional isometrics, and proprioceptive activities to maximize neuromuscular facilitation during early phases after injury.

Patient-Oriented Outcomes

- Best clinical practice uses patient-rated measures of function and disability to comprehensively assess patient response to treatment.
- There are many available scales for measuring functional loss and disability in patients with instability and one measure is likely not superior to another.[8,9]
- We recommend two measures, a general measure of shoulder function that includes pain, function, and patient satisfaction similar to the American Shoulder and Elbow Surgeons' (ASES), the Pennsylvania Shoulder Score (PSS) and a measure specifically for instability, such as the Western Ontario Instability Index (WOSI).[10-14]

Protection

- Treatment for pain/analgesia oral pain medications
- Electrical stimulation (TENS) is recommended to manage pain and muscle guarding. TENS units at home are often helpful to control pain, especially shortly after surgery.
- Intermittent cryotherapy for pain and inflammation reduction.[1] We recommend 20 minutes per hour for the first week following surgery.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Gentle joint distraction and grade I-III joint oscillations may be helpful before performing supervised PROM by the rehabilitation professional to decrease muscle guarding, restore capsular balance, and prepare the joint for ROM exercise. Anterior-inferior or inferior glides should not be performed. We recommend these positions to be performed in the scapular plane in approximately 30° of elevation, and neutral rotation to limit the stress on the capsulolabral repair.[5]

Soft Tissue Techniques

- Shortening, parallel techniques such as (Positional Release/Strain-Counterstrain) may be helpful to reduce protective guarding especially for the subscapularis, posterior rotator cuff, teres major, latissimus dorsi, and pectoralis major/minor.
- Passive ROM and active assist ROM exercises may be initiated after POW 2 for ER and FE (see Table 1-1).

Stretching/Flexibility Techniques for the Musculo-Tendinous Unit

- Should not be performed as these are end ROM exercises.

Other Therapeutic Exercises

- Gradual introduction of total body strengthening (TBS), total leg strength (TLS), core stability, uninvolved total arm strength (TAS), and cardiovascular conditioning can be initiated with attention to the safety of the activity. All exercises should be performed so that the patient does not have symptoms of instability during activity.

Activation of Primary Muscles Involved

- Scapular retraction and proprioceptive neuromuscular facilitation (PNF) patterns should be emphasized and positions based on patient tolerance. We recommend first achieving stability in a retracted position then progressing to scapular protraction to minimize increased stress on the anterior capsulolabral structures.[6,7] Although scapular elevation and retraction are safe we suggested limited resistance because of the load placed through the glenohumeral joint for most exercises.
- Active ROM and rotator cuff strengthening within the staged ROM goals in Table 1-1. The recommended procedure is to begin with submaximal isometric strengthening of the shoulder and elbow with the arm adducted to the side in neutral rotation first, then to progressively increase the angle of arm elevation and ER. As the patient demonstrates improved rotator cuff endurance and absence of pain or other symptoms it is recommended to progress to dynamic isometrics, then concentric/eccentric exercises, then AROM exercises within the ROM restrictions.

Sensorimotor Exercises

- Angular reposition, rhythmic stabilization, and repeated contractions within staged ROM limits may be implemented during Phase II.

Open and Closed Kinetic Chain Exercises

- Closed kinetic chain (CKC) exercises may be implemented below 90° of elevation during Phase II. These exercises should begin in a modified weight-bearing position and progressed to full weight-bearing as tolerated.[15]

Techniques to Increase Muscle Strength, Power, and Endurance

- See above w/AROM

Milestones for Progression to the Next Phase

- Appropriate healing of the surgical repair by adhering to the precautions and immobilization guidelines.
- Staged ROM goals achieved but not significantly exceeded
- Minimal to no pain (NPRS: 0—2/10) with ROM
- PSS greater than 60% and WOSI less than 50%. These are estimates based on reported normative data and our experience. This combined with other objective criteria provides clear communication between the patient and medical professionals on how the patient perceives their shoulder function, and gives potential insight as to how care can be improved upon.

Phase III

Goals

- Achieve staged ROM goals to normalize passive ROM and active ROM. DO NOT significantly exceed especially for ER at 90° of abduction

- Minimize shoulder pain (0/10 at rest and <2/10 following exercises or activity)
- Begin to increase strength and endurance
- Increase functional activities as evidenced by PSS > 80% and WOSI < 30%.

Clinical Pearls

- Nearly full active elevation in the plane of the scapula should be achieved before progressing to elevation in other planes or initiating resistive elevation exercises.
- Ensuring posterior rotator cuff performance and scapular stability below 90° of abduction before progressing to higher elevation and difficulty of exercises.
- Posterior-inferior glides are often helpful to gain full ER and FE. Addition of posterior shoulder flexibility exercises in conjunction with these mobs before and after exercise is helpful in the stiff shoulder.
- In our opinion, rapid gain of ER towards 90° of abduction should be avoided (before 8 weeks). If the athlete must return to overhead, throwing sports and the involved shoulder is their throwing arm, then more aggressive stretching of ER towards 90° of abduction may begin at 8 weeks.
- Functional exercises may begin toward the end of this phase. Simple patient instruction to *"keep their hands where they can see them"* will allow the patient to resume desired activities without risking reinjury.

Protection

- No sling use
- Avoid positions of max ER towards 90° of abduction, especially with a posteriorly directed load. (e.g., NO push-ups, bench press, pectoral flys)

Management of Pain and Swelling

- Pain should not be a limiting factor at this point. If pain is limiting progression of activities rest and reevaluation of all aspects of the shoulder should be performed in consultation with the referring surgeon
- Cryotherapy as needed.
- NSAIDS as needed.

Patient Education

- Counsel about using the upper extremity for appropriate ADLs in the pain-free ROM (starting with waist level activities and progressing to shoulder level and finally to overhead activities over time)
- Continue education regarding avoidance of heavy lifting or quick sudden motions
- Education to avoid positions which place stress on the anterior inferior capsule during ADLs

Techniques for Progressive Increase in Range of Motion

- FE should be progressed from active-assistive exercises (e.g., rope and pulley, wall walks), to active, to resistive upright exercises, then finally to prone exercises as per reported electomyography (EMG) activity of the shoulder.[3,4] Although protection of the rotator cuff is not needed, the EMG activity reflects overall stress to the shoulder and is a good guide to exercise progression.

Manual Therapy Techniques

- Grade I-III joint mobilizations (up to tissue resistance) are most often all that is required especially for anterior/inferior directions. If ROM is greater than 50% less than staged ROM goals as compared with the uninvolved extremity then gentle joint mobilizations may be performed. However they should be done only into the limited directions and only until staged ROM goals are achieved. It is crucial in the patients that appear "tight" to discern if there is capsuloligamentous tightness/stiffness, musculotendinous, pain limitation, or some combination.

Soft Tissue Techniques

- Deeper soft tissue techniques may be initiated during this phase. More aggressive techniques such as Active Release® or other instrumented soft tissue mobilizations to normalize muscle tone and extensibility. Particular attention should be paid to the subscapularis, latissimus, pectorals, teres major, and posterior rotator cuff. In our experience these techniques often allow for gradual return consistent with the staged goals without aggressive joint mobilizations or excessive end range stretching.

Stretching/Flexibility Techniques for the Musculo-Tendinous Unit

- Total upper quarter mobility should be evaluated with restoration of cervical, thoracic, and scapulothoracic mobility to facilitate optimal return upper extremity ROM.
- End range flexibility exercises may begin in particular for posterior shoulder (horizontal adduction and sleeper stretch beginning at 60° to 70° of elevation on side.[16,17] Pectoralis minor flexibility can begin with attention not to increase stress on anterior shoulder as these have been shown to be effective at increasing pectoralis minor length (Figure 1-14).[18,19] Gradual introduction of latissimus, posterior shoulder, and FE stretches as needed (Figure 1-15).

Other Therapeutic Exercises

- Address core stability deficits as needed beginning in the sagittal plane and progressing to frontal and transverse plane exercises.
- Total leg strengthening exercises may be progressed as tolerated but high loads should be avoided on the shoulder in activities such as power clean, dead lifts, and back squats should be avoided. Front squats during this phase are recommended to allow for safe positioning of the shoulder with large loads.

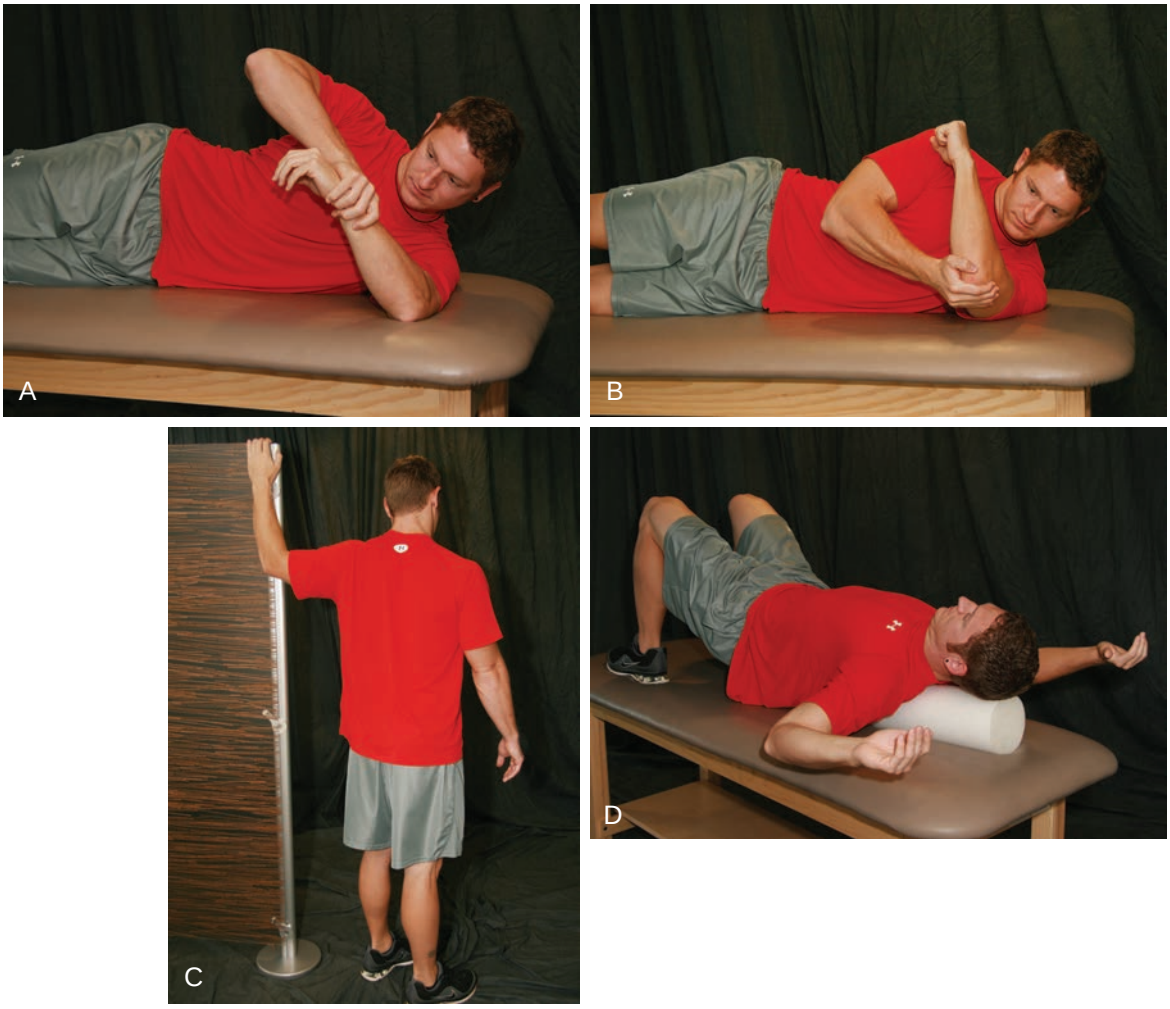

FIGURE 1-14. A, The pectoralis major and minor are stretched by placing the arm at 90° of abduction then leaning forward and rotating away from affected arm while keeping the elbow in line with the scapula and thorax. The patient should report feeling a "stretch" along the anterior shoulder and pectorals, not glenohumeral joint discomfort. **B,** The pectoralis major and minor are stretched by placing the arm at 120° of abduction then leaning forward and rotating away from affected arm the while keeping the elbow in line with the scapula and thorax. The patient should report feeling a "stretch" along the anterior shoulder and pectorals, not glenohumeral joint discomfort. **C, D,** Pectoralis minor flexibility can begin with attention not to increase stress on anterior shoulder as these have been shown to be effective at increasing pectoralis minor length.

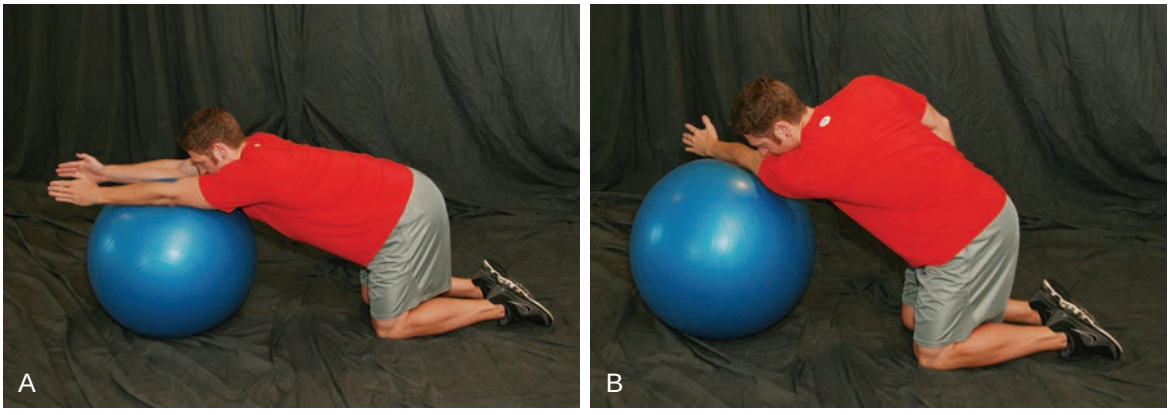

FIGURE 1-15. Latissimus and posterior shoulder flexibility on ball: (A) Patient actively rolls ball away from body and sits back on buttocks maintaining neutral spine then (B) adding trunk rotation away from affected side to change angle of stretch from distal latissimus to posterior cuff and teres major.

- It is also recommended to use this phase of rehabilitation to address kinetic chain deficits using basic functional screens such as the overhead squat, single leg squat, or more in-depth approaches such as the Functional Movement Screen. These approaches will provide areas for improvement for the athlete allowing for total body and lower extremity kinematic chain assessment.

Activation of Primary Muscles Involved

- Elbow flexion/extension strengthening with elbow by the side can begin in this phase
- Exercises and functional activities should be pain free and performed without substitutions or aberrant movement patterns (shrugging, thoracic extension)
- Balanced rotator cuff strengthening to maintain the humeral head centered within the glenoid fossa during progressively more challenging activities
- Should be initially performed in a position of comfort with low stress to the glenohumeral joint such as less than 45° elevation in the plane of the scapula (e.g., elastic band or dumbbell ER, IR, FE)
- Exercises should be progressive in terms of shoulder elevation (e.g., start with exercises performed at waist level progressing to shoulder level and finally overhead activities)
- Depending upon the goals of the exercise (control versus strengthening), rehabilitation activities may also be progressive in terms of speed once the patient demonstrates proficiency at slower speeds

Sensorimotor Exercises

- Activities to improve neuromuscular control of the rotator cuff and shoulder girdle such as use of unstable surfaces, body blade, and manual resistance exercises in conjunction with auditory, visual, or tactile cues or biofeedback.
- PNF patterns are particularly effective for restoring muscle balance and proper coordination patterns. This manual feedback is preferable, especially early during this phase because the clinician controls the load to the extremity and is able to best match the patient's level of performance.

Open and Closed Kinetic Chain Exercises

- Strengthen scapular retractors and upward rotators
- Weight-bearing exercises with a fixed distal segment. Examples: quadruped position while working to maintain proper position of the scapula, quadruped with scapula protraction, progressing from quadruped to tripod position, *no push-ups*[20]

Techniques to Increase Muscle Strength, Power, and Endurance

- Exercises should be progressive in terms of muscle demand. It is suggested to use activities that have muscle activity levels documented with EMG.[2,20-36] In general, increasing elevation increases deltoid and supraspinatus activity, whereas increasing ER at lower levels of elevation increases posterior rotator cuff EMG.[2,20-36] The subscapularis is most active during forward punches (combined scapular protraction and glenohumeral IR) and should be performed at lower and higher levels of elevation.[32]
- Exercises should be progressive in terms of adding stress to the anterior capsule, gradually working towards a position of 90° of ER and 90° of abduction by 12 weeks.
- Rehabilitation should include isolated and complex movement patterns progressing from isolated to complex movement patterns.
- The rotator cuff and scapula stabilizer strengthening program should emphasize high repetitions (typically 30 to 50 reps) and relatively low resistance (typically 1 to 2 kg) during this phase.
- General shoulder strengthening exercises (front/side raises, shoulder presses) may be initiated as full AROM is achieved and rotator cuff and scapular stabilizer strength is adequate for normal movement patterns. This is usually a late Phase III exercise and should begin with 3 to 5 kg and similar reps (15 to 20 for 3 to 4 sets).

Neuromuscular Dynamic Stability Exercises

- Development of dynamic stability is crucial during this phase of rehabilitation following stabilization procedure. Rhythmic stabilization starting at 45° of abduction in the scapular plane in neutral rotation and gradually increasing in elevation and ER as performance increases. Four to five bouts for 30 seconds are recommended before progressing the difficulty of exercises.
- CKC push up plus progression are important exercises as it promotes rotator cuff and scapular stabilizer co-contraction needed for dynamic stability.[30,37]

Plyometrics

- No heavy lifting or plyometrics should be performed during this stage.

Functional Exercises

- Functional exercises may be initiated toward the end of Phase III (weeks 9 to 12); however, we strongly recommend avoiding undue stress on the anterior shoulder.
- Multi-planar exercises should be progressed in a similar fashion as previously described, emphasizing rotational control across each plane of elevation.

Milestones for Progression to the Next Phase

- Staged active ROM goals achieved with minimal to no pain (NPRS 0 to 2/10) and without substitution patterns
- Appropriate scapular posture at rest and dynamic scapular control during ROM and strengthening exercises
- Strengthening activities completed with minimal to no pain (NPRS 0 to 2/10)
- <20% deficit using isokinetic or hand held dynamometer for ER, IR, abduction, and elevation.
- Able to complete 20 hand-taps during modified Davies CKC upper extremity (UE) test.[38] We recommend modifying the Davies test by using biacromial width as in our experience a standard 36″ is too wide for many patients.

- Able to complete 30 reps of ER at <20° of abduction in 30 seconds (1 rep/sec).

Phase IV

- The length of Phase IV will vary dependent upon sport participation. For noncontact sports it may be as simple as a gradual return to sport. For contact athletes it may require a more gradual return to activity in a braced condition.

Goals

- No complaints of pain at rest and minimal to no pain (NPRS 0 to 2/10) following activities
- No or minimal sensation of instability with activities
- Normalize strength, endurance, neuromuscular control, and power as evidenced by:
  - <10% deficit using isokinetic or hand held dynamometer for ER, IR, abduction, and elevation.
  - 30 reps in 30 seconds with blue Thera-Band at 0° and 90° abduction
  - Able to complete 90 hand-taps during modified Davies CKC UE test in 60 seconds.[38]
  - Gradual demonstration of confidence and performance in sports specific positions.
  - Functional improvement in ADLs and sport as evidenced by PSS > 90% and WOSI < 20%.

Clinical Pearls

- A balance of posterior and anterior rotator cuff strength (ER:IR ratio) of 66% before beginning return to sport training is recommended.[39,40]
- Progression of presport training activities should be monitored, re-evaluating the athlete's pain and strength (no >10% advancement as compared to presport).
- We recommend soreness rules avoiding activity postsoreness for 24 to 48 hours.[41]

Management of Pain and Swelling

- Pain should not be a limiting factor at this point. If pain is limiting progression of activities rest and reevaluation of all aspects of the shoulder should be performed in consultation with the referring surgeon
- Cryotherapy as needed
- NSAIDS as needed

Patient Education

- Counsel about using the upper extremity for appropriate ADLs in the pain-free ROM (starting with waist level activities and progressing to shoulder level and finally to overhead activities over time)
- Continue education regarding avoidance of heavy lifting or quick sudden motions
- Education to avoid positions which place stress on the anterior inferior capsule during ADLs

Other Therapeutic Exercises

- Progressing from Phase III there are no limitations to TBS/TLS or TAS. However, unless end range of motion is required for the athlete's sport then we strongly recommend avoiding training that stresses the shoulder in the ABER position as the risk of developing recurrent instability outweighs the benefits of training.

Open and Closed Kinetic Chain Exercises

- Progression of OKC and CKC consistent with principles previously outlined.

Techniques to Increase Muscle Strength, Power, and Endurance

- During this phase the focus of exercises should progress from endurance to strength and power. This will require increasing loads, speed of movements, and type of contraction.
- *Loads*—loads now may be increased appropriate to sport and body weight beginning with 3 to 5 sets of 10 and progressing to 3 to 5 sets of 4 to 6 reps over the next 8 to 10 weeks consistent with a traditional strength training program.
- *Speed of movement*—concentric movements are challenged first beginning with IR, then ER, then punches and complex movements. Punches are last as this as scapular protraction places increased stress on the capsulolabral complex and is a common mode of dislocation.
- *Type of contraction*—eccentric loads can now be initiated beginning with ER (towards IR) and abduction (towards adduction) first then progressing to IR and abduction in preparation for plyometric exercises.
- It is recommended to gradually progress to positions of high stress during this phase as needed. For example, to progress back to bench press begin with the athlete performing a dumbbell bench press on the floor, then barbell on the floor, then dumbbell (Figure 1-16).

Neuromuscular Dynamic Stability Exercises

- Integration of higher loads and greater perturbations are important in particular for athletes returning to sport.

Examples include:

- For football players clap pushups on foam or Dynadisc
- For throwers repeated ER yo-yos (with 1-kg weight on band)

Plyometrics

- Because of the explosive nature of this type of exercise, emphasis of plyometric exercises should be on quality not quantity. Additionally, 2 to 3 weeks of tolerance to high speed multi-planar activities is recommended, which progressively mimics functional demands before initiating plyometric exercises.
- Perform two to three times/week and utilize moderate reps (e.g., 3 to 5 sets of 15 to 20 reps).



FIGURE 1-16. A, B, The bench press progression begins with dumbbells and the athlete on the floor. The arms are shoulder level then the weight is pushed up finishing with scapular protraction. When the athlete can complete 3 sets of 15 without pain or soreness the barbell bench on the floor can be considered. **C,** The barbell progression is performed in the same manner as dumbbell bench press on the floor completing the exercise with full scapular protraction. **D,** Traditional bench press should begin after completing the floor progression. Hands should be shoulder width apart and the elbows should not go behind the body when the bar is to the chest to protect the anterior repair. A towel roll or other que can be used on the chest to help the athlete modify the exercise.

- Begin with unweighted balls and progress to lightly weighted balls (Plyoballs).

Functional Exercises

- Continue as per Phase III.

Sport-Specific Exercises

- Med ball throws against a wall, for distance for OKC sports.
- UE fitter/stepper in prone position for CKC sports (Figure 1-17).
- Dribbling on wall or rebounding with one hand.

Milestones for Progression to Advanced Sport-Specific Training and Conditioning

- Clearance from physician.
- PSS > 90% and WOSI < 10%.
- No complaints of pain at rest and minimal to no pain (NPRS 0 to 2/10) following activities.
- No or minimal sensation of instability with activities.
- Restoration of sufficient ROM to perform desired activities.
- Maintenance of strength and endurance as evidence by the following:
  - <10% deficit using isokinetic or hand held dynamometer for ER, IR, abduction, and elevation.
  - 30 repetitions in 30 seconds with blue Thera-Band at 0° and 90° abduction
  - Able to complete 90 hand-taps during modified Davies CKC UE test in 60 seconds.[38]

Phase V: Return to Sport Progression

- Similar to Phase IV, the length will vary dependent upon sport participation.
- The timing of this phase will be greatly impacted by risk of reinjury and timing relative to competition requirements.
- As risk of reinjury increases, a more conservative approach in return to competition is recommended.

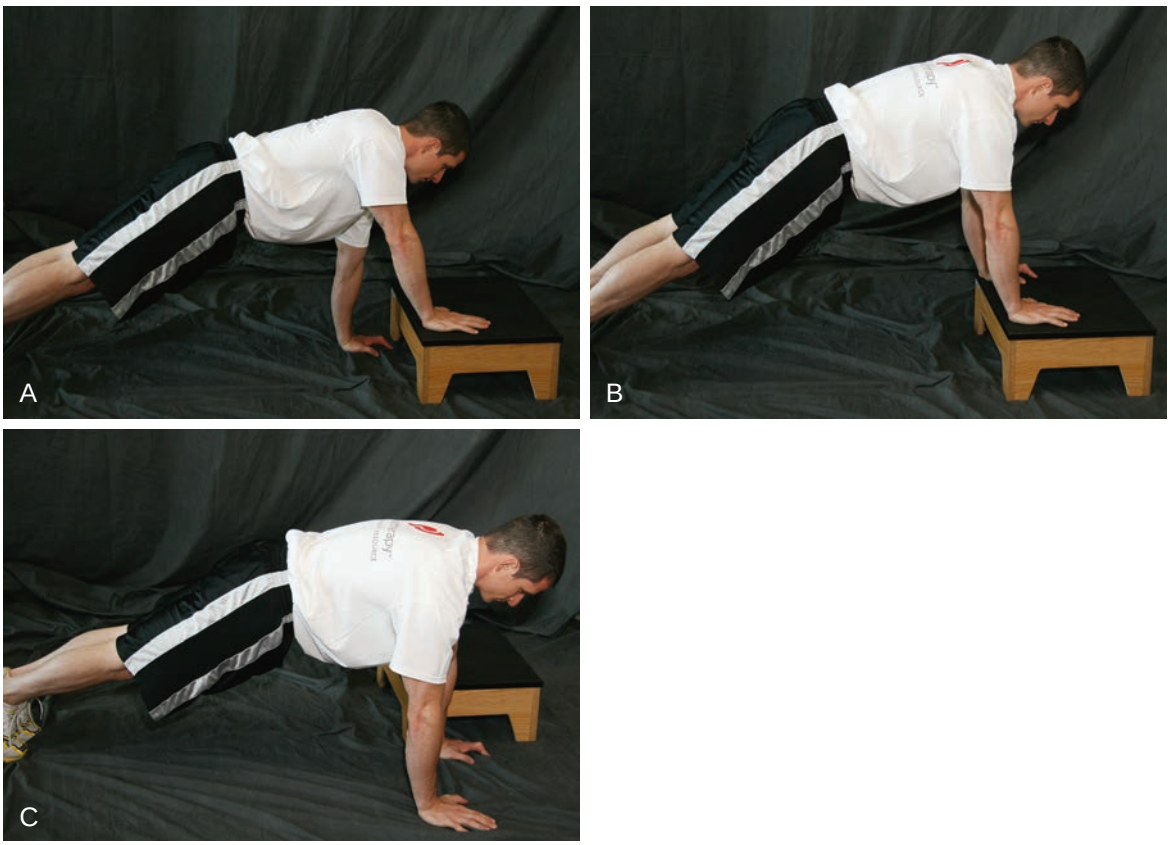

FIGURE 1-17. Hand Walks on Box: Patient "walks" one hand at a time up on box and back down maintaining scapular stability without shrugging and remaining symptom free for 1 rep/sec (both hands up and down) for 30 to 60 seconds.

- As maturity of the athlete and level of competition increase athlete education becomes imperative allowing the sports medicine team (athlete, PT, ATC, and MD) to reach the best decision for that athlete.

Goals

- No complaints of pain at rest and minimal to no pain (NPRS 0 to 2/10) following activities
- No or minimal sensation of instability with activities
- Maintenance of sufficient ROM to perform desired activities
- Maintenance of shoulder strength and endurance as previously described with minimal to no pain (NPRS 0 to 2/10) or difficulty

Clinical Pearls

- Soft tissue and joint mobilizations (once or twice per week) will prevent loss in ROM during the return to sport progression. Careful attention to maintenance of ROM and flexibility will allow for long-term successful return to sport.
- Begin sessions with a complete dynamic warm-up including rotator cuff before complex, functional, and plyometric exercises.
- Continued strengthening of the rotator cuff and scapular stabilization exercises to fatigue should be performed once or twice per week.

Protection

- Use of either a Sully or Donjoy (formerly SaWa) brace is recommended during initial return to sport, in particular for contact athletes. We prefer the SaWa brace-9 (lace up/strap brace) for contact athletes as it is the only brace demonstrated to limit ER and abd ROM.[42] The Sully (neoprene) is recommended for all others as it has been shown to increase proprioception and kinesthetic awareness which are altered in shoulders with anterior instability.[43,44]

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- As previously described PRN.

Soft Tissue Techniques

- As previously described PRN.

Stretching/Flexibility Techniques for the Musculo-Tendinous Unit

- Regular assessment of ROM/flexibility during the return to sport progression and after return to sport is important for long-term shoulder function.

Other Therapeutic Exercises

- As previously described.

Open and Closed Kinetic Chain Exercises

- As previously described.

Techniques to Increase Muscle Strength, Power, and Endurance

- Care should be taken to ensure that the athlete maintains shoulder-strengthening and dynamic strengthening exercises. We recommend 3 days for 20 to 30 minutes of focused rotator cuff and scapular stabilizing exercises in addition to TBS and TAS that may be apart from normal athletic activities.

Plyometrics

- PRN as previously described.

Sport-Specific Exercises

- PRN as previously described.

Criteria for Return to Sport

- PSS > 95% and WOSI < 10%.
- No complaints of pain at rest and minimal to no pain (NPRS 0 to 2/10) following activities.
- No or minimal sensation of instability with activities.
- Maintenance of sufficient ROM to perform desired activities.
- Maintenance of strength and endurance as evidenced by the following:
  - <10% side-to-side deficit using isokinetic or hand held dynameter for ER, IR, abduction, and elevation.
  - <33% unilateral ER:IR ratio[39,40]
  - 30 repetitions in 30 seconds with blue Thera-Band at 0° and 90° abduction
  - Able to complete 90 hand-taps during modified Davies CKC UE test in 60 seconds.[38]

Evidence

Arciero RA, Wheeler JH, Ryan JB, et al: Arthroscopic Bankart repair versus nonoperative treatment for acute, initial anterior shoulder dislocations. *Am J Sports Med* 22:589–594, 1994.

We will include all varsity, junior varsity, and freshmen baseball and softball players in our study. Players will be excluded from the study if they are being treated for a shoulder or elbow injury at the beginning of the preseason training. Players will be excluded if they are following a physician, therapist or trainer prescribed arm care program. Athletes complaining of pain during flexibility or strength testing will be excluded from the study. (Level IV evidence)

Bankart ASB: The pathology and treatment of recurrent shoulder dislocation of the shoulder. *Br J Surg* 26:23–29, 1939.

The article looks at the condition of recurrent shoulder dislocation and the operation techniques used to repair the disability, causes of the recurrent dislocation, and the recommended operation for most effective repair. Abnormal laxity in the capsule of the joint and weakness of the surrounding muscles have been associated with the condition. Stretching and imperfect healing from too much use early after reduction has said to cause the recurrent dislocation. Two types of operations to fix the problem are described; one which decreases the size of the capsule, and the other which is supposed to give support to the capsule. The problem with the two techniques is that they can limit normal movement and range of motion. The articles suggest an operation that exposes the anterior margin of the glenoid cavity, and repair the defect with sutures that pass through the free edge of the capsule and glenoid ligament. The goal of the technique is to correct the condition and still maintain normal motion. (Level IV evidence).

Buss DD, Lynch GP, Meyer CP, et al: Nonoperative management for in-season athletes with anterior shoulder instability. *Am J Sports Med* 32:1430–1433, 2004.

This is a prospective study of 30 athletes sustaining an episode of anterior shoulder instability. The athletes were treated conservatively without a sling and with physical therapy, if necessary, to restore range of motion and strength to symmetrical limits. The athletes were returned to full participation in their sport with a brace and were monitored for the number of recurrent instability episodes, additional injuries, and the ability to complete their season. (Level III evidence)

Edouard P, Degache F, Beguin L, et al: Rotator cuff strength in recurrent anterior shoulder instability. *J Bone Joint Surg Am* 93:759–765, 2011.

The study analyzes the relationship between internal/external rotator muscle strength and recurrent anterior shoulder instability. The study included 37 patients with recurrent unilateral shoulder dislocation and 11 healthy nonathletic subjects. A Con-Trex dynamometer was used to test internal and external rotator strength with side-to-side comparisons of the effected group as well as comparisons of the control group. Angles of measure were 180°, 120°, and 60° in concentric mode. Findings showed that patients with recurrent anterior shoulder instability also had weakness in the rotator cuff. Side-to-side differences in strength were present and increased depending on which arm was dominant or non-dominant. The strength difference increases when the nondominant arm was involved, and decreased when the dominant arm was involved. The control group was representative of other studies with healthy subjects who had more strength in the dominant arm. It is suggested that further studies be conducted to determine whether weakness contributes to or is a consequence of recurrent instability. (Level III evidence).

Ellenbecker TS, Mattalino AJ: Glenohumeral joint range of motion and rotator cuff strength following arthroscopic anterior stabilization with thermal capsulorraphy. *J Orthop Sports Phys Ther* 29:160–167, 1999.

This descriptive study of 20 patients diagnosed with anterior shoulder instability described their postoperative rehabilitation program following arthroscopic shoulder stabilization. The involved patients experienced return of ROM and scapular/rotator cuff strength at 12 weeks when compared with the uninjured extremity. (Level IV evidence).

Matias R, Pascoal AG: The unstable shoulder in arm elevation: a three-dimensional and electromyographic study in subjects with glenohumeral instability. *Clin Biomech (Bristol, Avon)* 21(Suppl 1):S52–S58, 2006. [Epub 2005 Nov 9];

An altered scapulohumeral rhythm is said to be related to some shoulder dysfunction, but little is known about the shoulder muscle activation patterns in patients with

glenohumeral instability. The study included six subjects with glenohumeral instability who all performed arm elevations in eight positions. A 6 DOF electromagnetic device was used to record the kinematics. The scapulohumeral rhythms were compared among subjects. The most significant differences were seen in the scapular protraction and spinal tilt and no differences were seen in the scapular lateral rotation. The kinematic changes during certain angles of arm elevation may be due to changes in alignment of the humeral head and glenoid and as a result contribute to shoulder instability. The study emphasizes the importance of assessing scapulohumeral rhythms in the rehabilitation process of individuals with shoulder instability. (Level IV evidence).

Myers JB, Ju YY, Hwang JH, et al: Reflexive muscle activation alterations in shoulders with anterior glenohumeral instability. *Am J Sports Med* 32:1013–1021, 2004.

The study looks at the relationship between anterior shoulder instability and muscle activation alterations. Eleven patients with anterior shoulder instability where matched with 11 control subjects. Each subject underwent external humeral rotation apprehension perturbation while muscle activation characteristics were recorded using electromyographic analysis. Patients with instability showed decreased pectoralis major and biceps brachii mean activation along with increased peak activation in the subscapularis, supraspinatus, and infraspinatus when compared with the control subjects. A much slower bicep brachii mean reflex latency as well as suppressed supraspinatus-subscapularis coactivation was seen in the patients with instability. These results may explain recurring episodes of instability in patients with glenohumeral instability. (Level IV evidence).

Paletta GA, Jr, Warner JJ, Warren RF, et al: Shoulder kinematics with two-plane x-ray evaluation in patients with anterior instability or rotator cuff tearing. *J Shoulder Elbow Surg* 6:516–527, 1997.

The study analyzes the relationship of biplanar glenohumeral kinematics and glenohumeral-scapulothoracic motion in normal patients using a two-plane radiograph series and then in patients with either shoulder instability or rotator cuff tear. The measurements were taken before and after surgery and after postoperative rehabilitation. X-rays of normal adults were obtained to have control values. Patients who had anterior instability showed abnormal motion anterior humeral translation in the anterior posterior plane and in the scapular plane. Following open stabilization the results were normal. The abnormal glenohumeral-scapulothoracic motion relationships persisted after open stabilization. Patients with rotator cuff tears also experienced abnormal glenohumeral kinematics, but after repair the problem become normal. It is suggested that further studies be conducted to understand the significance of the results. (Level IV evidence).

Rodosky MW, Harner CD, et al: The role of the long head of the biceps muscle and superior glenoid labrum in anterior stability of the shoulder. *Am J Sports Med* 22:121–130, 1994.

The study analyzes the role of the long head of the biceps muscle and superior glenoid labrum in anterior stability of the shoulder in overhead positions. Seven nonembalmed cadaver shoulders without history of articular disease where dissected for use in the study. The shoulders simulated the forces of the rotator cuff and long head biceps muscle as the glenohumeral joint was abducted and externally rotated by an Intron testing device. The device applied external rotator torque to the humerus. The testing was first completed on a normal shoulder, then the superior glenoid labrum was detached and the testing was repeated. Results showed that the long head of the biceps muscle contributes to the anterior stability of the shoulder through increasing torsional rigidity. This allows for resistance of external rotatory forces which occurs during abducted and externally rotated positions of the shoulder. In addition, the protective role of the biceps muscles helps to lessen the stress of the inferior glenohumeral ligament. Lesions to the superior glenoid labrum decrease the shoulder's torsional rigidity and put added strain on the inferior glenohumeral ligament and therefore lessen anterior shoulder stability. (Level IV evidence).

Rowe CR, Zarins B: Recurrent transient subluxation of the shoulder. *J Bone Joint Surg Am* 63:863–872, 1981.

Transient subluxation of the shoulder may be the causation of the "dead arm syndrome" characterized by sharp paralyzing pain occurring during extreme external rotation. Activities such as throwing and strained positions with the arm above the shoulder can cause the syndrome. The study includes 58 patients (60 shoulders) all with dead arm syndrome caused by transient dislocation. The treated patients were followed up at 2 to 16 years. Group 1 had the sensation of subluxation and group 2 did not have the sensation. Patients without the sensation are difficult to diagnose correctly. To obtain the most accurate physical finding for patients, an apprehension test was performed. Of the 50 shoulders that underwent a Bankart repair, the following grading system results were obtained: 70% excellent, 24% good, and 6% fair. Deficiencies in the shoulder capsule are said to be a factor of anterior subluxation of the shoulder. (Level III evidence).

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Multiple-Choice Questions

QUESTION 1. Recurrent episodes following traumatic anterior shoulder instability generally increase

A. The older a patient and less tissues involved.
B. The younger a patient and more tissues involved.
C. The older a patient and more tissues involved.
D. The younger a patient and less tissues involved.

QUESTION 2. Rotator cuff exercises in Phase I are best tolerated

A. In the "safe zone" of 20° to 30° abduction in the plane of the scapula.
B. In neutral abduction and rotation.
C. In supported elevation at 90° of abduction.
D. In 45° of abduction and 20° of IR.

QUESTION 3. Which statement best describes the rationale of why recurrent instability is worrisome?

A. Clearance for return to sport isn't based on number of recurrent episodes.
B. Contact athletes are at risk for rotator cuff tears with recurrent instability.
C. There is no evidence that recurrent instability increases injury risk or long-term disability.
D. Recurrent instability episodes may lead to increased incidence of intraarticular pathology and early onset osteoarthritis.

QUESTION 4. Criteria for initiating resistance exercises above shoulder height include

A. Pain free at rest, full AROM in abduction and ER.
B. Pain free at rest, PROM within functional limits, and negative apprehension test.
C. Pain free after exercise, AROM within functional limits, and tolerance of Phase 2 exercises.
D. Pain free at rest, AROM within functional limits, and tolerance of Phase 2 exercises.

QUESTION 5. A 16-year-old linebacker is 4 weeks s/p a right shoulder dislocation without labral or bony injuries confirmed by MRI. What criteria should they meet to return to play?

A. No sense of instability at end ROM, < 50% ER:IR strength ratio, and 60 hand-taps during CKC UE test.
B. No sense of instability at end ROM, < 50% ER:IR strength ratio, and 90 hand-taps during CKC UE test.
C. Minimal sense of instability at end ROM, < 33% ER:IR strength ratio, and 60 hand-taps during CKC UE test.
D. Minimal sense of instability at end ROM, < 33% ER:IR strength ratio, and 90 hand-taps during CKC UE test.

Answer Key

QUESTION 1. Correct answer: **B**. (see Overview)

QUESTION 2. Correct answer: **A**. (see ROM Guidelines Phase I)

QUESTION 3. Correct answer: **D**. (see Overview/Return to Sport-Phase IV)

QUESTION 4. Correct answer: **C**. (see Phases II and III)

QUESTION 5. Correct answer: **D**. (see Phase IV-Return to Sport)

POSTOPERATIVE REHABILITATION AFTER ARTHROSCOPIC ANTERIOR SHOULDER STABILIZATION

Charles A. Thigpen, PhD, PT, ATC, Ellen Shanley, PhD, PT, OCS, and Richard J. Hawkins, MD

Indications for Surgical Treatment

- Disability related to recurrent shoulder instability.
- Following first time dislocation selected patients combined with certain pathologies (e.g., full thickness rotator cuff tear following dislocation in older patient, large glenoid or humeral defect).

Brief Summary of Surgical Technique

Major Surgical Steps

- Examination under anesthesia for translation in all directions and range of motion.
- Positioning in lateral decubitus or sitting (beach chair) position (Figures 1-18 and 1-19). Either requires some lateral distraction.
- Prepping and draping protecting vulnerable areas and insuring sterility and accessibility.
- Insertion of scope for visualization (establish outflow when necessary) (Figures 1-20 and 1-21).
- Identify pathology and determine approach.
- Prepare anterior glenoid surface.
- Mobilize labrum and capsule (Figures 1-22 and 1-23).
- Secure capsule and labrum to anterior glenoid usually with bone anchors (Figure 1-24).
- Usually three anchors securing capsule and labrum.
- Amount of capsule incorporated varies based on the amount of laxity under exam under anesthesia (EUA), labral/capsular damage, and functional range of motion (ROM) requirements (thrower vs. linebacker)
- Usually three anchors. Anchors at apex or slightly upon the face of glenoid to recreate bumper.
- Remove traction and close portal sites in usual fashion.

Factors That May Affect Rehabilitation

Surgical

- In this section we discuss arthroscopic plication and the Bankart repair. The principles of open surgical reconstruction for anterior instability would be similar if soft tissue in nature (i.e., modified Bankart procedure). Bony procedures if secured by screws may allow earlier mobilization.
- Amount of capsular plication and integrity of the capsule.[2] ROM progression and goals may be delayed for excessive plication to correct excessive capsular redundancy or for patients with a long-standing instability history as their anterior-inferior capsule is often not robust.[2,3]
- Degree of labral repair/reconstruction repairs.[4] Typically, the labrum is detached from the 3 to 6 o'clock position off the glenoid. Tears that extend beyond these borders would require close consultation with the surgeon to modify ROM limits and precautions.
- Amount of glenoid bone loss.[5-7] The degree of glenoid bone loss will influence ROM expectations as well as amount of protection needed postoperatively. Emerging evidence suggests glenoid bone loss as a likely factor in recurrent dislocations. Significant bone loss anteriorly may suggest soft tissue arthroscopic reconstruction inadequate and may require a bony reconstruction (i.e., Latarjet).
- Associated injuries such as a Hill-Sachs lesion, SLAP (superior labral tear from anterior to posterior) tears,

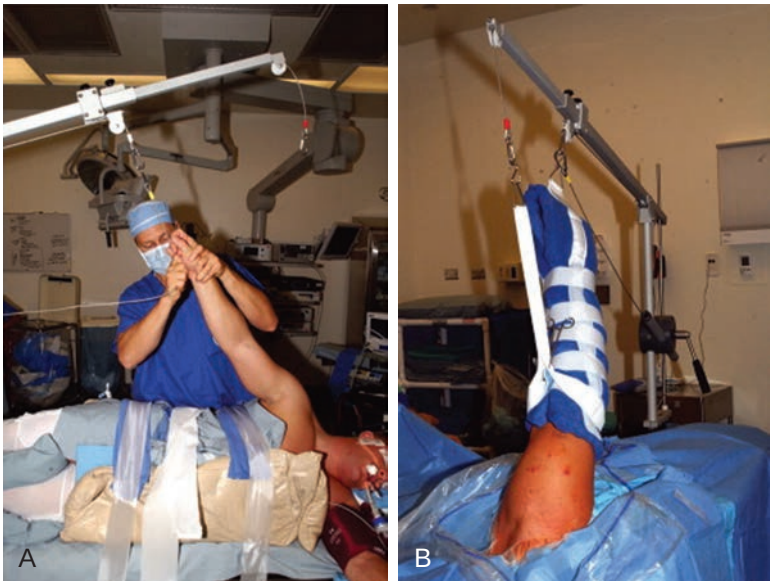

FIGURE 1-18. The lateral decubitus position. (A) Operative setup. The arm is usually abducted between 45 and 60 degrees. (B) Final balanced suspension setup with the arm abducted about 50 degrees and a lateral strap is used to facilitate the visualization of the glenohumeral joint. Care must be taken to ensure the lateral suspension strap is around a padded arm sleeve. *(From Provencher MT, Romeo AA, editors: Shoulder instability: a comprehensive approach, Philadelphia, 2011, Elsevier (Saunders), p. 37.) Fig. 3-10B and 3-12.*



FIGURE 1-19. Beach chair position. Final positioning with the arm reduced to a pneumatic arm positioner. It is easier to reduce the arm to the arm holder that has been previously placed on the pneumatic arm positioner. *(From Provencher MT, Romeo AA, editors: Shoulder instability: a comprehensive approach, Philadelphia, 2011, Elsevier (Saunders), p. 41.) Fig. 3-20C.*

rotator cuff tears, or other osteochondral injuries may also be present.[4] The impact of these concomitant injuries and potential procedures should be accounted for in the rehabilitation plan.

Anesthetic

- Anesthesia interscalene blocks are commonly used postoperatively for short-term pain control.
- Usually, one interscalene injection is appropriate for anterior instability procedures.
- Patients may perform ROM exercises carefully as directed by the surgeon.
- An interscalene block may require careful early mobilization under the direction of a Physical Therapist or Certified Athletic Trainer as directed by the surgeon.

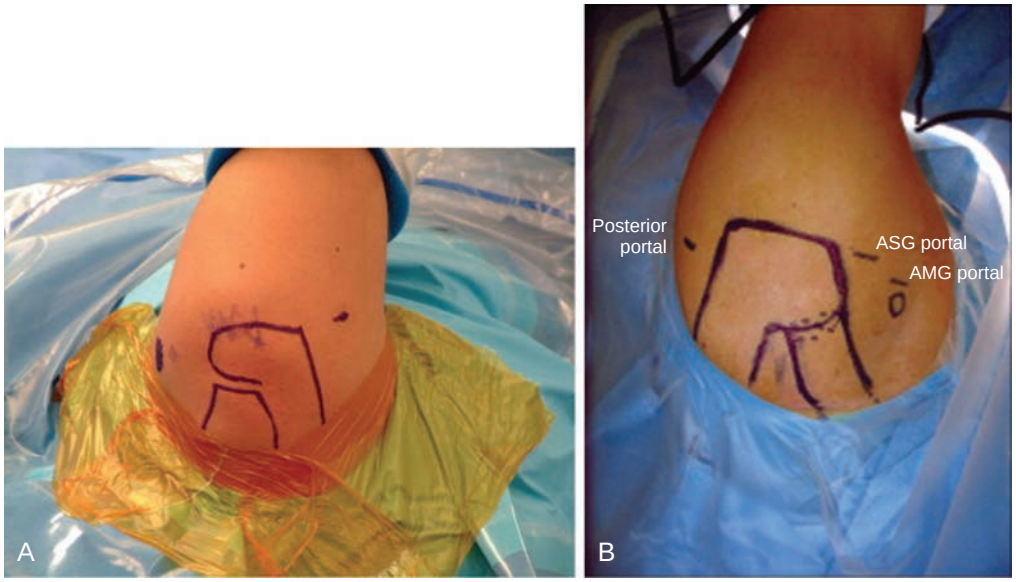

FIGURE 1-20. Surgical skin landmarks. **A,** Initial skin markings showing landmarks. Note lateral position of anticipated portal posteriorly. **B,** Shows portals. *(From Reider B, et al: Operative techniques: sports medicine surgery, Philadelphia, 2010, Elsevier (Saunders)) Fig. 11-14A and B.*



FIGURE 1-21. Outside picture demonstrating arthroscope posterior and 18-gauge needles placed in outside-in fashion. Note anterosuperior portal is adjacent to anterior acromion and anterior mid-glenoid portal is adjacent to coracoid. *From Provencher MT, Romeo AA, editors: Shoulder instability: a comprehensive approach, Philadelphia, 2011, Elsevier (Saunders), p. 135.) Fig. 11-15.*

Other Surgical Techniques and Options

- Major differences in other surgical techniques
  - Open Bankart repair is the same as the arthroscopic Bankart repair with the exception that the subscapularis is either detached or split for accessibility to the anterior labrum, capsule, and glenoid (see Figure 1-29).
  - Open procedures for bone loss or bony defects require secure fixation or a bone block such as a Latarjet (see Figure 1-33) with an associated soft tissue reconstruction. Rehab is much the same but may allow early mobilization. Other grafts may be used such as iliac crest graft or allograft. These are securely fixed to anterior glenoid. These also require subscapularis violation.
- This chapter is dedicated primarily to arthroscopic plication with or without a Bankart repair. The primary difference between the following guidelines and these surgical modifications is rate of ROM return. For the open surgical reconstruction significant attention should be given to external rotation (ER). ER should be limited to 30° with the arm at the side and a measured rate of ROM. We recommend ER to 0 for 3 weeks then gradual stretching with a goal of attaining 30° of ER by 6 weeks. In contrast, bony procedures if secured by screws may allow earlier mobilization with gradual return of ER and ABD ROM.

GUIDING PRINCIPLES OF POSTOPERATIVE REHABILITATION

- Understanding of the surgical procedure and anatomic structures, which require protection.
- Consideration of healing rates of the involved tissues while balancing the stresses needed for tissue proliferation/remodeling and protecting the repaired/reconstructed tissues.[1]
- Gradual restoration of PROM while protecting the anterior-inferior aspect of the glenohumeral joint through initial immobilization and the rate of ROM gain. Emphasizing PROM then AROM then resisted activities.
- Correct application of manual techniques and therapeutic exercises to promote static balance in glenohumeral joint mobility and optimum dynamic stabilization from the rotator cuff and associated shoulder girdle muscles.

Phase I (0 to 14 days): Immediate Postoperative Period

Goals

- Protect the surgical repair (capsule, ligaments, labrum, sutures)

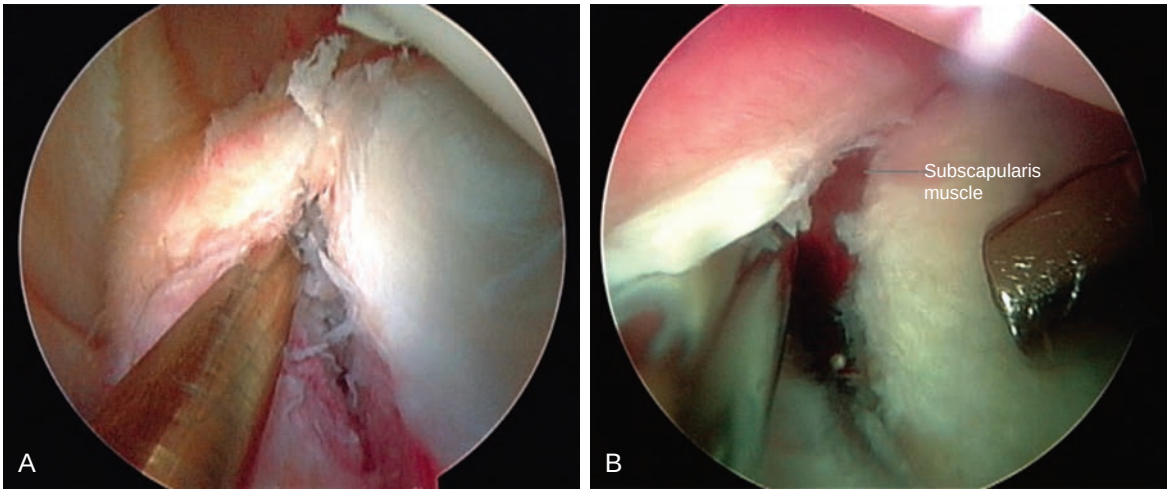

FIGURE 1-22. Preparation of anterior labrum. **A,** Arthroscopic view from anterosuperior portal in a right shoulder showing anterior-inferior capsulolabral avulsion. **B,** Right shoulder showing mobilization of anterior capsulolabral avulsion with subscapularis muscle visible deep to labrum. *From Provencher MT, Romeo AA, editors: Shoulder instability: a comprehensive approach, Philadelphia, 2011, Elsevier (Saunders), pp.136 and 137.) Fig. 11-20 and 11-22.*

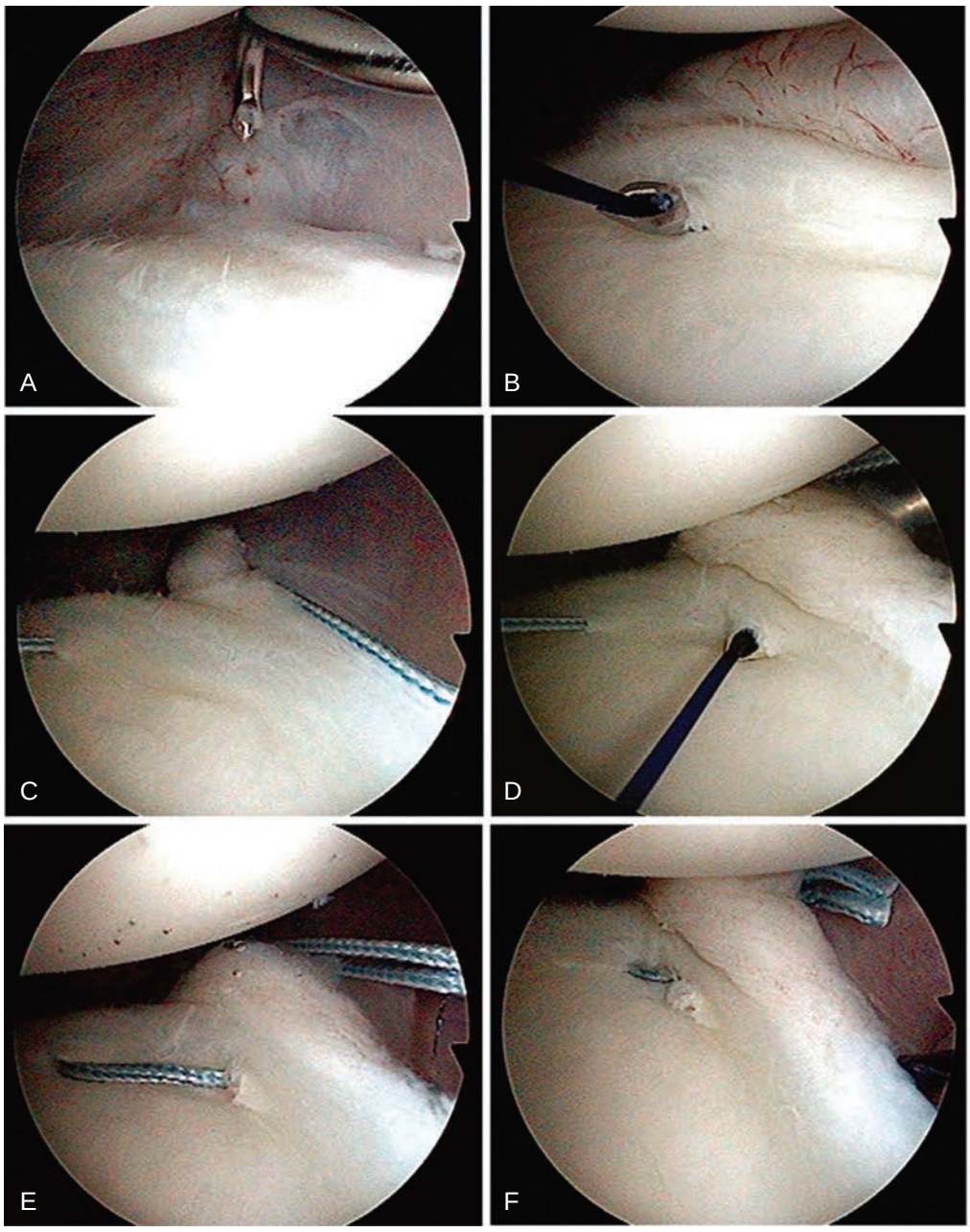

FIGURE 1-23. Mobilization of labrum and capsule. Sequence of performing plication posteroinferiorly as part of the initial phase of the repair in a right shoulder; viewing portal is anterosuperior. **A,** A suture shuttling device pierced capsule about 10 mm lateral to labrum at 6 o'clock position. **B,** The needle is then brought through the labrum and a monofilament suture (0 or No. 1) is passed and retrieved out of the anterior mid-glenoid portal. **C,** A nonabsorbable suture (No. 2) is tied to the monofilament suture outside the anterior mid-glenoid portal, and the monofilament suture acts to shuttle the nonabsorbable suture. **D,** Steps are repeated to shuttle the other limb of the nonabsorbable suture through labrum and capsule. **E,** Mattress plication suture in place posteroinferiorly. **F,** Mattress plication suture tied; note reduction of posteroinferior redundancy. *(From Provencher MT, Romeo AA, editors: Shoulder instability: a comprehensive approach, Philadelphia, 2011, Elsevier (Saunders), p. 138.) Fig. 11-24A-F.*

- Educate the patient in terms of restrictions, pain management, and ADLs
- Minimize shoulder pain
- Achieve staged ROM goals, DO NOT significantly exceed them
- Restore scapular control

Clinical Pearls

- When patients are very painful and guarded reviewing sleeping habits, sling use, and HEP are often helpful in managing pain allowing for gentle restoration of ROM.
- Gradual "weaning" of the sling in 4-hour increments/day provides for gradual introduction of stress to shoulder decreasing likelihood of development of pain and loss of ROM.

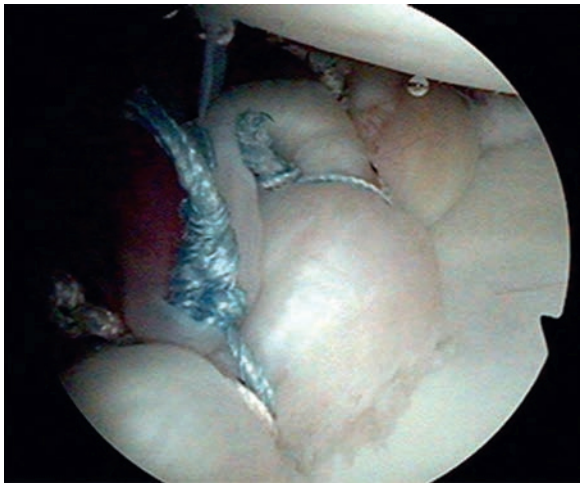

FIGURE 1-24. Securing labrum and capsule. Finished repair with combined plication and labral repair performed anteriorly with each anchor. In this case double-loaded anchors were used. *(From Provencher MT, Romeo AA, editors: Shoulder instability: a comprehensive approach, Philadelphia, 2011, Elsevier (Saunders), p. 142.) Fig. 11-31.*

Protection

- Postoperative immobilization using a sling (with or without a pillow) is recommended for patient comfort and limits stress on the anterior/inferior structures for the first 2 weeks.
  - The sling is to be used at all times, including during sleep
- We recommend gradual progression to no sling from weeks 4 to 6 based on pain, available ROM, muscle performance, and activity level.

Management of Pain and Swelling

- Interscalene pain pumps are often used during postoperative days 1 to 3 to control early postoperative pain.
- Oral pain medications.
- Electrical stimulation (Transcutaneous Electrical Neural Stimulation [TENS]) is recommended to manage pain and muscle guarding.
- Intermittent cryotherapy for pain and inflammation reduction.[8]
- Patient positioning: patients are encouraged to use pillows or bolsters to find a "position of comfort" which is usually slightly abducted (20° to 30°) in a neutral or slight internal rotation. This position is recommended to reduce stress on repaired structures as well as "unload" the surrounding muscles.

Techniques for Progressive Increase in Range of Motion (Table 1-2)

- The initial 2 weeks are essentially quiet with little or no ROM exercises required. The focus of this phase is resolving pain, decreasing swelling, and allowing the postsurgical shoulder to recover.
- Codman's pendulum exercises for gentle motion and joint distraction, supported FE (<90°), and ER to 0° at the side (<20° abd) can be performed 1 to 3 times/day to maintain joint mobility. We suggest all of these motions be performed with support to minimize rotator cuff activity due to incorrect technique.[9-11]
- Manual therapy techniques—gentle joint distraction and grade I-II joint oscillations may be helpful before performing supervised PROM by the rehabilitation professional to decrease muscle guarding and prepare the joint for ROM exercise. We recommend these treatments to be performed in the scapular plane in approximately 30° of elevation, and neutral rotation to limit the stress on the capsulolabral repair.[12]
- Soft tissue techniques—shortening, parallel techniques such as (Positional Release/Strain-Counter-strain) may be helpful to reduce protective guarding especially for the subscapularis, posterior rotator cuff, teres major, latissimus dorsi, and pectoralis major/minor.
- Stretching/flexibility techniques for the musculotendinous unit are not recommended at this time

TIMELINE 1-2: **Postoperative Rehabilitation After Arthroscopic Anterior Shoulder Stabilization**[1]

PHASE I (weeks 1 to 2)	PHASE II (weeks 3 to 6)	PHASE III (weeks 6 to 10)
• Sling • PT modalities • ROM-passive forward elevation to 90° • Active assistive Codman's exercises • TBS/TAS/TLS activities as recommended & tolerated	• Sling • PT Modalities • ROM wk 3—forward elevation to 90° • ROM wk 3—external rotation to 10–30° • TBS/TAS/TLS activities as recommended & tolerated • Scapular exercises • Wk 4—AAROM exercises • Wk 4—submaximal isometrics for GH joint muscles	• DC sling • PT Modalities as needed • ROM wk 6—forward elevation to 135° • ROM wk 6—external rotation to 35°–50° • ROM wk 9—forward elevation to 155° • ROM wk 9—external rotation to 35°–50° • Mobilizations as needed • TBS/TAS/TLS activities as recommended & tolerated • Scapular exercises—PREs • TAS—Biceps/Triceps PREs • Glenohumeral exercises—PREs • Rotator cuff exercises—PREs • PNF exercises • OKC Rhythmic stabilization exercises • CKC Exercises • CKC manual perturbation exercises

Table 1-2 Staged Range of Motion Goals for Arthroscopic Anterior Capsulolabral Repair

	PFE	PER at 20° abd	PER at 90° abd	AFE
POW 3	90°	10°–30°	Contraindicated	NA
POW 6	135°	35°–50°	45°	115°
POW 9	155°	50°–65°	75°	145°
POW 12	WNL	WNL	WNL	WNL
POW 12	WNL	WNL	WNL	WNL

AFE, Active forward elevation in the scapular plane; *NA*, not appropriate; *PER*, passive external rotation; *PFE*, passive forward elevation; *POW*, postoperative week; *WNL*, within normal limits.

because of the need to protect the repair. Cervicothoracic, elbow, hand, and wrist.

Other Therapeutic Exercises

- Although lower extremity and cardiovascular exercises may begin during the first 2 weeks while in the sling, in our experience patients do not tolerate these activities until after 14 days.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Submaximal isometric exercises may begin POW 1 as tolerated. We recommend performing these exercises in the "safe zone" of 20° to 30° abduction in the plane of the scapula in neutral rotation first with the elbow supported then gradually removing support.

Milestones for Progression to the Next Phase

Minimal to moderate pain (NPRS: 2 to 4/10) with minimal pain at rest (2/10)

- Staged ROM goals achieved but not significantly exceeded

Phase II: Weeks 2 to 6 Postoperatively

Goals

- Minimize shoulder pain (<2/10)
- Achieve staged ROM goals to normalize passive ROM and active ROM. **DO NOT** significantly exceed
- Normalize rotator cuff guarding and neuromuscular control
- Normalize scapular position and control

Clinical Pearls

- Avoid scapular protraction during the first 6 weeks as this position has been shown to have high levels of subscapularis activity and increases stress on the anterior capsulolabral structures.[13,14]
- Restoration of ER first then FE will allow for optimal ROM recovery.

TIMELINE 1-2: **Postoperative Rehabilitation after Arthroscopic Anterior Shoulder Stabilization** (Continued)

PHASE IV (weeks 10 to 14)	PHASE V (weeks 14 to 24)	PHASE V (weeks 24 to 52)
• PT Modalities as needed • PROM-full • Mobilizations as needed • ROM wk 12—forward elevation progress to full ROM • ROM wk 12—external rotation progress to full ROM at 90°/90° • Wk 12- begin terminal shoulder girdle stretches as needed • TBS/TAS/TLS activities as recommended & tolerated • Scapular exercises—PREs • Glenohumeral exercises—PREs • Rotator cuff exercises—PREs • PNF exercises • OKC Rhythmic stabilization exercises • CKC Exercises • CKC manual perturbation exercises	• PROM-maintain full motion • Mobilizations as needed • TBS/TAS/TLS activities as recommended & tolerated • Scapular exercises—PREs • TAS—Biceps/Triceps PREs • Glenohumeral exercises—PREs • Rotator cuff exercises—PREs • PNF exercises • OKC Rhythmic stabilization exercises • CKC Exercises • CKC manual perturbation exercises • Plyometrics—2 arm progressing to 1 arm • Overhead strengthening exercises • Sport specific exercises begin • Overhead throwing athletes can begin tossing at 30ft per the • interval throwing program	• PROM-maintain full motion • Mobilizations as needed • TBS/TAS/TLS activities as recommended & tolerated • Scapular exercises—PREs • Biceps/Triceps PREs • Glenohumeral exercises—PREs • Rotator cuff exercises—PREs • IR/ER exercises at 90° • Thrower's 10 progress intensity • PNF exercises • OKC Rhythmic stabilization exercises • Exercises • CKC manual perturbation exercises • Plyometrics—2 arm chest passes progressing to 90°/90° • Single arm plyometrics • Overhead strengthening exercises • Sport-specific exercises progressed • Overhead throwing athletes progress through an interval throwing program

Patient-Oriented Outcomes

- Best clinical practice uses patient-rated measures of function and disability to comprehensively assess patient response to treatment.
- There are many available scales for measuring functional loss and disability in patients with instability and one measure is likely not superior to another.[15,16]
- We recommend two measures, a general measure of shoulder function that includes pain, function, and patient satisfaction similar to the ASES, the Pennsylvania Shoulder Score (PSS) and a measure specifically for instability, such as the Western Ontario Instability Index (WOSI).[17-21]

Protection

- Treatment for pain/analgesia oral pain medications
- Electrical stimulation (TENS) is recommended to manage pain and muscle guarding. TENS units at home are often helpful to control pain especially early following surgery.
- Intermittent cryotherapy for pain and inflammation reduction.[8] We recommend 20 minutes on/hour for the first week following surgery.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Gentle joint distraction and grade I-III joint oscillations may be helpful before performing supervised PROM by the rehabilitation professional to decrease muscle guarding, restore capsular balance, and prepare the joint for ROM exercise. Anterior-inferior or inferior glides should not be performed. We recommend these positions to be performed in the scapular plane in approximately 30° of elevation, and neutral rotation to limit the stress on the capsulolabral repair.[12]

Soft Tissue Techniques

- Shortening, parallel techniques such as (positional release/strain-counterstrain) may be helpful to reduce protective guarding especially for the subscapularis, posterior rotator cuff, teres major, latissimus dorsi, and pectoralis major/minor.
- Passive ROM and active assist ROM exercises may be initiated after POW 2 for ER and FE (see Table 1-2)
- Stretching/flexibility techniques for the musculotendinous unit should not be performed as these are end ROM exercises.

Other Therapeutic Exercises

- Gradual introduction of TBS, TLS, core stability, and uninvolved TAS beginning POW 2.
- Additionally, cardiovascular conditioning can be initiated with attention to the safety of the activity.
- All exercises should be performed with the patient in the sling until POW 5 to 6 to decrease the use of index shoulder during these exercises.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Scapular retraction and PNF patterns may begin POW 3 based on patient tolerance (Figure 1-25). We recommend avoiding scapular protraction as this position has been shown to have high levels of subscapularis activity and increase stress on the anterior capsulolabral structures.[13,14] Although scapular elevation and retraction are safe we suggested limited resistance due to the load placed through the glenohumeral joint for most exercises.
- Active ROM and rotator cuff strengthening are purposefully de-emphasized until POW 6 because of the potentially detrimental effect to the healing tissues.[22,23] Although these exercises within the staged ROM goals would not likely result in excessive loading, in our opinion aggressive strengthening is not consistent with the achieving optimal healing of the repaired tissues. Therefore, we recommend beginning with sub-maximal isometric strengthening of the shoulder and elbow with the arm adducted to the side in neutral rotation. As the patient demonstrates improved rotator cuff endurance and absence of pain or other symptoms we recommend progressing to dynamic isometrics then AROM exercises within the ROM restrictions.

Sensorimotor Exercises

- Angular reposition, rhythmic stabilization, and repeated contractions within staged ROM limits may be implemented beginning POW 2.

Open and Closed Kinetic Chain Exercises

- CKC exercises may be implemented below 90° of elevation beginning POW 2. These exercises should begin in a modified weight-bearing position and progressed to full weight-bearing by POW 6.

Techniques to Increase Muscle Strength, Power, and Endurance

- See above w/AROM

Milestones for Progression to the Next Phase

- Appropriate healing of the surgical repair by adhering to the precautions and immobilization guidelines.
- Staged ROM goals achieved but not significantly exceeded
- Minimal to no pain (NPRS: 0 to 2/10) with ROM
- PSS greater than 60% and WOSI less than 50%. These are estimates based on reported normative data and our experience. This combined with other objective criteria provides clear communication between the patient and medical professionals on how the patient perceives their shoulder function and potential insight as to how care can be improved upon.

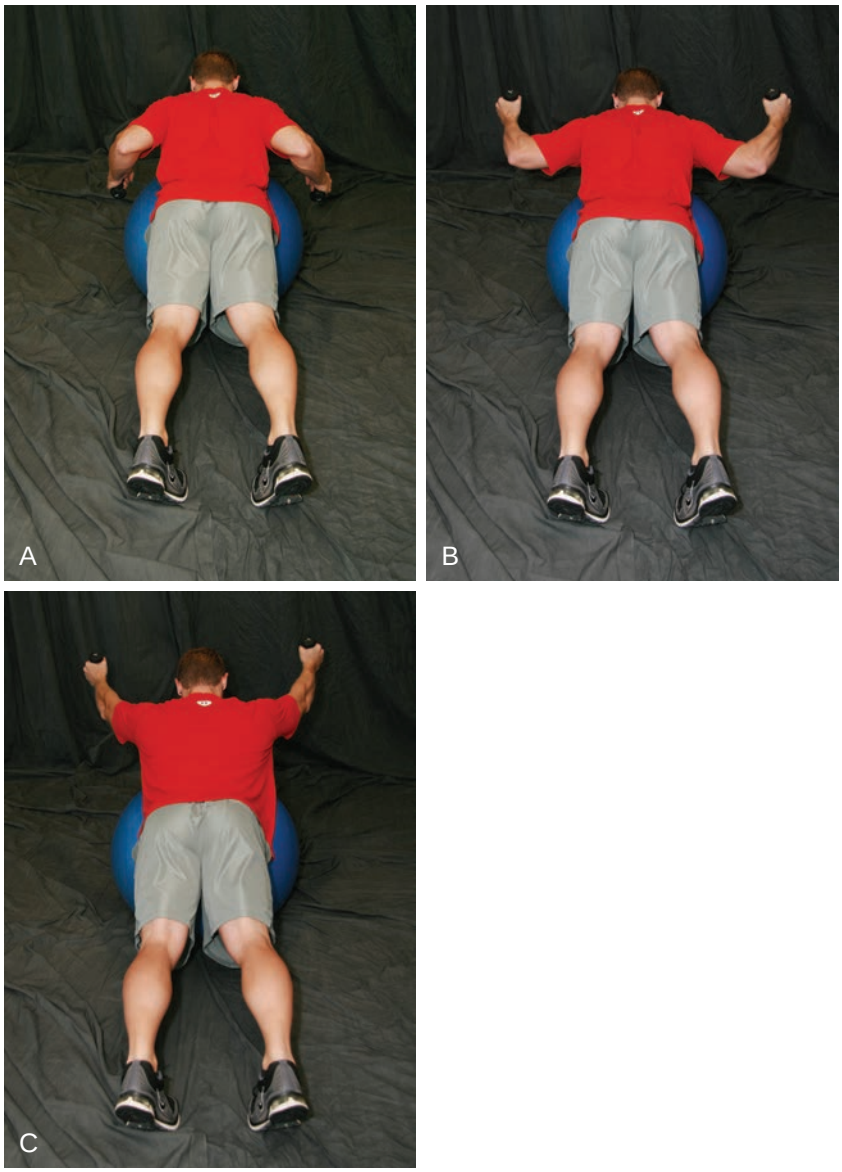

FIGURE 1-25. A–C, Ws to Ys: Patient performs scapular retraction, then glenohumeral external rotation, then elevates to the "Y" position while maintaining scapular stability.

Phase III: Weeks 7 to 12 Postoperatively

Goals

- Achieve staged ROM goals to normalize passive ROM and active ROM. DO NOT significantly exceed especially for ER at 90° of abduction.
- Minimize shoulder pain (0/10 at rest and <2/10 following exercises or activity).
- Begin to increase strength and endurance.
- Increase functional activities as evidenced by PSS > 80% and WOSI < 30%.

Clinical Pearls

- Nearly full active forward elevation should be achieved before progressing to elevation in other planes or initiating resistive elevation exercises.
- Ensuring posterior rotator cuff performance and scapular stability below 90° of abduction before progressing to higher elevation and difficulty of exercises.
- Anterior-inferior glides are often helpful to gain full ER and FE. Addition of posterior shoulder flexibility exercises in conjunction with these mobs before and after exercise is helpful in the stiff shoulder.
- In our opinion, rapid gain of ER towards 90° of abduction should be avoided (before 8 weeks). If the athlete must return to overhead, throwing sports and the involved shoulder is their throwing arm, then more aggressive stretching of ER towards 90° of abduction may begin at 8 weeks.
- Functional exercises may begin toward the end of this phase. Simple patient instruction of *"keeping their hands where they can see them"* will allow the patient to resume desired activities without risking reinjury.

Protection

- No sling use.
- Avoid positions of max ER towards 90° of abduction, especially with a posteriorly directed load. (e.g., NO push-ups, bench press, pectoral flys).

Management of Pain and Swelling

- Pain should not be a limiting factor at this point. If pain is limiting progression of activities rest and reevaluation of all aspects of the shoulder should be performed in consultation with the referring surgeon.
- Cryotherapy as needed.
- NSAIDS as needed.

Patient Education

- Counsel about using the upper extremity for appropriate ADLs in the pain-free and nonprovocative ROM (starting with waist level activities and progressing to shoulder level and finally to overhead activities over time).
- Continue education regarding avoidance of heavy lifting or quick sudden motions.
- Education to avoid positions which place stress on the anterior inferior capsule during ADLs.

Techniques for Progressive Increase in Range of Motion

- Forward elevation should be progressed from active-assistive exercises (e.g., rope and pulley, wall walks), to active, to resistive upright exercises, then finally to prone exercises as per reported EMG activity of the shoulder.[10,11] Although protection of the rotator cuff is not needed we feel the EMG activity reflects overall stress to the shoulder and good guide to exercise progression.

Manual Therapy Techniques

- Grade I-III joint mobilizations (up to tissue resistance) are most often all that is required especially for anterior/inferior directions. If ROM is greater than 50% less than staged ROM goals as compared with the uninvolved extremity then gentle joint mobilizations may be performed. However, they should be done only into the limited directions and only until staged ROM goals are achieved. It is crucial in the patients that appear "tight" to discern if there is capsuloligamentous tightness/stiffness, musculotendinous, pain limited or some combination.

Soft Tissue Techniques

- Deeper soft tissue techniques may be initiated during this phase. More aggressive techniques such as Active Release® or other instrumented soft tissue mobilizations to normalize muscle tone and extensibility. Particular attention should be paid to the subscapularis, latissimus, pectorals, teres major, and posterior rotator cuff. In our experience these techniques often allow for gradual return consistent with the staged goals without aggressive joint mobilizations or excessive end range stretching.
- Stretching/flexibility techniques for the musculotendinous unit.
- Total upper quarter mobility should be evaluated with restoration of cervical, thoracic, and scapulothoracic mobility to facilitate optimal return upper extremity ROM.
- End range flexibility exercises may begin in particular for posterior shoulder (horizontal adduction and sleeper stretch beginning at 60° to 70° of elevation on side (Figure 1-14*A*,*B*).[24,25] Pectoralis minor flexibility can begin with attention not to increase stress on anterior shoulder as these have been shown to be effective at increasing pectoralis minor length.[26,27] Gradual introduction of latissimus, posterior shoulder, and FE stretches as needed.

Other Therapeutic Exercises

- Address core stability deficits PRN beginning in the sagittal plane and progressing to frontal and transverse plane exercises.
- Total leg strengthening exercises may be progressed as tolerated but high loads should be avoided on the shoulder in activities such as power clean, dead lifts, and back squats should be avoided. We recommend front squats during this phase to allow for safe positioning of the shoulder with large loads.
- We also recommend using this phase of rehabilitation to address kinetic chain deficits using basic functional screens such as the overhead squat, single leg squat, or more in-depth approaches such as the Functional Movement Screen. These approaches will provide areas for improvement for the athlete allowing for total body movement evaluation of the entire kinematic chain.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Elbow flexion/extension strengthening with elbow by the side can begin in this phase
- Exercises and functional activities should be pain free and performed without substitutions or aberrant movement patterns (shrugging, thoracic extension)
- Balanced rotator cuff strengthening to maintain the humeral head centered within the glenoid fossa during progressively more challenging activities
- Should be initially performed in a position of comfort with low stress to the glenohumeral joint such as less than 45° elevation in the plane of the scapula (e.g., elastic band or dumbbell external rotation, internal rotation, forward elevation).
- Exercises should be progressive in terms of shoulder elevation (e.g., start w/exercises performed at waist level progressing to shoulder level and finally overhead activities).
- Depending upon the goals of the exercise (control vs. strengthening), rehabilitation activities may also be progressive in terms of speed once the patient demonstrates proficiency at slower speeds.

Sensorimotor Exercises

- Activities to improve neuromuscular control of the rotator cuff and shoulder girdle such as use of unstable surfaces, body blade, and manual resistance exercises in conjunction with auditory, visual, or tactile cues or biofeedback.
- Proprioceptive Neuromuscular Facilitation (PNF) patterns are particularly effective for restoring muscle balance and proper coordination patterns. We prefer this manual feedback especially early during this phase as the clinician controls the load to the extremity and is able to best match the patient's level of performance.

Open and Closed Kinetic Chain Exercises

- Strengthen scapular retractors and upward rotators
- Weight-bearing exercises with a fixed distal segment. Examples: quadruped position while working to maintain proper position of the scapula, quadruped with scapula protraction, progressing from quadruped to tripod position, *no push-ups*.[28]

Techniques to Increase Muscle Strength, Power, and Endurance

- Exercises should be progressive in terms of muscle demand. It is suggested to use activities that have muscle activity levels documented with EMG.[9,28-44] In general, increasing elevation increases deltoid and supraspinatus activity while increasing ER at lower levels of elevation increases posterior rotator cuff EMG.[9,28-44] The subscapularis is most active during forward punches (combined scapular protraction and glenohumeral IR) and should be performed at lower and higher levels of elevation (Figure 1-26).[40]
- Exercises should be progressive in terms of adding stress to the anterior capsule, gradually working towards a position of 90° of ER and 90° of abduction by 12 weeks.
- Rehabilitation should include isolated and complex movement patterns progressing form isolated to complex movement patterns.
- The rotator cuff and scapula stabilizer strengthening program should emphasize high repetitions (typically 30 to 50 reps) and relatively low resistance (typically 1 to 2 kg) during this phase.
- General shoulder strengthening exercises (front/side raises, shoulder presses) may be initiated as full AROM is achieved and rotator cuff and scapular stabilizer strength is adequate for normal movement patterns. This is usually a late Phase III exercise and should begin with 3 to 5 kg and similar repetitions (15 to 20 for 3 to 4 sets).

Neuromuscular Dynamic Stability Exercises

- Development of dynamic stability is crucial during this phase of rehabilitation following stabilization

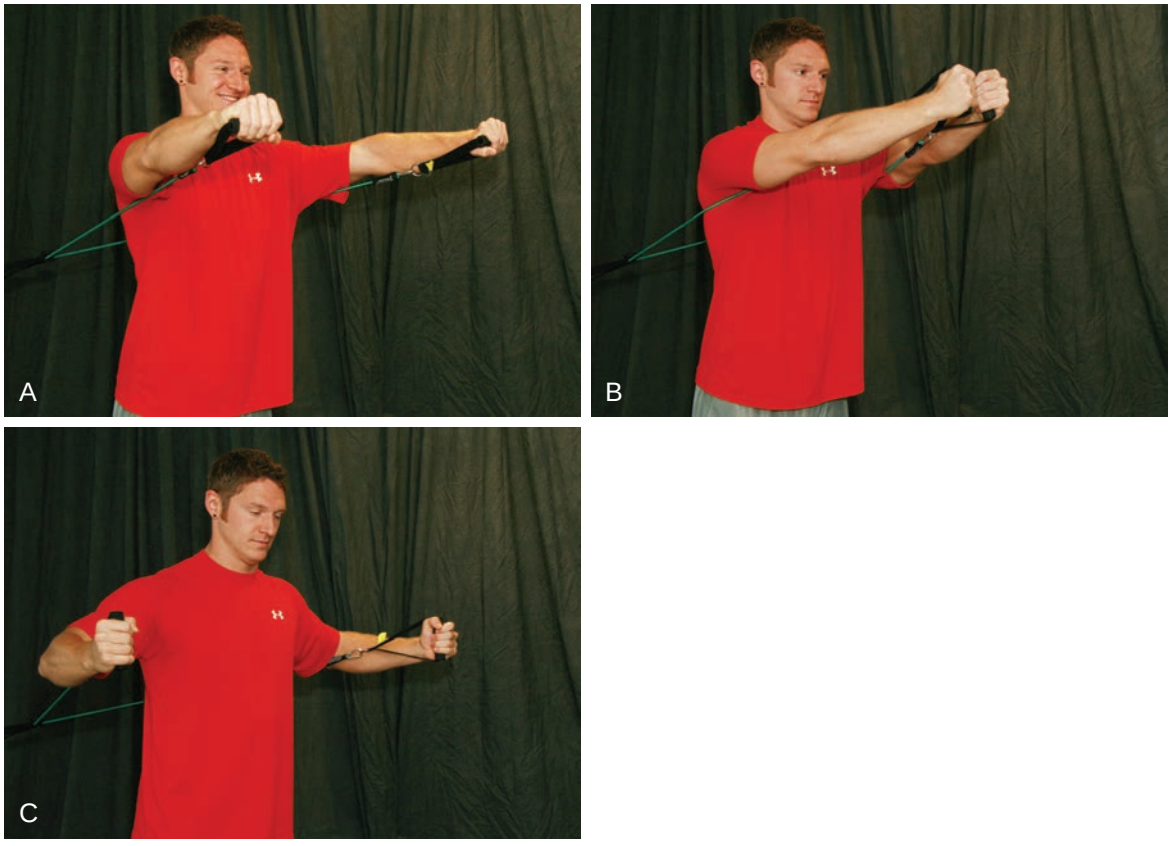

FIGURE 1-26. A–C, Forward punches with internal rotation: The patient steps and punches forward emphasizing scapular protraction without scapular elevation at varying levels of forward elevation then internally rotating the humerus at the end of the motion.

procedure. Rhythmic stabilization starting at 45° of abduction in the scapular pane in neutral rotation and gradually increasing in elevation and ER as performance increases. Four to five bouts for 30 seconds is recommended before progressing difficulty of exercises.
- CKC pushup plus progression are important exercises as it promotes rotator cuff and scapular stabilizer co-contraction needed for dynamic stability.[38,45]

Plyometrics

- No heavy lifting or plyometrics should be performed during this stage.

Functional Exercises

- Functional exercises may be initiated toward the end of Phase III (weeks 9 to 12) however we strongly recommend avoiding undue stress on the anterior shoulder.
- Multiplanar exercises should be progressed in a similar fashion as previously described emphasizing rotational control across each plane of elevation.

Milestones for Progression to the Next Phase

- Staged active ROM goals achieved with minimal to no pain (NPRS 0 to 2/10) and without substitution patterns
- Appropriate scapular posture at rest and dynamic scapular control during ROM and strengthening exercises
- Strengthening activities completed with minimal to no pain (NPRS 0 to 2/10).
- <20% deficit using isokinetic or hand held dynamometer for ER, IR, abduction, and elevation.
- Able to complete 20 hand-taps during modified Davies CKC UE test.[46] We recommend modifying the Davies test by using biacromial width as in our experience a standard 36″ is too wide for many patients.
- Able to complete 30 reps of ER at <20° of abduction in 30 seconds (1 rep/sec).

Phase IV: Weeks 13 to 24 Postoperatively

The length of Phase IV will vary dependent upon sport participation. For noncontact sports with less stress on the anterior shoulder and therefore reinjury risk return to sport progression may begin at 16 weeks. For contact sports with high dislocation rates (football, wrestling) or high stress on the anterior shoulder (throwing sports) return to sport progression will begin between POW 20 to 24. Phase IV will overlap with Phase V return to sport progression depending on injury, sport, and timing of season and return to play goals.

Goals

- No complaints of pain at rest and minimal to no pain (NPRS 0 to 2/10) following activities.
- No or minimal sensation of instability with activities.
- Normalize strength, endurance, neuromuscular control, and power as evidenced by:
  - <10% deficit using isokinetic or hand held dynameter for ER, IR, abduction, and elevation.
  - 30 repetitions in 30 seconds with blue Thera-Band at 0° and 90° abduction.
  - Able to complete 90 hand-taps during modified Davies CKC UE test in 60 seconds.[46]
  - Gradual demonstration of confidence and performance in sports specific positions.
  - Functional improvement in ADLs and sport as evidenced by PSS > 90% and WOSI < 20%.

Clinical Pearls

- Athletes should perform a structured, reproducible dynamic warm up including rotator cuff exercises before pre sport and sport activities.
- Progression of presport training activities should be monitored reevaluating the athlete's pain & strength (no >10% advancement as compared to presport).
- We recommend a balance of posterior and anterior rotator cuff strength (ER:IR ratio) of 66% before beginning return to sport training.[47,48]

Management of Pain and Swelling

- Pain should not be a limiting factor at this point. If pain is limiting progression of activities rest and reevaluation of all aspects of the shoulder should be performed in consultation with the referring surgeon.
- Cryotherapy as needed.
- NSAIDS as needed.

Patient Education

- Counsel about using the upper extremity for appropriate ADLs in the pain-free ROM (starting with waist level activities and progressing to shoulder level and finally to overhead activities over time).
- Continue education regarding avoidance of heavy lifting or quick sudden motions.
- Education to avoid positions which place stress on the anterior inferior capsule during ADLs.

Other Therapeutic Exercises

- Progressing from Phase III there are no limitations to TBS/TLS or TAS. However, unless end range of motion is required for the athlete's sport then we strongly recommend avoiding training that stresses the shoulder the ABER position as the risk of developing recurrent instability outweighs the benefits of training.

Open and Closed Kinetic Chain Exercises

- Progression of OKC and CKC consistent with principles previously outlined.

Techniques to Increase Muscle Strength, Power, and Endurance

- During this phase the focus of exercises should progress from endurance to strength and power. This will require increasing loads, speed of movements, and type of contraction.
- Loads—loads now may be increased appropriate to sport and body weight beginning with 3 to 5 sets of 10 and progressing to 3 to 5 sets of 4 to 6 reps over the next 8 to 10 weeks consistent with a traditional strength training program.
- Speed of movement—concentric movements are challenged first beginning with IR, then ER, then punches and complex movements. Punches are last as this as scapular protraction places increased stress on the capsulolabral complex and is a common mode of dislocation.
- Type of contraction—eccentric loads can now be initiated beginning with ER (towards IR) and abduction (towards adduction) first then progressing to IR and abduction in preparation for plyometric exercises.
- We recommend gradually progressing to positions of high stress during this phase as needed. For example, in order to progress back to bench press begin with the athlete performing dumbbell bench press on the floor, then barbell on the floor, then dumbbell.

Neuromuscular Dynamic Stability Exercises

Integration of higher loads and greater perturbations are important in particular for athletes returning to sport.

Examples include:

- For football players clap pushups on foam or DynaDisc.
- For throwers repeated ER yo-yos (with 1-kg weight on band) (Figure 1-27).

Plyometrics

- Because of the explosive nature of this type of exercise, emphasis of plyometric exercises should be on quality not quantity. Additionally, we recommend 2 to 3 weeks of tolerance to high speed multiplanar activities which progressively mimic functional demands before initiating plyometric exercises.
- Perform two to three times/week and utilize moderate repetitions (e.g., 3 to 5 sets of 15 to 20 repetitions)
- Begin with unweighted balls and progress to lightly weighted balls (Plyoballs)

Functional Exercises

- Continue per Phase III.

Sport-Specific Exercises

- Med ball throws against a wall, for distance for OKC sports.
- UE fitter/stepper in prone position for CKC sports.
- Dribbling on wall or rebounding with one hand.

Milestones for Progression to the Next Phase

- Clearance from physician.
- PSS > 90% and WOSI < 10%.
- No complaints of pain at rest and minimal to no pain (NPRS 0 to 2/10) following activities.
- No or minimal sensation of instability with activities.
- Restoration of sufficient ROM to perform desired activities.
- Maintenance of strength and endurance as evidence by:
  - < 10% deficit using isokinetic or hand held dynameter for ER, IR, abduction, and elevation.
  - 30 repetitions in 30 seconds with blue Thera-Band at 0° and 90° abduction.
  - Able to complete 90 hand-taps during modified Davies CKC UE test in 60 seconds.[46]

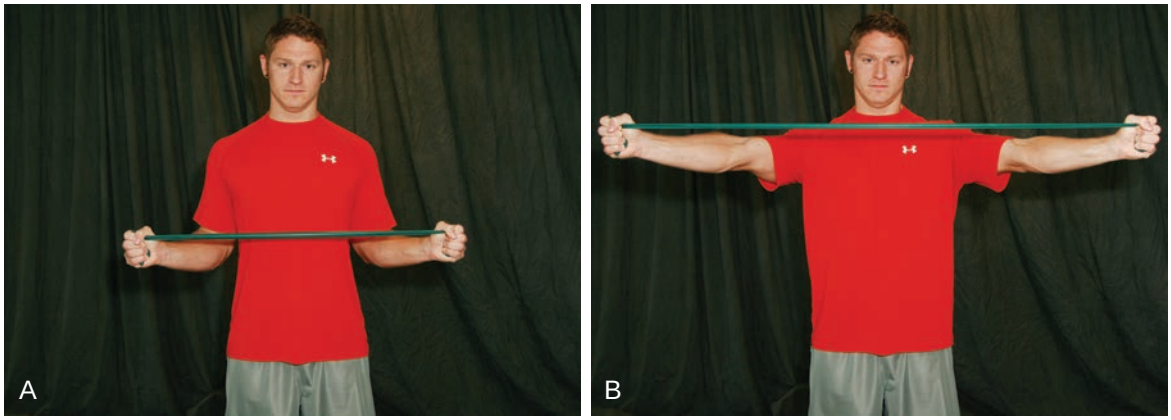

FIGURE 1-27. A,B, External rotation to scaption. Patient holds a 1-kg weight tied into a Thera-Band at 0° of ER, then externally rotates and elevates to 90°.

Phase V: >Weeks 16 to 24 Postoperatively—Return to Sport Progression

Similar to Phase IV the length will vary dependent upon sport participation. The timing of this phase will be greatly impacted by risk of reinjury and timing relative to competition requirements. As risk of reinjury increases we recommend more conservative approach in return to competition. As maturity of the athlete and level of competition increase athlete education becomes imperative allowing the sports medicine team (athlete, PT, ATC, and MD) to reach the best decision for that athlete.

Goals

- No complaints of pain at rest and minimal to no pain (NPRS 0 to 2/10) following activities.
- No or minimal sensation of instability with activities.
- Maintenance of sufficient ROM to perform desired activities.
- Maintenance of shoulder strength and endurance as previously described with minimal to no pain (NPRS 0 to 2/10) or difficulty.

Clinical Pearls

- 1 to 2 times/week of soft tissue and joint mobilizations will prevent loss in ROM during the return to sport progression. Careful attention to maintenance of ROM and flexibility will allow for long-term successful return to sport.
- Begin sessions with a complete dynamic warm-up including rotator cuff before complex, functional, and plyometric exercises.
- Continued strengthening of the rotator cuff and scapular stabilization exercises to fatigue should be performed 1 to 2 times/week.
- Instruct patients to: *"Perform all exercises so that you can see the backs of your hands"* to protect their surgical repair.

Protection

- Use of either a Sully or Donjoy (formerly SaWa) brace is recommended during initial return to sport, in particular for contact athletes. We prefer the SaWa brace (lace up/strap brace) for contact athletes as it is the only brace demonstrated to limit ER and abduction ROM.[49] We recommend the Sully (neoprene) for all others as it has been shown to increase proprioception and kinesthetic awareness which are altered in shoulders with anterior instability.[50,51]

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- As previously described PRN.

Soft Tissue Techniques

- As previously described PRN.

Stretching/Flexibility Techniques for the Musculo-Tendinous Unit

- Regular assessment of ROM/flexibility during the return to sport progression and after return to sport is important for long term shoulder function.

Other Therapeutic Exercises

- As previously described.

Open and Closed Kinetic Chain Exercises

- As previously described.

Techniques to Increase Muscle Strength, Power, and Endurance

- Care should be taken to ensure that the athlete maintains shoulder-strengthening and dynamic strengthening exercises. We recommend 3 days for 20 to 30 minutes of focused rotator cuff and scapular stabilizing exercises in addition to TBS and TAS that may be apart from normal athletic activities.

Plyometrics

- PRN as previously described.

Sport-Specific Exercises

- PRN as previously described.

Criteria for Return to Sport

General

- PSS > 95% and WOSI < 10%.
- No complaints of pain at rest and minimal to no pain (NPRS 0 to 2/10) following activities.
- No or minimal sensation of instability with activities.
- Maintenance of sufficient ROM to perform desired activities.
- A balance of posterior and anterior rotator cuff strength (ER:IR ratio) of 66% before beginning return to sport training.[47,48]
- Maintenance of strength and endurance as evidence by <10% change in strength measures post activity using isokinetic or hand held dynameter for ER, IR, abduction, and elevation.
- 30 repetitions in 30 seconds with blue Thera-Band at 0° and 90° abduction.
- Able to complete 90 hand-taps during modified Davies CKC UE test in 60 seconds.[46]

Sport-Specific

Overhead athlete—The return to sport of an overhead athlete requires consideration for all position specific

factors before return to full participation. Before and during of progression of throwing, batting, and hitting activities the following criteria should be obtained and maintained throughout the interval throwing program:

- PSS > 95% and WOSI < 10%.
- No sensation of instability with activities.
- No complaints of pain at rest or during activity. Minimal discomfort postactivity with minimal discomfort (NPRS 0 to 2/10) following activities.
- Before throwing/hitting, the throwing arm rotational ROM must measure within 15° of the non-throwing arm. Total rotation must be >150°. External rotation must measure ≥100°. Additionally, horizontal adduction (HA) ROM must be within 15° of the non-throwing arm.
- Postthrowing/hitting the rotational and HA ROM should be within 10% of the prethrowing/hitting ROM within 24 to 48 hours and return to preactivity baseline ROM before subsequent participation.
- The athlete should recover from soreness for 24 to 48 hours before returning to full participation.
- Before competition or practice, throwing arm ER strength should be similar to the nonthrowing arm ER strength[52] and the athlete should demonstrate a balance of posterior and anterior throwing arm rotator cuff strength (ER:IR ratio) of 66%.[47,48]
- The athlete must demonstrate sufficient core and scapula control for participation. This is measured by completion 90 hand taps during the modified Davies CKC UE test in 60 seconds before throwing/hitting.[46]
- Post throwing/hitting the rotational strength and stability (hand taps during modified Davies CKC UE test in 60 seconds) should be within 10% of the prethrowing/hitting levels within 24 to 48 hours and return to preactivity baseline before subsequent participation.
- Athletes should be monitored for performance and fatigue levels during their progression to full competition as athletes pitching while fatigued have 36 times greater risk of injury.[53]

After Return to Sport

Continuing Fitness or Rehabilitation Exercises

- Maintain ROM with regular flexibility routine in particular for latissimus, pectoralis and posterior shoulder flexibility.
- Maintain rotator cuff and scapular stabilization force couples with 2 to 3 times/week of core exercises integrated into regular fitness/training routine.

Exercises and Other Techniques for Prevention of Recurrent Injury

- We recommend postoperative bracing for at least the first season returning to competition.
- Unless the sport requires motion in extremes of abduction and ER limit training in these ranges.
  - For all training patients are instructed to: "*Perform all exercises so that you can see the backs of your hands*"

Evidence

Boileau P, Villalba M: Risk factors for recurrence of shoulder instability after arthroscopic Bankart repair. *J Bone Joint Surg* 88A(8):1755–1763, 2006.

This is a retrospective study conducted to look at outcomes and determine risk factors related to the recurrence of shoulder instability following arthroscopic Bankart repair. Ninety-one patients who underwent arthroscopic stabilization were included in the study and followed up at a mean of 36 weeks. Absorbable suture anchors were used for capsulolabral reattaching and capsule retensioning. Fourteen patients experienced recurrent instability, six experienced dislocation, and eight had an episode of subluxation. The study results suggest that bone loss or defect on the glenoid or humeral side along with anterior or inferior hyperlaxity was significantly related to postoperative recurrent instability. The presence of either condition led to a 75% recurrence rate in the study. In addition, less than three sutures used during surgery led to an increased risk of recurrence. The study suggests that arthroscopic treatment for shoulder instability should be used only after patient selection and rigorous technique.

Ellenbecker TS, Mattalino AJ: Glenohumeral joint range of motion and rotator cuff strength following arthroscopic anterior stabilization with thermal capsulorraphy. *J Orthop Sports Phys Ther* 29:160–167, 1999.

This descriptive study of 20 patients diagnosed with anterior shoulder instability described their postoperative rehabilitation program following arthroscopic shoulder stabilization. The involved patients experienced return of ROM and scapular/ rotator cuff strength at 12 weeks when compared with the uninjured extremity.

Hiemstra LA, Sasyniuk TM, Mohtadi NG, et al: Shoulder strength after open versus arthroscopic stabilization. *Am J Sports Med* 36:861–867, 2008.

Arthroscopic or open shoulder stabilization surgeries are currently the standard of treatment for recurrent anterior shoulder dislocations. The difference between the surgical techniques is the violation of the subscapularis tendon during the open stabilization. This study looks at the strength differences in internal and external rotation of the two surgical groups. The study included 48 patients with an average age of 30.6 who were randomized into either the open or arthroscopic group. Each group underwent standardized rehabilitation and was followed up with isokinetic strength testing (concentric and eccentric peaks at 60 and 180 degrees) between 12 and 36 weeks postop. The results showed no significant difference between groups in the area of age, gender, and operative limb. When comparing the arthroscopic versus open surgical shoulder stabilization, no significant isokinetic strength deficits were observed. Both groups showed strength deficits when compared to the non-involved limb.

Kim SH, Ha KI, Kim HS, et al: Electromyographic activity of the biceps brachii muscle in shoulders with anterior instability. *Arthroscopy* 17:864–868, 2001.

The study evaluated the activity of the biceps muscle in 38 patients with traumatic anterior shoulder instability. The abduction and external rotation positions were evaluated. Electromyographic (EMG) data was used to determine activity levels of the biceps muscles. The unstable side was compared with the opposite non-involved shoulder of each patient. EMG data was obtained for the following positions:

0°, 45°, 90°, and 120°. The root mean squared voltage of the bicep muscle was significantly greater in the unstable shoulder in all positions. The maximum voltage was greatest in the unstable arm at 90° and 120° of external rotation. No difference was seen in the RMS voltage of the supraspinatus muscle. In conclusion, the results show that in an unstable shoulder, in the abducted and externally rotated positions, the bicep muscles play a compensatory role.

Matias R, Pascoal AG: The unstable shoulder in arm elevation: a three-dimensional and electromyographic study in subjects with glenohumeral instability. *Clin Biomech (Bristol, Avon)* 21(Suppl 1):S52–S58, 2006.

An altered scapula-humeral rhythm is said to be related to some shoulder dysfunction, but little is known about the shoulder muscle activation patterns in patients with glenohumeral instability. The study included 6 subjects with glenohumeral instability who were all performed arm elevations in 8 positions. A 6 DOF electromagnetic device was used to record the kinematics. The scapulohumeral rhythms were compared among subjects. The most significant differences were seen in the scapular protraction and spinal tilt and no differences were seen in the scapular lateral rotation. The kinematic changes during certain angles of arm elevation may be due to changes in alignment of the humeral head and glenoid and as results contributing to shoulder instability. The study emphasizes the importance of assessing scapulohumeral rhythms in the rehabilitations process of individuals with shoulder instability.

Myers JB, Ju YY, Hwang JH, et al: Reflexive muscle activation alterations in shoulders with anterior glenohumeral instability. *Am J Sports Med* 32:1013–1021, 2004.

The study looks at the relationship between anterior shoulder instability and muscle activation alterations. Eleven patients with anterior shoulder instability where matched with 11 control subjects. Each subjected underwent external humeral rotation apprehension perturbation while muscle activation characteristics were recorded using electromyographic analysis. Patients with instability showed decreased pectoralis major and biceps brachii mean activation along with increases peak activation in the subscapularis, supraspinatus, and infraspinatus when compared with the control subjects. A much slower bicep brachii mean reflex latency as well as suppressed supraspinatus-subscapularis coactivation was seen in the patients with instability. These results may explain recurring episodes of instability in patients with glenohumeral instability.

McMahon PJ, Jobe FW, Pink MM, et al: Comparative electromyographic analysis of shoulder muscles during planar motions: anterior glenohumeral instability versus normal. *J Shoulder Elbow Surg* 5:118–123, 1996.

The electromyographic activity of the rotator cuff and scapular muscles were compared between normal subjects and those with anterior instability. 23 subjects had instability, 15 were normal. Fine wire electrodes were placed in the scapular muscles. Abduction, scaption, and forward flexion were performed over the range of motion. In patients with instability, the supraspinatus showed significantly less electromyographic activity from 30° to 60° during abduction and scaption compared with normal shoulders. During all three motions, shoulder with instability showed significantly less activity in the serratus muscle compared with the normal shoulders at 30° to 120° of abduction and 0° to 120° of scaption and forward flexion. These results show that the supraspinatus and serratus muscles may be under challenged in daily activities and add to the complexity of shoulder instability.

Nelson BJ, Aciero RA: Arthroscopic management of glenohumeral instability. *Am J Sports Med* 28:602–614, 2000.

Over the last 20 years there have been new developments in arthroscopic shoulder techniques, especially in the area of shoulder instability. The article discusses the various arthroscopic surgical techniques used to treat the unstable glenohumeral joint. The article looks at arthroscopic stabilization techniques for primary anterior glenohumeral instability, recurrent anterior instability, and multidirectional instability. The wide ranges of results are also discussed.

Uhorchak JM, Arciero RA, Huggard D, et al: Recurrent shoulder instability after open reconstruction in collision and contact sports. *Am J Sports Med* 28:794–799, 2000.

This study evaluated the recurrence of instability in a group of 66 young athletes who had previously undergone open shoulder stabilization using a modified Bankart repair and anterior capsulorrhaphy. In order for the incidence to be considered a recurrent dislocation, it had to be a complete dislocation with manual reduction. "Slipping or popping" was considered a recurrent subluxation. The results showed that two patients experienced recurrent shoulder instability, eight patients had fewer than three episodes of subluxation, and five patients had multiple episodes of recurrent subluxation. The studied concluded that a 3% to 5% recurrent dislocation rate is reasonable to expect after undergoing open Bankart repair/capsulorrhaphy for young athletes involved in collision sports. This same patient group experiences a 20% frequency in recurrent postsurgical subluxations. This incidence is higher than most literature and is attributed the athletes being involved in collision sports. Factors such as age, activity level and type of instability may influence postoperative recurrence rates.

Warner JJ, Micheli LJ, Arslanian LE, et al: Patterns of flexibility, laxity, and strength in normal shoulders and shoulders with instability and impingement. *Am J Sports Med* 18:366–375, 1990.

This is a prospective study looking at factors of flexibility, laxity, strength and their causality to the conditions of shoulder impingement and instability. Fifty-three subjects were included in the study: 15 asymptomatic volunteers, 28 patients with glenohumeral instability, and 10 patients with impingement. Range of motion was performed using a goniometer and Biodex testing was used to measure strength. Normal subjects showed significant differences in IR/ER ratios for peak torque between the dominant and nondominant shoulder and greater IR strength in the dominant side. Impingement was linked to posterior capsular tightness and weakness of the external rotators. Anterior instability was associated with excessive external rotation and weakness of the internal rotators. Rehabilitation should include an emphasis on shoulder strengthening and capsular stretching for treatment of impingement. Performing isokinetic strength testing in the modified abducted position can help determine if either impingement or instability is the problem.

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Multiple-Choice Questions

QUESTION 1. Clear communication from the surgeon to the rehabilitation team concerning tissues to be considered following anterior instability surgery includes:

A. Capsule, labrum, biceps, humerus, and subscapularis.
B. Capsule, labrum, glenoid, humerus and subscapularis.
C. Labrum, biceps, glenoid, humerus, and subscapularis.
D. Capsule, labrum, biceps, glenoid, and subscapularis.

QUESTION 2. Which of the following is not included in the guiding principles of postoperative rehabilitation?

A. Understanding of the surgical procedure and anatomic structures, which require protection.
B. When patients are very painful and guarded reviewing sleeping habits, sling use, and HEP are often helpful in managing pain allowing for gentle restoration of ROM.
C. Correct application of manual techniques and therapeutic exercises to promote static balance in glenohumeral joint mobility and optimum dynamic stabilization from the rotator cuff and associated shoulder girdle muscles.
D. Gradual restoration of PROM while protecting the anterior-inferior aspect of the glenohumeral joint through initial immobilization and the rate of ROM gain.

QUESTION 3. The following goals: minimize shoulder pain, achieve staged ROM goals to normalize passive ROM and active ROM, normalize rotator cuff guarding and neuromuscular control, normalize scapular position and control, are expected by:

A. First 14 days postoperatively.
B. 2 to 6 weeks postoperatively.
C. 7 to 12 weeks postoperatively.
D. 13 to 24 weeks postoperatively.

QUESTION 4. The primary rationale for limiting ROM during Phase I is:

A. Glenoid bone loss occurs in all instability and requires protection.
B. Labral repairs require significant protection.
C. Loading from resistance exercises may "stretch out" the capsulolabral repair.
D. Cyclical loading may "stretch out" the capsulolabral repair.

QUESTION 5. A 23-year-old wrestler presents 3 months status after R anterior arthroscopic Bankart repair and capsular plication. His ROM is as follows: 145 degrees of FE, 20 degrees of IR at 90, and 75 degrees of ER at 90. Based on this you recommend:

A. Anterior stretching of the shoulder including pectorals.
B. Posterior stretching of the shoulder including sleeper stretch.
C. Anterior stretching of the shoulder for ER with hands behind the head.
D. No stretching needed his ROM is within the guidelines.

Answer Key

QUESTION 1. Correct answer: **C** (see Surgical Summary)

QUESTION 2. Correct answer: **B** (see After Surgery PostOp Rehab)

QUESTION 3. Correct answer: **B** (see Phase I)

QUESTION 4. Correct answer: **D** (see Phase I)

QUESTION 5. Correct answer: **C** (see Phase II-III criteria)

POSTOPERATIVE REHABILITATION AFTER OPEN ANTERIOR STABILIZATION OF THE SHOULDER WITH OR WITHOUT BONE GRAFTING (ILIAC CREST GRAFT, LATARJET PROCEDURE)

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Emilie Schmidt, DPT, SCS, ATC, CSCS, and Courtney A. Shinost, M.S, CSCS, NSCA-CPT

Indications for Surgical Treatment

- Recurrent anterior instability of the glenohumeral joint.
- Chronic instability with recurrent subluxation or dislocation.
- First-time instability event in a young, athletic, or high-demand patient.
- Known osseous deficiency of the glenoid and/or humeral head.
- Failure of conservative treatment.
- Failure of prior anterior instability surgical procedures to address soft tissue and/or bony insufficiency.

Brief Summary of Surgical Technique

Clinical Pearls

- There are two main variations of surgical techniques for open anterior stabilization of the shoulder: with and without bone grafting. In the procedure that does not involve bone grafting, there are two options for treatment of the subscapularis which will serve as a key distinction in both the surgical procedure as well as the course of rehabilitation as reflected below.
- It remains difficult to determine which type of bone graft is chosen as there is no clear evidence of which one is superior, however, for those with very large loss, an iliac crest (or allograft) is likely the best option, versus those that have minimal loss to moderate amount of loss (usually up to 25% to 30%), a Latarjet procedure is preferred.

Major Surgical Steps

Open Shoulder Stabilization/Open Capsulolabral Repair without Bone Grafting

- Patient in "beach chair" position.
- General anesthetic, may be supplemented with regional (i.e., interscalene) block.
- Deltopectoral incision in an open Bankart incision, approximately 6 cm in length starting inferiorly just above the axillary crease and extending superiorly lateral to the coracoid.
- Identify the deltopectoral interval through axillary vein location. Keep the vein lateral (more vascular penetrators to the deltoid) (Figure 1-28).

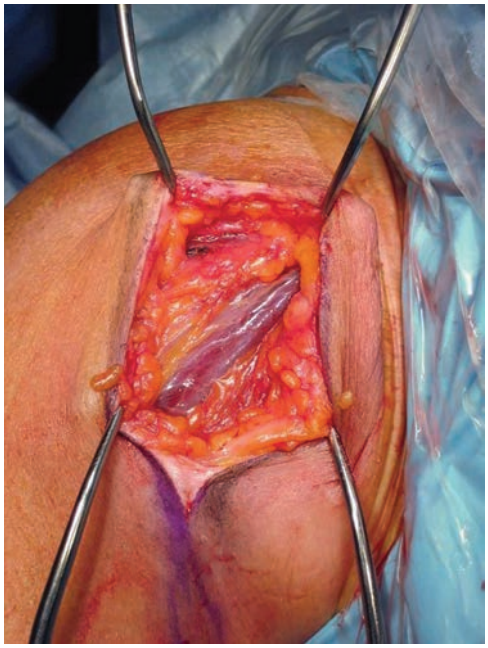


FIGURE 1-28. Identification of the deltopectoral interval and cephalic vein. *(Copyright by Michael J. Pagnani, MD. From Provencher MT, Romeo AA, editors: Shoulder instability: a comprehensive approach. Philadelphia, 2011, Elsevier (Saunders), p. 151.)*

- Develop the deltopectoral interval with gentle blunt dissection down to the bursa over the subscapularis and intertubercular groove.
- Once the biceps (long head) groove is identified, slightly externally rotate the humerus to observe the subscapularis tendon insertion, which attaches onto the lesser tuberosity just medial to the bicipital groove at an angle of about 150 degrees to the groove.
- Two options on how to handle the subscapularis tendon are outlined below:
  - Superior aspect of subscapularis takedown and repair (Figure 1-29)
    - The superior rolled edge of the subscapularis is taken laterally off the lesser tuberosity with either a knife or needle-tip bovie. A small cuff of subscapularis tissue (2 to 3 mm) is maintained in order to perform a repair at the end of the case
    - The superior two thirds of the subscapularis is taken off the lesser tuberosity and tagged with a No. 2 suture

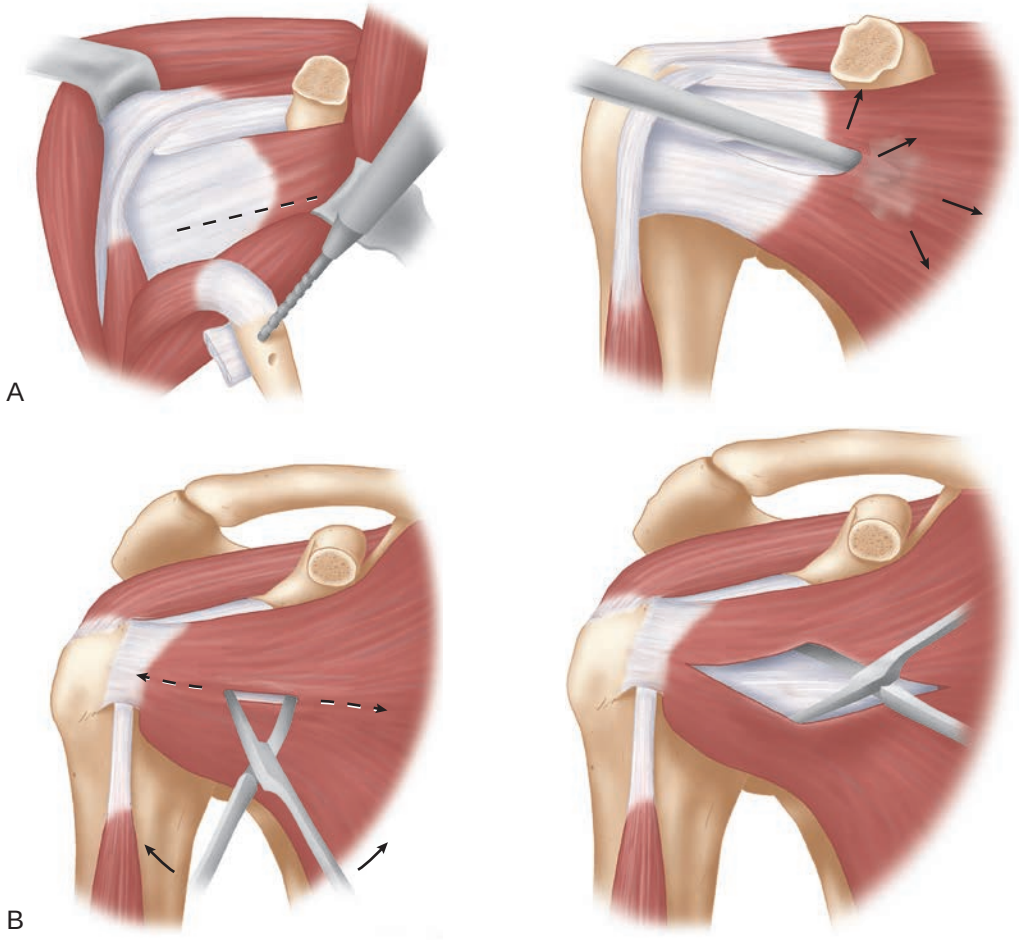


FIGURE 1-29. A, Division of the subscapularis at the junction of the upper two thirds and inferior one third. **B,** The subscapularis is split in line with its fibers, the scissors are opened vertically to expose the underlying capsule. *(From Provencher MT, Romeo AA, editors: Shoulder instability: a comprehensive approach. Philadelphia, 2011, Elsevier (Saunders))*

- Care is taken to preserve the vasculature at the inferior edge of the subscapularis (the "three sisters")
- The subscapularis is dissected off the capsule medially staying on the posterior surface of the subscapularis
- The capsule is identified and is taken sharply off the glenoid with the torn labrum (due to dislocation). The labrum may also be healed on the glenoid in an anterior labral periosteal sleeve avulsion (ALPSA) configuration and will need to be sharply elevated.
- Three to four suture anchors are then drilled into the inferior two thirds of the glenoid and then the capsular-labral complex is repaired to the suture on the suture anchors and affixed anatomically back into position. The knots are then extracapsular (anterior to the capsule) and tied securely.
- The subscapularis is then repaired using high strength No. 2 or No. 5 suture to the native remaining lateral cuff of subscapularis anatomically. Suture anchors may also be utilized.
- The deltopectoral interval is closed with absorbable suture, followed by a standard skin closure.

- Subscapularis split (preferred method) (Figure 1-29)
  - This procedure is similar to the subscapularis takedown, except that the subscapularis insertion on the lesser tuberosity is preserved.
  - This is preferred since the subscapularis insertion is preserved.
  - A longitudinal (in-line with the fibers) incision of the subscapularis starting just medial to the biceps groove and extending to the muscle-tendon junction is carried out at about the halfway position (superior to inferior) on the subscapularis (see Figure 1-30).
  - The capsule of the shoulder is identified medially and then the procedure is carried out as above with capsular and labrum takedown and anatomic repair with suture anchors.
  - The subscapularis split is closed anatomically with No. 2 *figure of eight* sutures.
  - The remainder of the closure is identical to that noted above for the subscapularis takedown.

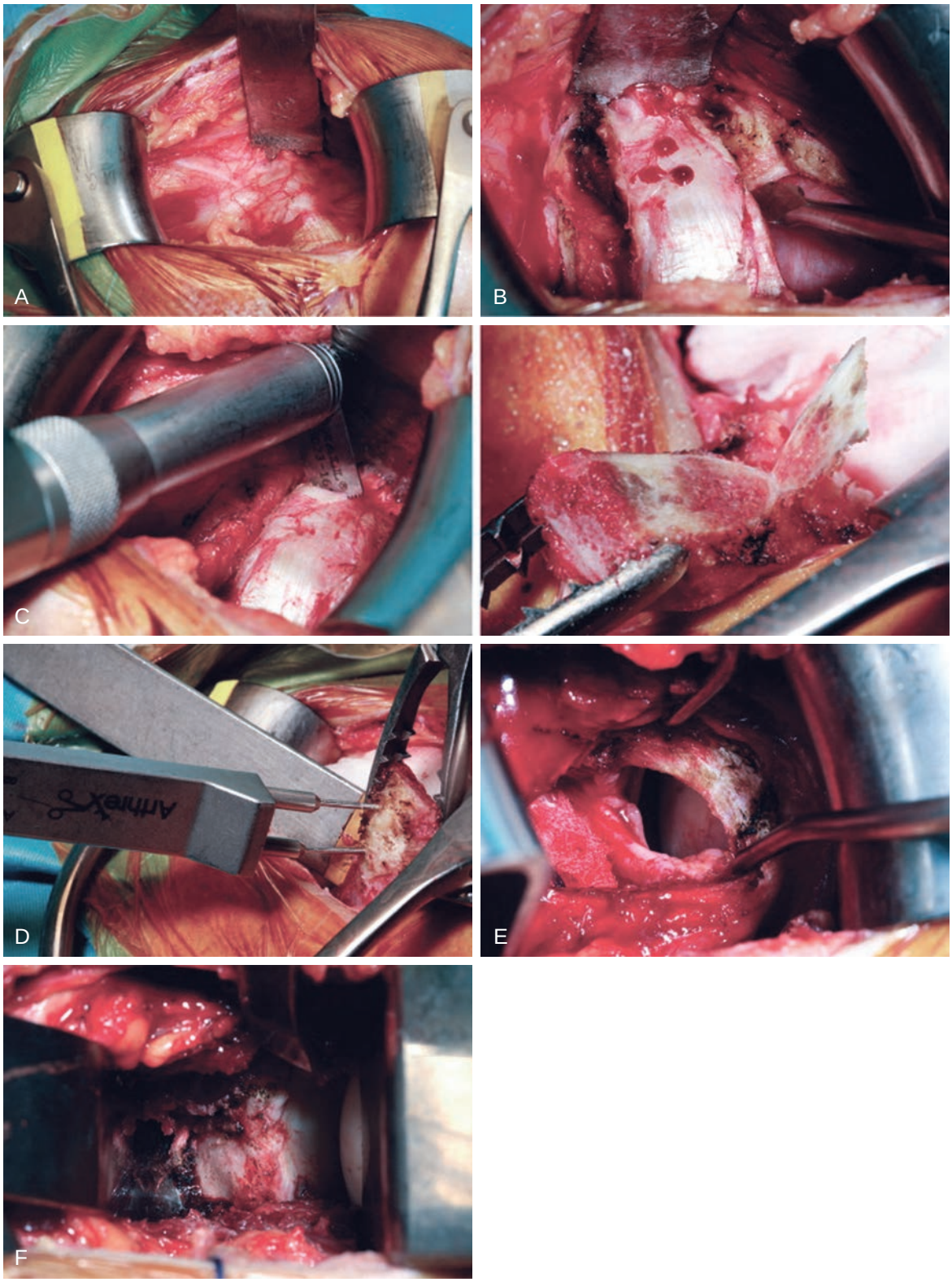


FIGURE 1-30. **A,** Exposing the coracoid process in the left shoulder with the aid of self-retaining retractor. **B,** The coracoacromial ligament and the pectoralis minor tendon insertion released from the coracoid process. **C,** Left: Osteotomy of the coracoid process with the microsagittal 90-degree angled blade. Right: Decortication of the deep surface of the coracoid bone graft. **D,** The guide wire jig allows the surgeon to insert two guide wires into the coracoid graft. **E,** Left glenohumeral joint exposure through a subscapularis split. **F,** Retractor placed on the anterior scapular neck as medial as possible to improve the visualization of the site of coracoid graft insertion.

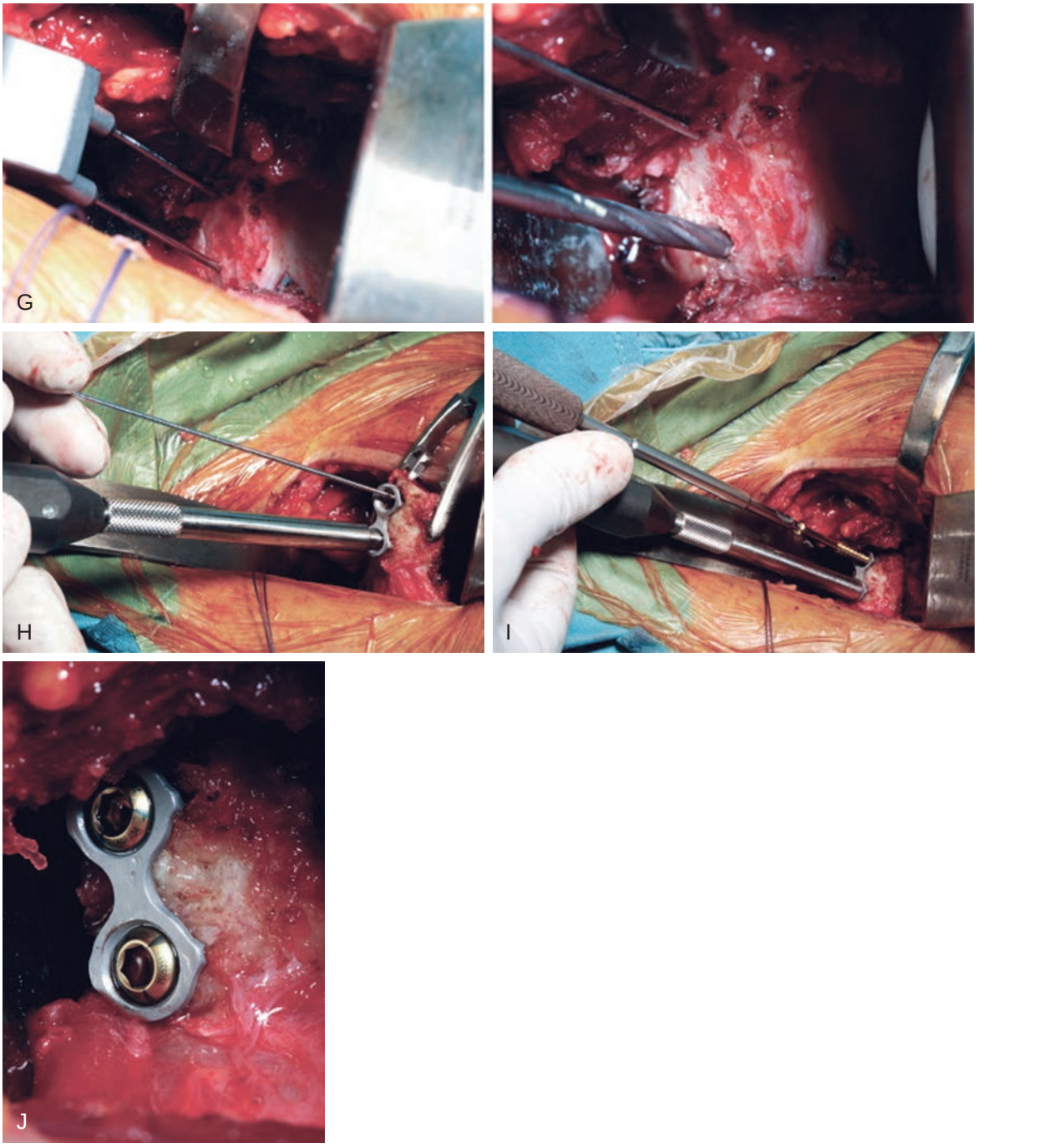


FIGURE 1-30, cont'd G, Left: Anterior glenoid neck prepared for the placement of the coracoid bone graft and insertion of two K-wires. Right: Anterior glenoid neck drilled with the 2.7-mm cannulated drill. **H,** Using the cannulated temporary compression device (TCD), we stabilize the plate over the coracoid bone graft through the inferior drilled hole. **I,** Insertion of the cannulated screw through the superior guide wire. **J,** The Mini-plate (wedge profile plate) in final fixed position. *(From Provencher MT, Romeo AA, editors: Shoulder instability: a comprehensive approach. Philadelphia, 2011, Elsevier (Saunders)).*

Open Shoulder Stabilization: With Bone Grafting

Clinical Pearl

The principle of placing the conjoint tendon through a split in the subscapularis is based on the stability of the shoulder joint that is obtained from several coordinated biomechanical factors:

- The bone of the coracoid that is transferred to the glenoid (larger glenoid surface for which the humerus to articulate or restoration of normal glenoid bone surface if the glenoid is deficient).
- The conjoint tendon which is used as a soft tissue "sling effect" through a split in the subscapularis tendon which becomes more taut with abduction and external rotation and will help decrease subluxation of the joint (Figure 1-30)
- Capsular repair.

- Latarjet procedure: coracoid transfer (Figure 1-31). The procedure is the same as for an open shoulder instability repair with subscapularis split with the following additions and modifications

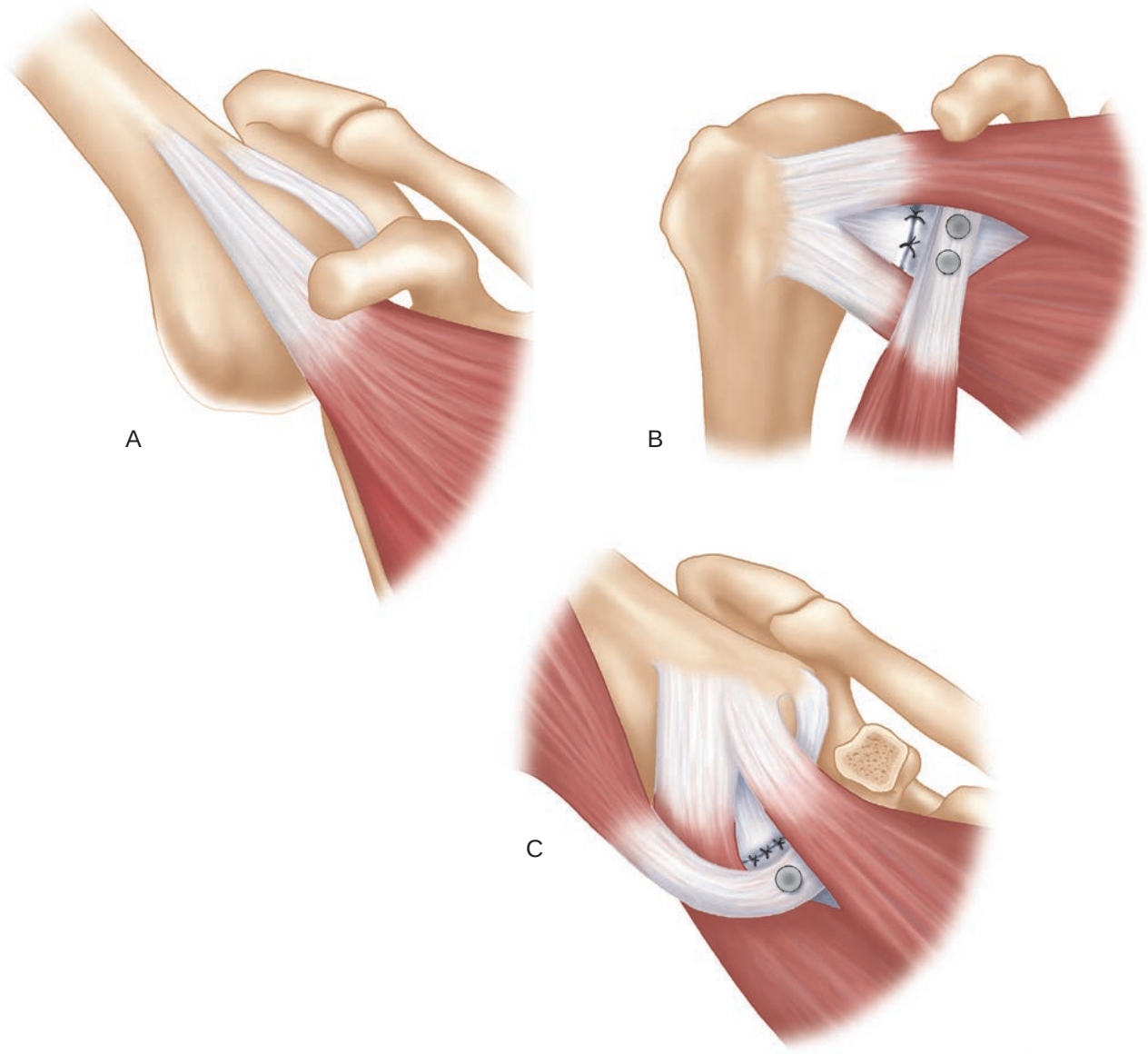


FIGURE 1-31. "Sling effect." **A,** Normal position of the subscapularis. **B,** Completed Latarjet with the arm in neutral, anterior bone block, and capsule repaired to coracoacromial ligament (CAL). **C,** The inferior displacement of the subscapularis by the conjoint tendon creates a "sling" beneath the anteriorinferior capsule, especially in the abducted, externally rotated position of the upper extremity. *(From Provencher MT, Romeo AA, editors: Shoulder instability: a comprehensive approach. Philadelphia, 2011, Elsevier (Saunders)).*

- After the deltopectoral interval is identified, the coracoid is isolated superiorly and dissected free of soft tissue.
- Pectoralis minor is attached medially (it is not reattached).
- The coracoacromial (CA) ligament is left of the coracoid and left about 1 cm in length.
- The CA ligament is then sutured to the capsule of the shoulder that was taken down the medial neck of the glenoid. Thus, some lengthening of the capsule is obtained and the capsule may be repaired by a CA ligament to capsular repair, preserving external rotation of the arm at the side (Figures 1-32 to 1-34).
- The conjoint tendon remains intact.
  - Alternative ways to handle the capsule:
    - Not to repair capsule at all.
    - Suture anchors to native glenoid and repair capsule to the native glenoid via suture anchors.
    - Suture the capsule to the anterior aspect of the coracoid underneath the washers and suture the capsule to sutures attached to the washers.
  - Approximately a 20 to 25 mm length of coracoid is harvested with either a sharp 10-mm sagittal saw or curved osteotomes just as the coracoid starts to curve. This preserves the coracoclavicular (CC) ligaments.
  - The coracoid is harvested and tucked in the inferior part of the wound
  - A subscapularis split and capsular takedown off the glenoid is performed

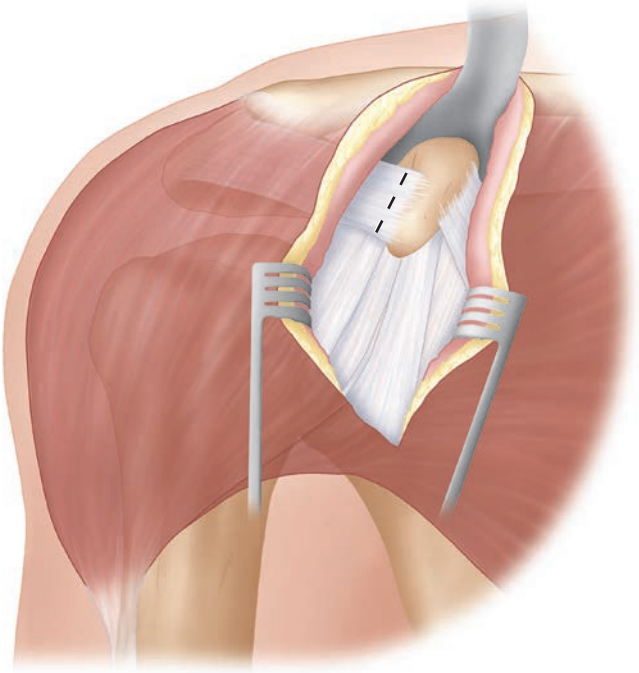


FIGURE 1-32. The CAL incised 1 cm from the coracoid insertion (arm in external rotation). *(From Provencher MT, Romeo AA, editors: Shoulder instability: a comprehensive approach. Philadelphia, 2011, Elsevier (Saunders)).*

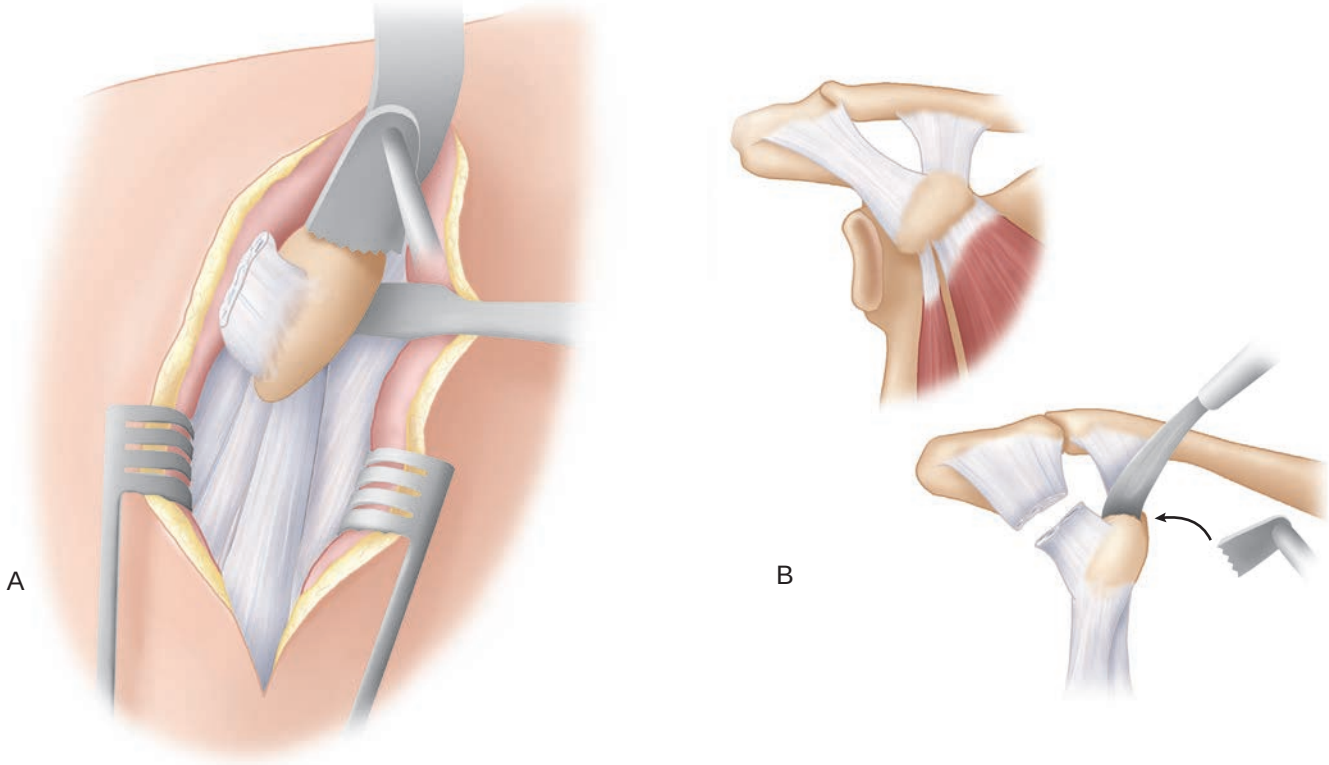


FIGURE 1-33. The pectoralis minor is released and the osteotomy is performed at the inferior coracoid. *(From Provencher MT, Romeo AA, editors: Shoulder instability: a comprehensive approach. Philadelphia, 2011, Elsevier (Saunders))*

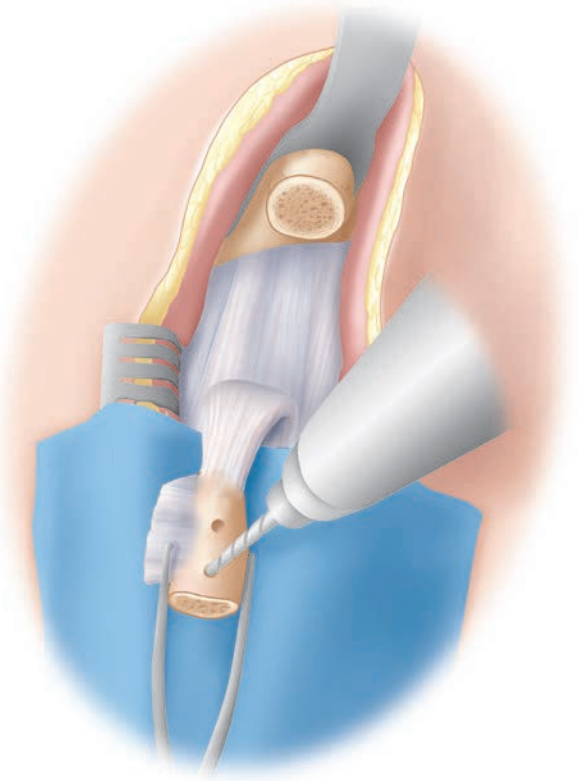


FIGURE 1-34. Preparation of the coracoid process. *(From Provencher MT, Romeo AA, editors: Shoulder instability: a comprehensive approach. Philadelphia, 2011, Elsevier (Saunders)).*

- The bony glenoid is then rasped and burred to allow for the coracoid to be transferred (bottom two thirds of the glenoid).
- The coracoid is also prepared and soft tissue dissected off (except for CA ligament).
- The bone is oriented so that the CA ligament is lateral for capsular repair (Figures 1-35 to 1-37).
- Two 35- to 38-mm bicortical screws (3.5 mm diameter) are utilized to fix the coracoid in place on the glenoid utilizing a compression technique.
- The capsule of the shoulder is repaired to the CA ligament that remains attached to the coracoid.
- The conjoint tendon drapes naturally over the subscapularis split and the lateral half of the split is closed with nonabsorbable suture.
- The remainder of the closure is the same as described above.

- Bone augmentation: iliac crest, distal tibia, or other allograft.
  - This is similar to the Latarjet procedure through either a subscapularis split or subscapularis takedown, except that the coracoid is not harvested.
  - The bone is affixed similar to the Latarjet (two screws), and the capsule may be repaired to sutures that are attached to the screws (Figure 1-38).
  - The subscapularis split is closed with *figure of eight* sutures, or if done with a subscapularis takedown, is repaired back to the native subscapularis remnant and remainder of the closure is the same.

Factors that May Affect Rehabilitation

- **Key Principle:** The treatment of the subscapularis will dictate the progression of the early stages of rehabilitation.
  - Subscapularis takedown will dictate a slower course of rehabilitation, especially in Internal Rotation (IR) strengthening and External Rotation (ER) limitations.

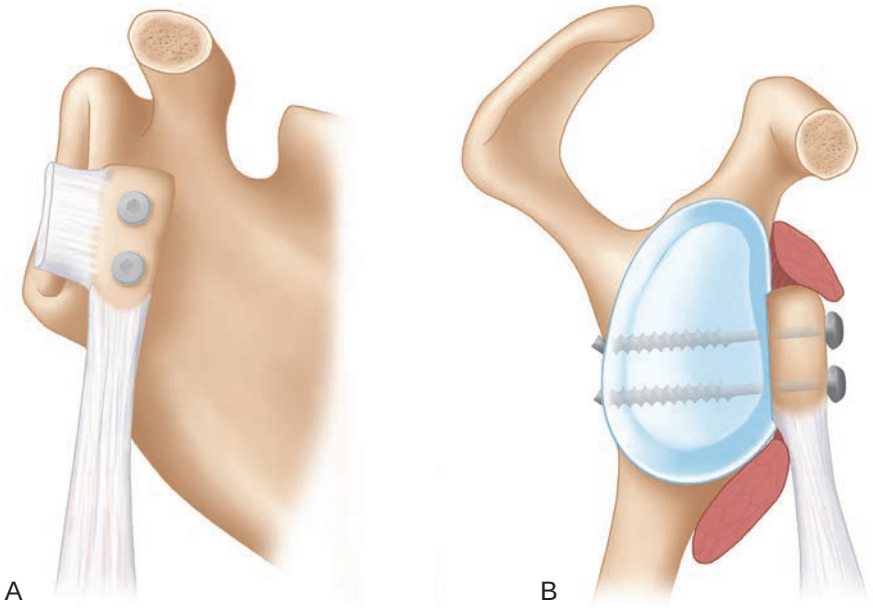


FIGURE 1-35. A, Coracoid graft securely fixed to glenoid with two screws with no lateral overhang. **B,** Lateral view of the reconstruction. *(From Provencher MT, Romeo AA, editors: Shoulder instability: a comprehensive approach. Philadelphia, 2011, Elsevier (Saunders)).*

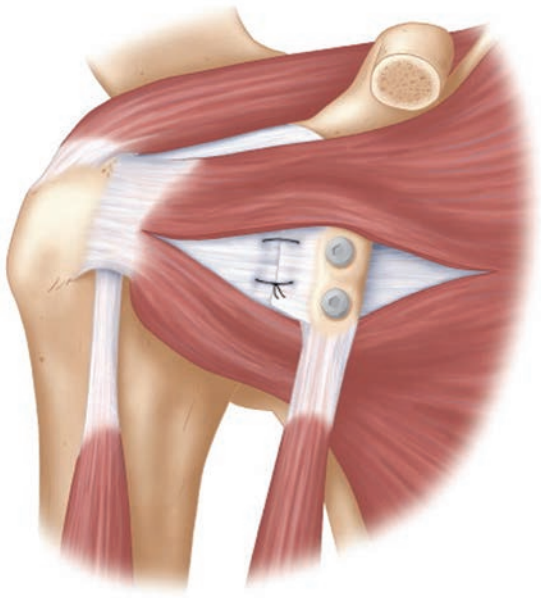


FIGURE 1-36. Anterior view of final reconstruction following repair of capsule to CAL remnant (arm in full external rotation with elbow by the side). *(From Provencher MT, Romeo AA, editors: Shoulder instability: a comprehensive approach. Philadelphia, 2011, Elsevier (Saunders)).*

- Subscapularis split will allow for more aggressive progression with the IR strengthening, but may also need ER limitations.
- Latarjet procedure (conjoint tendon transfer with coracoid fixation).
  - The sling of the conjoint may add some slight motion limitations.
  - The capsular repair may add motion limitations, especially in external rotation and abduction. This is traditionally done via a subscapularis split.

Other Surgical Techniques and Options

- Provencher et al.[1] suggests there is the potential added benefit of restoration of the articular surface of the glenoid, with the ability to provide for an anatomic fit by customizing the graft size for the defect. The distal tibia allograft provides several advantages over a glenoid allograft.
- A case series by Warner et al.[2] concluded glenoid with autogenous iliac crest bone graft for recurrent glenohumeral instability due to setting of bone deficiency is an effective form of treatment for this problem.
  - Autograft: Iliac crest (Figure 1-39).



FIGURE 1-37. X-rays from Gilles Walch—Postoperative radiographs (**A**, True AP; **B**, Lateral; and **C**, Bernageau views) demonstrating correct placement of the graft with no lateral overhang and bicortical screw fixation. *(From Provencher MT, Romeo AA, editors: Shoulder instability: a comprehensive approach. Philadelphia, 2011, Elsevier (Saunders)).*

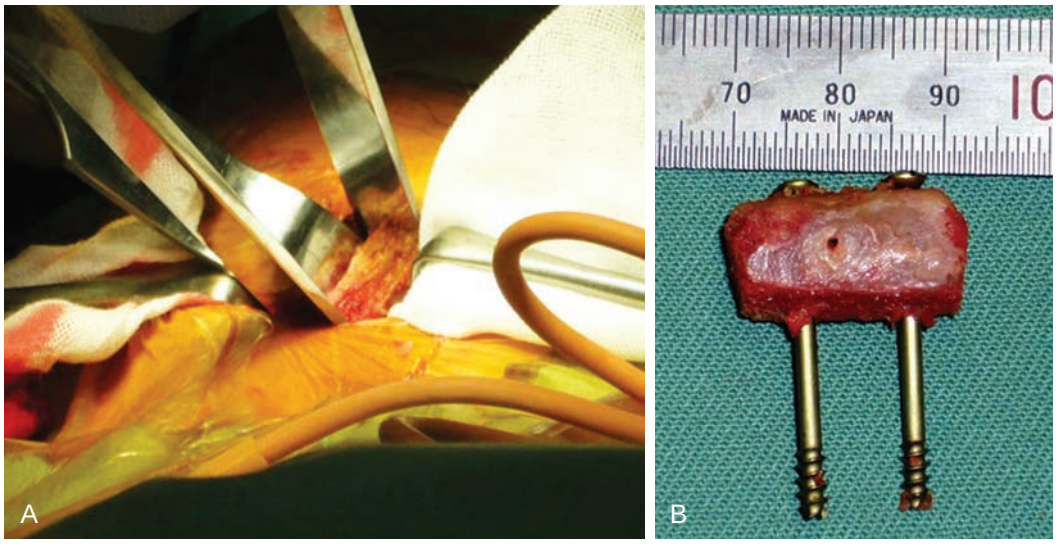


FIGURE 1-38. Iliac tricortical bone is harvested from the iliac crest and prepared using two screws. *(A, From Sugaya H: Instability with bone loss. In Angelo R, et al:, AANA advanced shoulder arthroscopy, Philadelphia, 2010, Elsevier; B, From Provencher MT, Romeo AA, editors: Shoulder instability: a comprehensive approach. Philadelphia, 2011, Elsevier (Saunders)).*

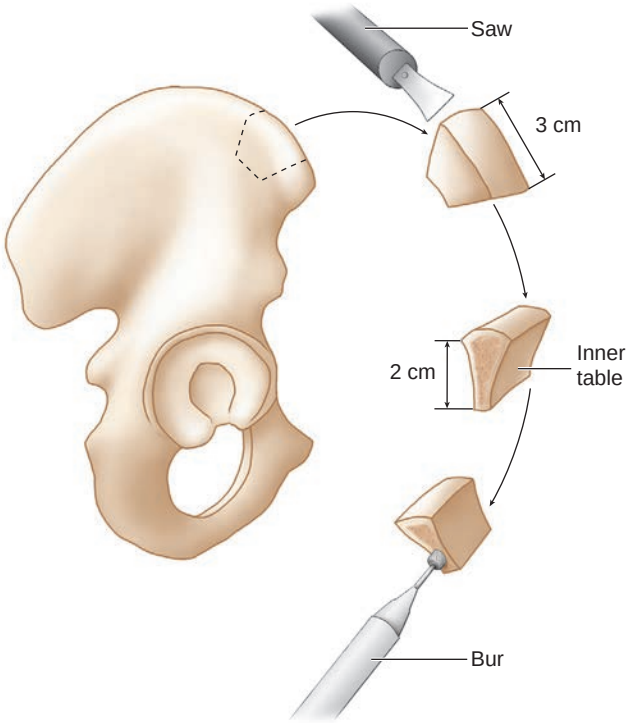


FIGURE 1-39. Harvesting and preparing iliac crest autograft. *(From Provencher MT, Romeo AA, editors: Shoulder instability: a comprehensive approach. Philadelphia, 2011, Elsevier (Saunders)).*

- Allograft: distal tibial allograft, femoral head, glenoid and others have been described.[1,2]
- These differences in type of repair may affect rehabilitation guidelines especially in consideration of the limitations in ER after the procedure for a varied period of time. Clarification from the surgeon is necessary (Figures 1-40 to 1-42).

Before Surgery: Overview of Goals, Milestones, and Guidelines[1]

GUIDING PRINCIPLES OF POSTOPERATIVE REHABILITATION

- Rehabilitation protocols must be tailored to specific surgical technique performed.
- Bone to bone healing occurs at approximately 6 to 8 weeks
- Subscapularis takedown will require attention to the healing rotator cuff as well as integrating bone graft. Active internal rotation should be limited for 6 weeks as well as passive external rotation should be gained in a protected manner.

Phase I: Weeks 0 to 3 Postoperatively (Subscapularis Takedown)

Goals

- Minimize postoperative pain and inflammation.
- Patient education regarding the stressors to the graft and soft tissues.
- Emphasize importance of sling compliance to include proper positioning to allow incision healing and minimize stress to healing soft tissues and protect bone graft.
- Surgeon-therapist communication regarding type of soft tissue and osseous structures repaired.

[1]*Prehabilitation, if appropriate, is described in the Nonoperative Rehabilitation section of this chapter.*

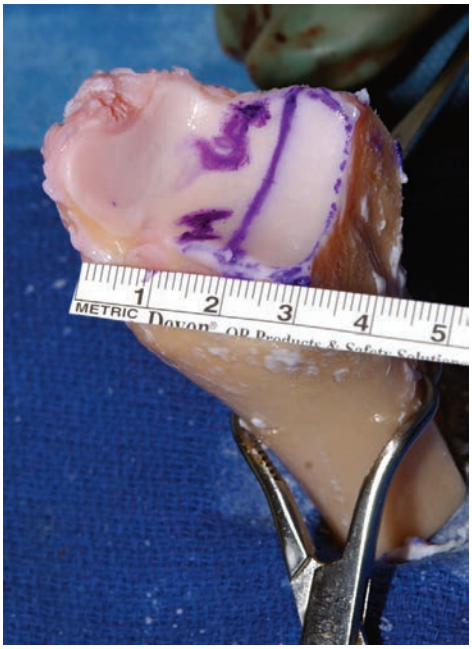


FIGURE 1-40. The lateral portion of the tibial plafond for use as an allograft. *(From Provencher MT, Romeo AA, editors: Shoulder instability: a comprehensive approach. Philadelphia, 2011, Elsevier (Saunders)).*

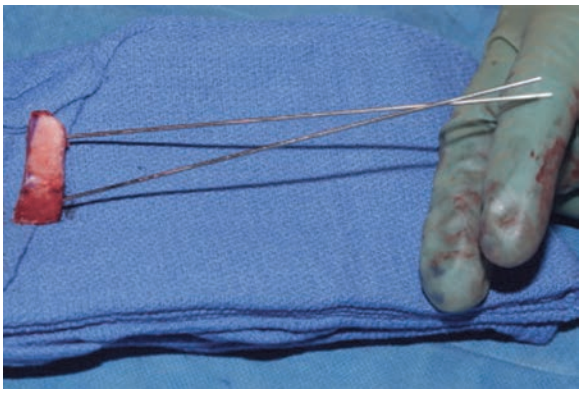


FIGURE 1-41. Two 1.6-mm K-wires are used for provisional fixation. These should be placed at a 45-degree angle to the articular surface in order to avoid penetration of the joint and achieve optimal purchase. The K-wires should be placed in a location that will allow for eventual placement of two 3.5-mm fully threaded cortical screws around them. *(From Provencher MT, Romeo AA, editors: Shoulder instability: a comprehensive approach. Philadelphia, 2011, Elsevier (Saunders)).*

- Protect both graft and soft tissue healing structures (subscapularis repair).
- Maintain elbow, wrist, and hand motion as well as postural/scapular stabilizer tone.

Clinical Pearl

- Understand what happened to the subscapularis. This is the number one item to communicate between the surgeon-rehabilitation team, as external rotation is limited due to the bone graft. The normal postoperative emphasis on internal rotation must be altered, as manual IR techniques would compromise the healing subscapularis. It is important to have patient understanding of limiting active internal rotation for the initial 6 weeks postoperatively.
- Also, clinically we have observed that pectoralis major and minor muscular restrictions and swelling at the anterior chest/shoulder region near the incision can be a pain generator. Often, soft tissue mobilization to the restricted pectoralis group will mobilize swelling and decrease muscle guarding. In addition, emphasis on patient relaxation of the pectoralis muscles has been observed to reduce pain.

TIMELINE 1-3: **Postoperative Rehabilitation After Open Anterior Stabilization of the Shoulder With or Without Bone Graft (Iliac Crest, Latarjet, etc.)**

PHASE I (weeks 1 to 2)	PHASE II (weeks 3 to 6)	PHASE III (weeks 6 to 10)
• Sling • PT modalities: e-stim, CP • PROM-scapular plane elevation and flexion to 100° • Active assistive Codman's exercises • TBS/TAS/TLS activities as recommended & tolerated	• Sling (may d/c at wk 5–6) • PT Modalities: e-stim, CP, MHP • PROM-wk-4 scaption and flexion to full • PROM-wk-6 ER to 45° • PROM-wk-6 IR to 0° • TBS/TAS/TLS activities as recommended & tolerated • Scapular exercises • Wk 4-AAROM exercises • Wk 4-submax isometrics for GH joint muscles • Wk 6-submax isometrics for ER	• DC sling • PT Modalities as needed • PROM-full • Mobilizations as needed • TBS/TAS/TLS activities as recommended & tolerated • Scapular exercises—PREs • TAS—Biceps/Triceps PREs • Glenohumeral exercises—PREs • Rotator cuff exercises—PREs • Limit IR exercises to minimize strain to posterior capsule and subscapularis • PNF exercises • OKC Rhythmic stabilization exercises • CKC Exercises • Wk 10-Seated press-ups and increased weight-bearing through joint • CKC manual perturbation exercises

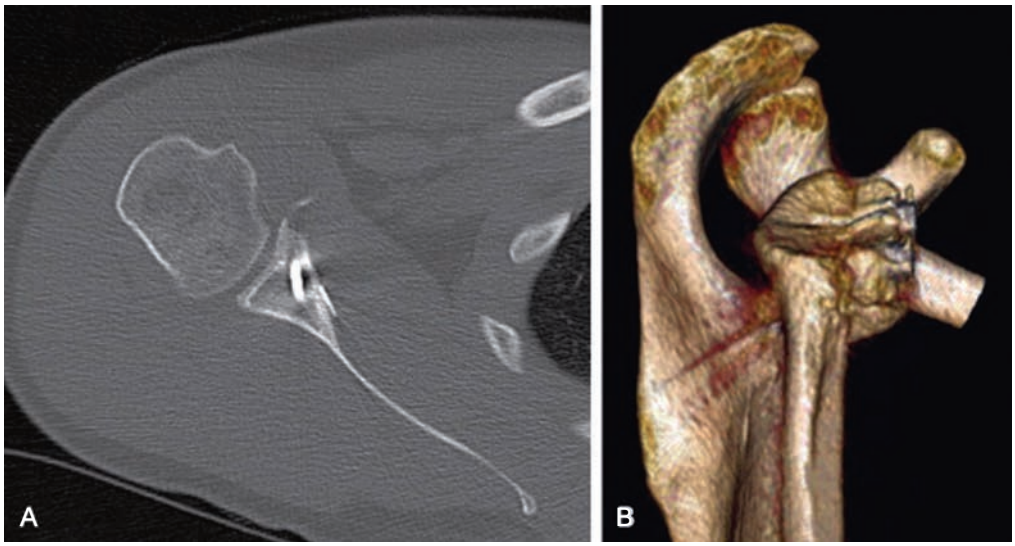


FIGURE 1-42. (**A**) Two- and (**B**) three-dimensional CT images that illustrate the excellent match of the radius of curvature of the native glenoid and distal tibia allograft. *(From Provencher MT, Romeo AA, editors: Shoulder instability: a comprehensive approach. Philadelphia, 2011, Elsevier (Saunders)).*

Protection

- Sling immobilization for at least 4 weeks is recommended by most; others recommend 5 to 6 weeks. This is based on the surgeon's discretion.

Management of Pain and Swelling

- Position of comfort, adjust sling as required for comfort and also to protect and minimize stresses to healing structures and tissues.
- Interferential current has been documented and observed to reduce postoperative pain and swelling.
- Cold therapy for pain and swelling (Figure 1-43).
- Sleeping and resting with the upper extremity supported and slightly elevated.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- May begin active and passive range of motion (PROM) of the wrist and hand immediately.
- Active and passive elbow flexion and extension is allowed.
- *For subscapularis takedown*: PROM glenohumeral joint (GHJ) to 100 degrees flexion, 0 degrees ER.
- *For subscapularis split*: PROM GHJ to 100 degrees flex, 15 degrees ER at 30 degrees abduction at week 2 and 30 degrees ER at 45 degrees abduction at week 3.
- No active range of motion (ROM) of the GHJ.

TIMELINE 1-3: **Postoperative Rehabilitation After Open Anterior Stabilization of the Shoulder With or Without Bone Graft (Iliac Crest, Latarjet, etc.)** (Continued)

PHASE IV (weeks 10 to 14)	PHASE V (weeks 14 to 24)	PHASE V (weeks 24 to 52)
• PT Modalities as needed • PROM-full • Mobilizations as needed • Wk 12-IR sleeper stretch • TBS/TAS/TLS activities as recommended & tolerated • Scapular exercises—PREs • TAS—Biceps/Triceps PREs • Glenohumeral exercises—PREs • Rotator cuff exercises—PREs • Thrower's 10 • Limit IR exercises to minimize strain to posterior capsule and subscapularis • Begin running at 12 wks • PNF exercises • OKC rhythmic stabilization exercises • CKC exercises • CKC manual perturbation exercises	• PROM-maintain full motion • Mobilizations as needed • TBS/TAS/TLS activities as recommended & tolerated • Scapular exercises—PREs • TAS—Biceps/Triceps PREs • Glenohumeral exercises—PREs • Rotator cuff exercises—PREs • Thrower's 10 progress intensity • PNF exercises • OKC rhythmic stabilization exercises • CKC exercises • CKC manual perturbation exercises • Plyometrics—2 arm progressing to 1 arm • Overhead strengthening exercises • Sport specific exercises begin • Overhead throwing athletes can begin an easy interval throwing program • 20 wks-begin full windup throwing	• PROM-maintain full motion • Mobilizations as needed • TBS/TAS/TLS activities as recommended & tolerated • Scapular exercises—PREs • TAS—Biceps/Triceps PREs • Glenohumeral exercises—PREs • Rotator cuff exercises—PREs • IR/ER exercises at 90° • Thrower's 10 progress intensity • PNF exercises • OKC Rhythmic stabilization exercises • CKC Exercises • CKC manual perturbation exercises • Plyometrics—2 arm chest passes progressing to 90°/90° 1 arm plyos • Overhead strengthening exercises • Sport-specific exercises progressed • Overhead throwing athletes progress through an interval throwing program



FIGURE 1-43. Cold therapy. *(From Provencher MT, Romeo AA, editors: Shoulder instability: a comprehensive approach. Philadelphia, 2011, Elsevier (Saunders)).*

Soft Tissue Techniques

- Soft tissue techniques to cervical musculature (levator scapulae and upper trapezius), anterior shoulder and chest wall/pectoralis major, periincisional.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Stretching/flexibility techniques for the levator scapular and upper trapezius during this phase as needed to relieve pain, shoulder girdle elevation, and the effects of immobilization and guarding.

Other Therapeutic Exercises

- For the elite athlete, lower body strengthening can continue safely in the early postoperative period. Core strengthening can be performed with the arm in the sling. Stationary bicycle can be used for cardiovascular maintenance, conditioning and circulation.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- No active shoulder movements for 4 to 5 weeks.
- Maybe isometrics on *subscapularis split* into IR at 2 weeks' postop.
- For half *subscapularis split/takedown*, refrain from active IR for 3 to 4 weeks.
- No strengthening of internal rotation for 6 weeks if subscapularis was taken down during surgery.

Sensorimotor Exercises

- Again, for the elite athlete these can begin immediately following surgery in a supervised setting with the arm in a sling. For most patients this would be restricted until at least 6 to 8 weeks to avoid falling or loss of balance that may produce sudden movements of the protected upper extremity.

Open and Closed Kinetic Chain Exercises

- No active range of motion (AROM) of the glenohumeral joint.
- Supported or short lever Codman's exercises (Figure 1-44) during this phase, three times/day.
- Ball Squeeze for hand.
- Wrist and gripping exercises.

Techniques to Increase Muscle Strength, Power, and Endurance

- Strengthening should be avoided until full passive and active motion have returned.

Neuromuscular Dynamic Stability Exercises

- Elite athletes may begin this during Phase II.

Plyometrics

- Lower extremity plyometrics can begin at 8 weeks following surgery.

Milestones for Progression to the Next Phase

- Minimal to no pain.
- 100% sling/immobilizer compliance.
- No signs or symptoms of compromise or failure of the repair.



FIGURE 1-44. Short lever or supported Codman's exercises. *(From Provencher MT, Romeo AA, editors: Shoulder instability: a comprehensive approach. Philadelphia, 2011, Elsevier (Saunders)).*

Phase II: Weeks 4 to 6 Postoperatively

Goals

- Prevent loss of motion of hand, wrist, and elbow
- Protect graft and continue to prevent stresses soft tissue repair.
- Pain-free GHJ PROM within postoperative restrictions to prevent stiffness.
- Eliminate postoperative pain and swelling.

Clinical Pearl

Pain during this phase is often at the supraspinatus or subacromial space. This may occur upon initiating PROM of the GHJ. Clinically we have had success eliminating this pain during this phase with soft tissue mobilization to the supraspinatus tendon while the GHJ is in the loose packed position. In addition, gentle grade 1 to 2 joint mobilizations to the GHJ (posterior glides in general due to ROM limitations) may be applied to improve arthrokinematics that may be contributing to subtle rotator cuff (RC) impingement caused by stiffness and faulty mechanics.

Protection

- The sling may be weaned at week 4 to 5 unless indicated by the surgeon.

Management of Pain and Swelling

- Cold therapy and electric stimulation modalities may be continued as needed during this phase.
- Moist heat may be applied to the pectoralis group if patient has difficulty relaxing or guarding continues during this phase.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- No active GHJ ROM.
- PROM GHJ flexion and scaption to pain-free tolerance. ER 0 to 45 degrees in 45 degrees abduction until week 6. IR PROM to 45 degrees in 30 degrees abduction.
- Continue PROM to the wrist and elbow. Grade 1 to 2 posterior joint mobilization to the GHJ (no anterior or inferior mobilization) to facilitate PROM (Figure 1-45).

Soft Tissue Techniques

- Continue soft tissue mobilization to muscles discussed in Phase I.



FIGURE 1-45. Therapist performs PROM of GHJ within postoperative external rotation restrictions. *(From Provencher MT, Romeo AA, editors: Shoulder instability: a comprehensive approach. Philadelphia, 2011, Elsevier (Saunders)).*

- Begin scar mobilization when incisions are sufficiently closed.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Stretching/flexibility techniques for the cervical and shoulder girdle musculature as discussed in Phase I.

Other Therapeutic Exercises

- Stationary bike at week 4 while wearing sling.

Sensorimotor Exercises

- Elite athletes may begin lower extremity (LE) unilateral balance and proprioceptive exercises, single limb LE balance with head movements.

Open and Closed Kinetic Chain Exercises

- May begin trunk or thoracic rotation while wearing sling.

Functional Exercises

- Functional one third squats (wearing sling).
- Stationary lunges.

Milestones for Progression to the Next Phase

- No postoperative swelling or pain.
- Elbow, wrist, and hand ROM within normal limits
- Full PROM except ER by week 6.
- No signs or symptoms of compromise or failure of the repair.

Phase III: Weeks 6 to 10 Postoperatively

Goals

- Full pain-free end range AROM without sensation of instability.
- Gradual, pain-free steady return of end range abduction external rotation (ABER).
- Restore arthrokinematics.
- Maximize scapular stabilizer strength and restore rotator cuff strength.

Clinical Pearl

As a patient begins AROM, clinically we have observed the patient exhibiting signs and symptoms consistent with impingement. Continue soft tissue mobilization to the supraspinatus or posterior rotator cuff if tender and painful during this phase. Cautiously and gently apply GHJ mobilization inferiorly and anteriorly toward the later stage of this phase as appropriate to address stiffness. Restore scapulohumeral rhythm with manual cueing to further improve faulty arthrokinematics. Initiation of serratus anterior and lower trapezius strengthening is key to facilitate proper mechanics.

Protection

- Discontinue sling completely prior to initiation of this phase.

Management of Pain and Swelling

- NSAIDs as needed.
- Moist heat may be applied to the GHJ for stiffness.
- Continue ice for any residual pain or swelling apply to rotator cuff if indicated.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Continue joint mobilizations, manually facilitate scapulohumeral rhythm. Continue PROM and AAROM to full AROM by week 10.

Soft Tissue Techniques

- Continue stretching and flexibility for the restricted shoulder girdle and parascapular muscle groups (i.e., pectoralis major, minor, levator scapula, upper trapezius).

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Stretching/flexibility techniques restricted muscles (i.e. pectoralis major, minor).

Other Therapeutic Exercises

- LE gym weights and machines, light resistance.
- Elliptical (week 8), StairMaster (week 6).
- UBE minimal resistance week 6, progress resistance (week 8).
- Stationary bike with increased resistance.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Begin isometrics of IR after week 6. Begin gentle PREs of biceps, triceps, deltoids, middle, and lower trapezius and ER at week 6.

Sensorimotor Exercises

- Hand on baps board in partial UE weight-bearing (WBing) at 6 weeks.
- Progress to body blade at side in neutral at week 8.

Open and Closed Kinetic Chain Exercises

- AAROM using towel for end range IR.
- AAROM using with wand or dowel for flexion, abduction, ER.
- Closed chain scapular exercises and kinetic chain exercises begin at 8 weeks, allowing the patient to improve scapular kinetics
- Scapular clocks.
- Wall protraction at weeks 8 to 10 with B UEs, progressing to unilateral UE.

Techniques to Increase Muscle Strength, Power, and Endurance

- Seated small arc scapular depression at week 6.
- Seated scapular retraction at week 6.
- Prone "I" scapular three-step exercise at weeks 8 to 10.
- Isometric ER, IR, flexion, extension and abduction at week 6.
- Progress to light resistance band for RC strength, in neutral at week 8.
- Progress to scapular depression and rows with light resistance band at week 8.
- Sidelying ER with no resistance.

Neuromuscular Dynamic Stability Exercises

- Scapular PNF in sidelying; repeated isometric progressing to slow reversals.
- IR and ER PNF repeated contractions after week 6 beginning in neutral.
- GHJ PNF in supine; rhythmic stabilization progressing to slow reversals.
- Elbow PNF.

Plyometrics

- LE low impact plyometrics at week 8 for elite athletes.

Functional Exercises

- Lawnmowers (Figure 1-46).
- Romanian dead lifts (RDLs).
- Thoracic spine ROM and mobility, functional trunk movements and activities.

Sport-Specific Exercises

- LE sport specific agility drills for elite athletes.

Milestones for Progression to the Next Phase

- Full AROM GHJ without compensatory movement strategies.
- No pain or sensation of instability.
- Strength UE and scapular stabilizers 4+/5.
- Restored joint mobility.

Phase IV: Weeks 10 to 14 Postoperatively

Goals

- Restore scapulohumeral rhythm and normalize arthrokinematics.
- Maximize strength of UE and parascapular musculature.
- Initiate overhead (ABER) functional movement patterns.

Clinical Pearl

To attain end range ABER, careful anterior, inferior or combined anterior-inferior joint mobilization may be helpful. In addition, scapular tilting is often observed. Pectoralis minor stretching may assist in restoring the normal resting position of the scapula during the later stages of this phase into the next phase.

Protection

- May apply postural tape, kinesiotape to cue or facilitate parascapular muscles.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Continue joint mobilization.
- Manually facilitate scapulohumeral rhythm.
- Low-load long-duration capsular stretch if lacking end range combined ABIR or ABER.

Soft Tissue Techniques

- Continue scar mobilization and soft tissue mobilization as described in previous phases.

Stretching/Flexibility Techniques for the Musculo-Tendinous Unit

- Hold relax stretching of pectoralis major, minor, latissumus dorsi, levator scapula as needed.



FIGURE 1-46. Lawnmowers. *(From Provencher MT, Romeo AA, editors: Shoulder instability: a comprehensive approach. Philadelphia, 2011, Elsevier (Saunders))*

Other Therapeutic Exercises

- Upper body ergometer (UBE).
- LE gym weights and machines, increase resistance.
- Add bent over low row with light weight.
- Progress to low- and mid-row machine, low resistance.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Full Can to 90 degrees only for nonthrowers with light weights.
- Shoulder raises (flexion, abduction) to 90 degrees with light weights.
- Biceps curls, begin with supported preacher curl.

Sensorimotor Exercises

- Increase UE WBing on unstable surface (i.e., half-kneeling UE balance on BOSU ball).
- Progress UE resistance band exercises with decrease base of support (unilateral balance or on unstable surface).

Techniques to Increase Muscle Strength, Power, and Endurance

- Add PNF patterns with resistance bands.
- Prone T and Y.
- Isometric ER, IR, flexion, extension, and abduction at week 6.
- Begin isokinetics.
- Wall pushup progression.

Neuromuscular Dynamic Stability Exercises

- Seated GHJ PNF.
- Body blade at varying flexion, abduction and scaption angles.

Plyometrics

- Progress LE plyometrics.

Functional Exercises

- Begin jogging at week 12

Sport-Specific Exercises

- LE sport specific agility drills for elite athletes.

Milestones for Progression to the Next Phase

- Strength of RC and parascapular stabilizers all 5/5.
- No pain or instability.
- Optimized scapulohumeral rhythm and arthrokinematics.

Phase V: Weeks 14 to 24 Postoperatively

Goals

- Continue strengthening, focusing on scapular stabilizing muscles and core strengthening.
- Initiate sports specific exercises.
- Maximize muscular strength, flexibility, and endurance.

Clinical Pearl

Observation of trunk and torso ROM (i.e. combined thoracic extension and rotation) while the patient begins overhead GHJ movements is important. Any asymmetries should be addressed with thoracic spine AROM, joint mobilization and strengthening to prevent return to sport, in particular throwing, without faulty mechanics.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Continue Gr 3 to 4 GHJ mobilization, scapulothoracic joint mobilization as needed.

Soft Tissue Techniques

- PRN as described previously.

Stretching/Flexibility Techniques for the Musculo-Tendinous Unit

- PRN as described previously.

Other Therapeutic Exercises

- Sit ups.
- Begin plank progression (start with half planks or pillars).

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Progress to cables for RC strengthening (see below).
- Lat pulls.
- Seated row machine.
- Gentle seated chest press from midrange.

Sensorimotor Exercises

- Hand-eye coordination drills for racquet or overhead athletes.

Open and Closed Kinetic Chain Exercises

- Increase resistance to rotator cuff, middle and lower trapezius, and serratus anterior strength.

- Protraction progression: unilateral at wall, bilateral at table, bilateral ½ kneeling unstable surface.

Techniques to Increase Muscle Strength, Power, and Endurance

- Add "endurance" sets to all PREs.
- Transition from hypertrophic to strength load.

Neuromuscular Dynamic Stability Exercises

- Progress UE weight on unstable surface (i.e., unilateral wall ball perturbations)

Plyometrics

- Begin UE plyometrics (i.e., dribble on floor, progress to wall dribble).

Functional Exercises

- Begin swimming at week 16.

Sport-Specific Exercises

- Overhead athletes begin throwing program (Table 1-3).
- Thrower's Ten (Figure 1-47).

Milestones for Progression to the Next Phase

- Strength 5/5 including RC, middle and lower trapezius and serratus anterior.
- Minimal torso/thoracic ROM deficiencies or asymmetries.

Phase VI: Weeks 24 to 52 Postoperatively

Goals

- Return to sport when full ROM and strength at 90% of contralateral extremity.
- Maintenance of scapular stabilizing strength.
- Maximize core strength and endurance.
- Optimize throwing mechanics and UE agility.
- Prevent future injury.

Clinical Pearl

The authors emphasize ongoing targeted and specific scapular muscular strengthening and optimal scapulohumeral rhythm for successful return to sport. Progress the athlete through a linear periodization consisting of hypertrophy, strength, strength-power, power, and de-load phases. This allows the athlete to build a foundation of strength as the musculoskeletal system responds better to volume rather than intensity after a long period of inactivity. When considering functional exercises, utilize the Olympic lifts and complex training to restore power. As the exercises get more sport specific, choose a dumbbell snatch as an overhead exercise to elicit power. The use of a single arm dumbbell snatch will reinforce the importance of unilateral movement especially in throwing athletes.

Techniques for Progressive Increase in Range of Motion

Stretching/Flexibility Techniques for the Musculo-Tendinous Unit

- Ongoing static stretching for muscle groups used throughout workout to emphasize continued mobility

Techniques to Increase Muscle Strength, Power, and Endurance

- Linear periodization for return to sport.
- Body responds to volume before intensity.
- Weeks 24 to 29: Hypertrophy phase.
  - Higher repetition scheme with longer rest times.
  - 3 days per week of lifting and 2 days per week of conditioning.
- Weeks 30 to 36: Strength phase.
  - Upper/lower body split, multijoint exercises.
  - 4 days per week lifting and 3 days per week of conditioning.
- Week 37: De-load
  - 3 days per week of full body lifting at approximately 65% to 70% max.
  - 2 days per week of conditioning with an increase of mobility exercises.
- Weeks 38 to 44: Strength/Power phase.
  - Reintroduce Olympic lifting.
  - Reintroduce more complex plyometric exercises.
  - 3 days per week of lifting and 3 days per week of conditioning.
- Weeks 38 to 41: 3 days of lifting consisting of total body.
- Weeks 42 to 44: 1 day consisting of upper body lifting, 1 day consisting of lower body lifting, and 1 day consisting of total body lifting.
- Week 45: De-load
  - 3 days per week of lifting and 3 days per week of conditioning.
- Weeks 46 to 52: Power phase.
  - Olympic lifting and complex training.
  - 3 days per week of lifting (2 days per week if in preseason phase).
  - 4 days per week of conditioning (3 days per week if in preseason phase).

Neuromuscular Dynamic Stability Exercises

- Olympic lifting.
  - Clean and Jerk (modifications and variations).
  - Snatch (modifications and variations).

Table 1-3 High School, College, and Professional Baseball Pitchers Interval Throwing Program

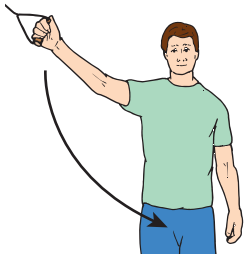
Phase I	Return to Throwing Throws at 50% Effort	Phase II	Return to Pitching Throws at Effort Level Given	Phase III	Intensified Pitching
Step 1	Warmup toss to 60′ 15 throws at 30′* 15 throws at 30′* 15 throws at 30′* 20 long tosses to 60′	Step 7	15 throws at 60′6″ (75%)* 20 throws at 60′6″ (75%)* 20 throws at 60′6″ (75%)* 15 throws at 60′6″ (75%)* 20 throws at 60′6″ (75%)*	Step 12	25 fastballs (75%)* 20 fastballs (100%)* 10 fastballs (75%)* 15 fastballs (100%)* 25 fastballs (75%)*
Step 2	Warmup toss to 75′ 15 throws at 60′* 15 throws at 60′* 15 throws at 60′* 20 long tosses to 90′	Step 8	20 throws at 60′6″ (75%)* 20 throws at 60′6″ (75%)* 20 throws at 60′6″ (75%)*	Step 13	(Active rest)20 throws at 80′* 20 throws at 80′* 20 throws at 80′* 20 throws at 80′*
Step 3	Warmup toss to 105′15 throws at 75′* 15 throws at 75′* 15 throws at 75′* 20 long tosses to 105′	Step 9	20 fastballs (50%)* 20 fastballs (50%)* 20 fastballs (50%)* 20 fastballs (50%)* 25 throws at 60′6″ (75%)*	Step 14	20 fastballs (75%)* 20 fastballs (100%) 5 off-speed pitches * 15 fastballs (100%) 5 off-speed pitches* Field bunts and comebacks†
Step 4	Warmup toss to 120′ 15 throws at 90′* 20 throws at 90′* 15 throws at 90′* 20 long tosses at 120′	Step 10	20 fastballs (50%)* 20 fastballs (75%)* 20 fastballs (50%)* 15 fastballs (75%)* 25 throws at 60′6″ (75%)*	Step 15	20 fastballs (100%)* 15 fastballs (100%) 5 off-speed pitches 5 pickoff throws to 1st* 20 fastballs (100%) 5 off-speed pitches* 20 fastballs (100%) 5 off-speed pitches*
Step 5	Warmup toss to 120′ 20 throws at 105′* 20 throws at 105′* 15 throws at 105′* 20 long tosses at 120′	Step 11	25 fastballs (50%)* 20 fastballs (75%)* 20 fastballs (75%)* 20 fastballs (75%)* 20 fastballs (75%)	Step 16	15 fastballs (100%) 5 off-speed pitches* 15 fastballs (100%) 3 pickoff throws to 1st* 20 fastballs (100%) 5 off-speed pitches* 15 fastballs (100%) 3 pickoff throws to 2nd* 15 fastballs 100%) 5 off-speed pitches*
Step 6	Warmup toss to 120′ 20 throws at 120′* 20 throws at 120′* 20 throws at 120′* 20 long tosses at 120′			Step 17	(Active rest) Repeat step 14
				Step 18	20 fastballs (100%) 5 off-speed pitches* 20 fastballs (100%) 3 pickoff throws to 1st* 20 fastballs (100%) 3 pickoff throws to 2nd* 15 fastballs (100%) 5 off-speed pitches* 15 fastballs (100%) 5 off-speed pitches*
				Step 19	Batting practice 110–120 pitches Field bunts and comebacks
				Step 20	Simulated game

*Rest 6 minutes after these sets.
†Relievers and closing pitchers can go to step 21 on the next throwing day after completing this step.
(From Tyler T, Jenk D: In: Brotzman SB, Manske RC, editors: Clinical Orthopaedic Rehabilitation, ed 3, Philadelphia, 2011, Elsevier (Mosby), p. 138.)

- Power lifts.
  - Deadlift.
  - Squat.
  - Bench press.
- Rotation and antirotation.
  - Cable and banded rotation.
  - Cable and banded antirotation.

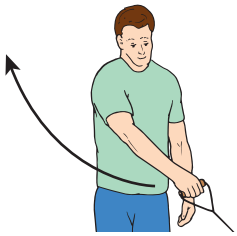
Plyometrics

- Lower body plyometrics.
  - Hurdle hops (double and single leg).
  - Double leg jump.
  - Single leg jump.
  - Single leg bound.
  - Box step-up/step-down.



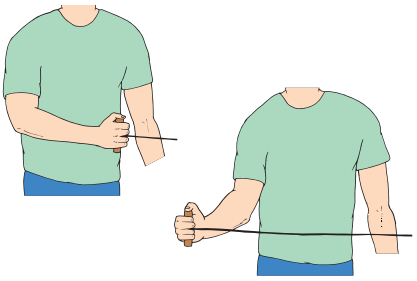
Diagonal pattern D2 extension:
Involved hand will grip tubing handle overhead and out to the side. Pull tubing down and across your body to the opposite side of leg. During the motion, lead with your thumb.

Perform ___ sets of ___ repetitions ___ daily.



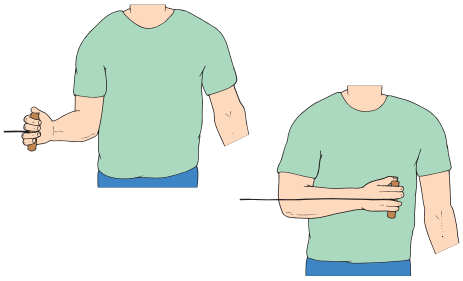
Diagonal pattern D2 flexion:
Gripping tubing handle in hand of involved arm, begin with arm out from side 45° and palm facing backward. After turning palm forward, proceed to flex elbow and bring arm up and over involved shoulder. Turn palm down and reverse to take arm to starting position.

Perform ___ sets of ___ repetitions ___ daily.



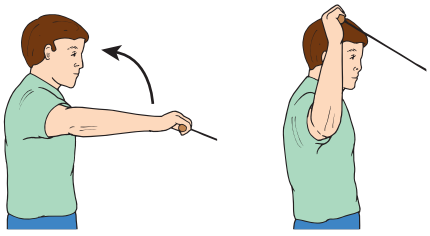
External rotation at 0° abduction:
Stand with involved elbow fixed at side, elbow at 90° and involved arm across front of body. Grip tubing handle while the other end of tubing is fixed. Pull out arm, keeping elbow at side. Return tubing slowly and controlled.

Perform ___ sets of ___ repetitions ___ daily.



Internal rotation at 0° abduction:
Standing with elbow at side fixed at 90° and shoulder rotated out. Grip tubing handle while other end of tubing is fixed. Pull arm across body keeping elbow at side. Return tubing slowly and controlled.

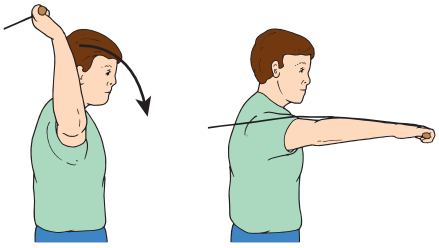
Perform ___ sets of ___ repetitions ___ daily.



(Optional) **External rotation at 90° abduction:**
Stand with shoulder abducted 90°. Grip tubing handle while the other end is fixed straight ahead, slightly lower than the shoulder. Keeping elbow at 90°. Return tubing and hand to start position.

I. Slow speed sets: (Slow and controlled)
Perform ___ sets of ___ repetitions ___ daily.

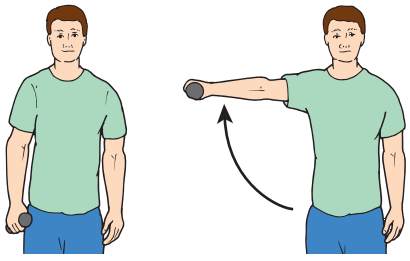
II. Fast speed sets:
Perform ___ sets of ___ repetitions ___ daily.



(Optional) **Internal rotation at 90° abduction:**
Stand with shoulder abducted to 90°, externally rotated 90° and elbow bent to 90°. Keeping shoulder abducted, rotate shoulder forward, keeping elbow bent at 90°. Return tubing and hand to start position.

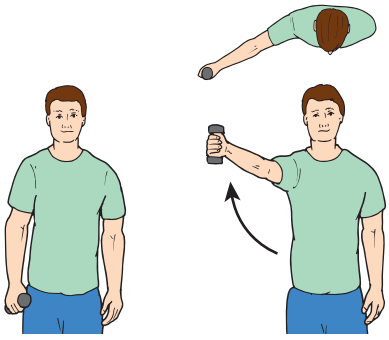
I. Slow speed sets: (Slow and controlled)
Perform ___ sets of ___ repetitions ___ daily.

II. Fast speed sets:
Perform ___ sets of ___ repetitions ___ daily.



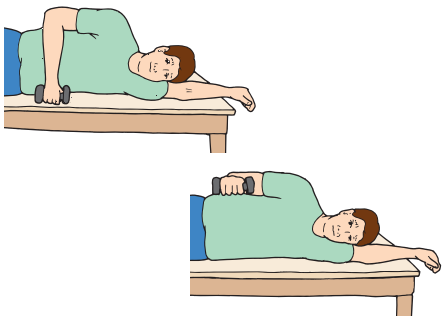
Shoulder abduction to 90°:
Stand with arm at side, elbow straight, and palm against side. Raise arm to the side, palm down, until arm reaches 90° (shoulder level).

Perform ___ sets of ___ repetitions ___ daily.



Scaption, external rotation:
Stand with elbow straight and thumb up. Raise arm to shoulder level at 30° angle in front of body. Do not go above shoulder height. Hold 2 seconds and lower slowly.

Perform ___ sets of ___ repetitions ___ daily.

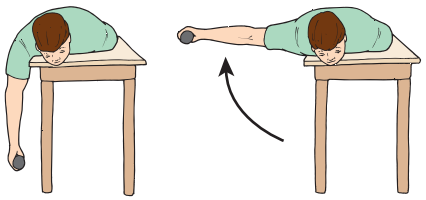


Sidelying external rotation:
Lie on uninvolved side, with involved arm at side of body and elbow bent to 90°. Keeping the elbow of involved arm fixed to side, raise arm. Holds 2 seconds and lower slowly.

Perform ___ sets of ___ repetitions ___ daily.

FIGURE 1-47. The "Thrower's Ten Program" is designed to exercise the major muscles necessary for throwing. The program's goal is to be an organized and concise exercise program. In addition, all exercises included are specific to the thrower and are designed to improve strength, power and endurance of the shoulder complex musculature. *(Modified from Wilk KE, et al: Preventative and rehabilitative exercises for the shoulder and elbow, Birmingham, AL, 2001, American Sports Medicine Institute, pp. 34–37.)*

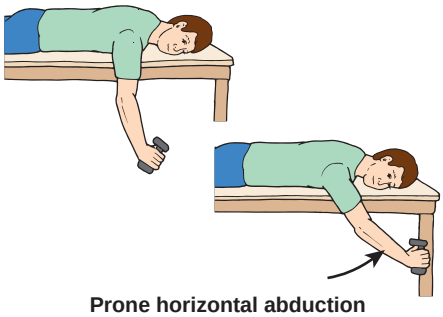
Continued



Prone horizontal abduction (Neutral):

Lie on table, face down, with involved arm hanging straight to the floor, and palm facing down. Raise arm out to the side, parallel to the floor. Hold 2 seconds and lower slowly.

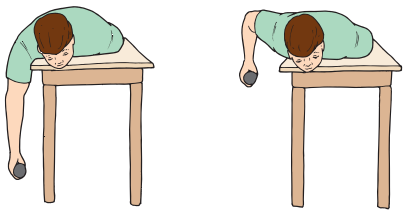
Perform ___ sets of ___ repetitions ___ daily.



Prone horizontal abduction (Full ER, 100° ABD):

Lie on table face down, with involved arm hanging straight to the floor, and thumb rotated up (hitchhiker). Raise arm out to the side with arm slightly in front of shoulder, parallel to the floor. Hold 2 seconds and lower slowly.

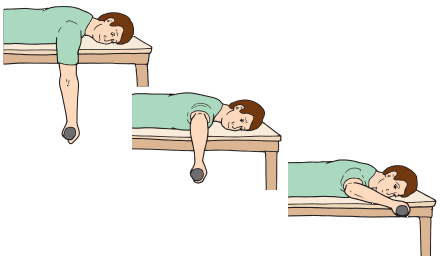
Perform ___ sets of ___ repetitions ___ daily.



Prone rowing:

Lying on your stomach with your involved arm hanging over the side of the table. dumbbell in hand and elbow straight. Slowly raise arm, bending elbow, and bring dumbbell as high as possible. Hold at top for 2 seconds, then slowly lower.

Perform ___ sets of ___ repetitions ___ daily.



Prone rowing into external rotation:

Lying on your stomach with your involved arm hanging over the side of the table, dumbbell in hand and elbow straight. Slowly raise arm, bending elbow, up to the level of the table. Pause one second. The rotate shoulder upward until dumbbell is even with the table, keeping elbow at 90°. Hold at top for 2 seconds, then then slowly lower taking 2-3 seconds.

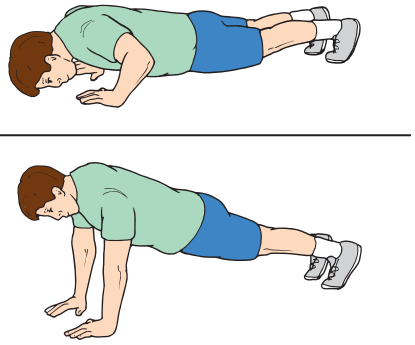
Perform ___ sets of ___ repetitions ___ daily.



Press ups:

Seated on a chair or table, place both hands firmly on the sides of the chair or table, palm down and fingers pointed outward. Hands should be placed equal with shoulders. Slowly push downward through the hands to elevate your body. Hold the elevated position for 2 seconds and lower body slowly.

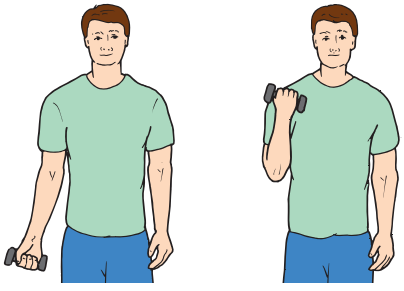
Perform ___ sets of ___ repetitions ___ daily.



Push-ups:

Start in the bottom position with arms in a comfortable position. Place hands no more than shoulder width apart. Push up as high as possible, rolling shoulders forward after elbows are straight. Start with a push-up into wall. Gradually progress to table top and eventually to floor as tolerable.

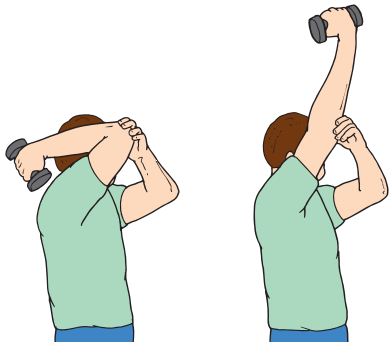
Perform ___ sets of ___ repetitions ___ daily.



Elbow flexion:

Standing with arm against side and palm facing inward, bend elbow upward turning palm up as you progress. Hold 2 seconds and lower slowly.

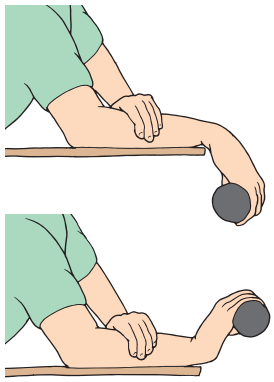
Perform ___ sets of ___ repetitions ___ daily.



Elbow extension (Abduction):

Raise involved arm overhead. Provide support at elbow from uninvolved hand. Straighten arm overhead. Hold 2 seconds and lower slowly.

Perform ___ sets of ___ repetitions ___ daily.

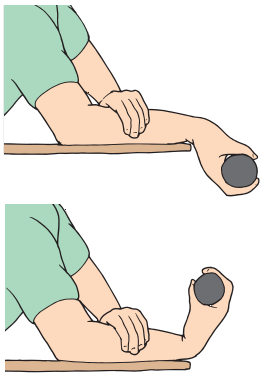


Wrist extension:

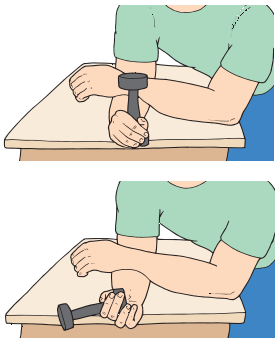
Supporting the forearm and with palm facing downward, raise weight in hand as far as possible. Hold 2 seconds and lower slowly.

Perform ___ sets of ___ repetitions ___ daily.

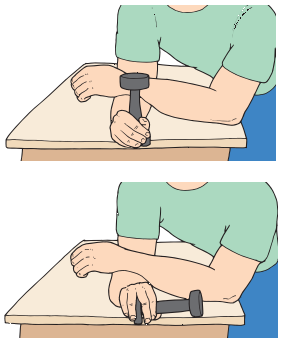
FIGURE 1-47, cont'd



Wrist flexion:
Supporting the forearm ans with palm facing upward, lower a weight in hand as far as possible and then curl it up as high as possible. Hold 2 seconds and lower slowly.
Perform ___ sets of ___ repetitions ___ daily.



Supination:
Forearm supported on table with wrist in neutral position. Using a weight or hammer, roll wrist taking palm up. Hold for a 2 count and return to starting position.
Perform ___ sets of ___ repetitions ___ daily.



Pronation:
Forearm should be supported on a table with wrist in neutral position. Using a weight or hammer, roll wrist taking palm down. Hold for a 2 count and return to starting position.
Perform ___ sets of ___ repetitions ___ daily.

FIGURE 1-47, cont'd

- Box jump/step-down
- Lateral box jump
- Seated box jump
- Depth jump
- Upper body plyometrics
  - Pushup plus
  - Pushup plus beyond ROM
  - Medicine ball pushups
  - Medicine ball standing chest pass
  - Medicine ball seated chest pass
  - Medicine ball lying chest pass
  - Clapping pushups

Functional Exercises

- Olympic lift modifications.
  - Primarily dumbbell snatch as athlete progresses closer to return to sport.
- Power lifts.
- Single arm exercises with dumbbell and neutral grip.
- Single leg exercises.

Sport-Specific Exercises

- Throwing deceleration progression.
- Anti-rotation push/pull exercises.
- Posterior deltoid exercises.

Milestones for Progression to the Next Phase

- Ability to correctly execute sport specific exercises.
- Ability to progress with throwing exercises.

Criteria for Return to Sport

General

- No pain with sport specific movements.
- Full active and passive shoulder ROM without pain.
- Strength greater than or equal to 90% of the contralateral extremity.
- No instability or subluxations/dislocations.

Evidence

Escamilla RF, Fleisig GS, Yamashiro K, et al: Effects of a 4-week youth baseball conditioning program on throwing velocity. *J Strength Cond Res* 24:3247–3254, 2010.

This randomized controlled trial demonstrated the effectiveness of a 4-week baseball conditioning program on increasing maximum throwing velocity of youth baseball players. This authors concluded that a conditioning program including a sport-specific warmup, resistance training, throwing program, and stretching increased throwing velocity. (Level I evidence).

Lauder MA, Lake JP: Biomechanical comparison of unilateral and bilateral power snatch lifts. *J Strength Cond Res* 22:653–660, 2008.

In this study, the authors quantify unilateral and bilateral weightlifting movement data. The findings suggest how unilateral weightlifting variations may provide an alternative training approach for athletes. (Level III evidence).

Owens BD, Dickens JF, Kilcoyne KG, et al: Management of mid-season traumatic anterior shoulder instability in athletes. *J Am Acad Orthop Surg* 20:518–526, 2012.

This article reviews the controversial management of mid-season traumatic shoulder instability. Rehabilitation, bracing and surgical management are discussed. (Level III evidence).

Provencher MT, Ghodadra N, LeClere L, et al: Technical note: anatomic osteochondral glenoid reconstruction for recurrent glenohumeral instability with glenoid deficiency using a distal tibia allograft. *Arthroscopy: J Arthrosc Rel Surg* 25:446–452, 2009.

This article describes a novel surgical treatment of shoulder instability with glenoid bone loss by using a distal tibia allograft. It describes the surgical technique and discusses the, initial results in a series of three patient cases. (Level IV evidence).

Terzis G, Stratakos G, Manta P, et al: Throwing performance after resistance training and detraining. *J Strength Cond Res* 22:1198–1204, 2008.

This study examined the effect of short -term resistance training and a detraining on shot put throwing performance. The authors investigated muscular strength, fat-free mass, muscle fiber type composition and cross-sectional area. Their results suggest that 4 weeks of detraining did not affect performance in moderately resistance-trained subjects. (Level II evidence).

Warner JJ, Gill TJ, O'Hollerhan JD, et al: Anatomical glenoid reconstruction for recurrent anterior glenohumeral instability with glenoid deficiency using an autogenous tricortical iliac crest bone graft. *Am J Sports Med* 34:205–212, 2006.

In this article, the authors review 11 cases of traumatic recurrent anterior shoulder instability that underwent boney reconstruction using an iliac crest bone graft. It was concluded that this is an effective form of treatment for this condition and all patients were able to return to sport without complaint of recurrent instability. (Level IV evidence).

REFERENCES

1. Provencher MT, Ghodadra N, LeClere L, et al: Technical note: Anatomic osteochondral glenoid reconstruction for recurrent glenohumeral instability with glenoid deficiency using a distal tibia allograft. Arthroscopy. *J Arthrosc Rel Surg* 25:446–452, 2009.
2. Warner JJ, Gill TJ, O'Hollerhan JD, et al: Anatomical glenoid reconstruction for recurrent anterior glenohumeral instability with glenoid deficiency using an autogenous tricortical iliac crest bone graft. *Am J Sports Med* 34:205–212, 2006.

Multiple-Choice Questions

QUESTION 1. What is the minimum time for immobilization following this surgical procedure?

A. 0 weeks.
B. 2 weeks.
C. 4 weeks.
D. 8 weeks.

QUESTION 2. What muscle must be protected for 6 weeks if taken down and reattached during this procedure?

A. Supraspinatus.
B. Subscapularis.
C. Long head biceps.
D. Pectoralis minor.

QUESTION 3. How many days per week should the athlete be lifting during a pre-season power phase?

A. 2 days.
B. 3 days.
C. 4 days.
D. No lifting at all.

QUESTION 4. During which weeks should Olympic lifting be reintroduced to the athlete?

A. Weeks 24 to 29.
B. Weeks 31 to 36.
C. Weeks 38 to 44.
D. Weeks 46 to 52.

Answer Key

QUESTION 1. Correct answer: **C**. (see Phase II, weeks 4 to 6)

QUESTION 2. Correct answer: **B** (see Open Shoulder Stabilization: With Bone Grafting, Clinical Pearl)

QUESTION 3. Correct answer: **B** (see weeks 26 to 52)

QUESTION 4. Correct answer: **C** (see weeks 38 to 44)

Chapter 2



Posterior Shoulder Instability

INTRODUCTION

Demetris Delos, MD, Travis G. Maak, MD, and Russell F. Warren, MD

Epidemiology

- Posterior shoulder instability is less frequently encountered than anterior instability, accounting for only 2% to 10% of all instability cases.[1,2]
- Treatment of this condition can be challenging, and a high index of suspicion is often required for an accurate diagnosis.
- The literature is primarily limited to small case series and retrospective studies; however, from this, an epidemiological pattern emerges.

Age

- Most series describing outcomes after surgical treatment for symptomatic posterior instability report a median patient age between 20 and 30 years.[3,4]
- In a recent report that included the largest series of patients with posterior glenohumeral dislocation to date, the median age at time of diagnosis of posterior *dislocation* was 43 years.[5]

Sex

- Males constitute the majority of patients in most operative series of patients with posterior instability (51% to 100%).[1,3]

Sport

- Sports commonly associated with posterior shoulder instability include
  - American football
  - Overhead weight lifting
  - Rowing
  - Racket sports
  - Swimming
  - Golf

Position

- Lineman in American football
- Bench press, overhead press in weight lifting

Pathophysiology

Intrinsic Factors

Intrinsic factors that may contribute to posterior glenohumeral joint (GHJ) instability may be classified as biological or anatomical in nature.

- Biological
  - Collagen disorders such as Ehlers-Danlos syndrome
  - Generalized ligamentous laxity
- Anatomical
  - Glenohumeral bony abnormalities:
    - Glenoid hypoplasia/dysplasia
    - Glenoid retroversion
    - Humeral retroversion
- Activities such as the following place the shoulder in the provocative position
  - Heavy bench pressing
  - Blocking during American football (such as demonstrated by football linemen)
  - The backswing in golf
- Provocative positions include
  - Flexion
  - Adduction
  - Internal rotation (IR)
- Provocative positions increase the risk of posterior instability (both microinstability and frank dislocation).
- These repetitive activities can lead to microtrauma and attenuation of the posterior inferior glenohumeral ligament (PIGHL) and posterior capsulolabral structures over time.[6–8]

- Pathological attenuation of the posterior structures of the shoulder that can manifest in clinically significant instability can be caused by
  - Overhead weight lifting
  - Rowing
  - Racket sports
  - Swimming

In most cases subluxation events may be painless because of capsular redundancy, which may initiate labral breakdown and injury with subsequent pain. However, acute traumatic dislocation events typically produce frank labral tears.

Classic Pathological Findings

- Pain and/or sense of glenohumeral instability with the shoulder placed in the provocative position (flexion, adduction, IR)
- Attenuation of the posterior inferior glenohumeral ligament and posterior capsulolabral structures
- For frank posterior glenohumeral dislocations, patients often demonstrate a prominent coracoid anteriorly and humeral head posteriorly on examination.
- The shoulder is typically maintained in the adducted, internally rotated position.
- This is why posterior dislocations may be missed in that the patient is most comfortable in a traditional sling.
- Shoulder external rotation (ER) and abduction are limited because of mechanical block.

Clinical Presentation

History

- The patient history is a crucial component of diagnosis and management in posterior shoulder instability.
- Complaints of generalized posterior shoulder discomfort, pain, and weakness are commonly associated with this pathology. Nevertheless, patients may also complain of anterior shoulder pain during shoulder adduction.
- Difficulty with or reduced performance during athletic activities may also be described, including poor performance during bench press or push-ups.[9]
- Although these complaints are less common, the patient may also report mechanical symptoms, including
  - Catching
  - Clicking
  - Popping
- Background regarding the inciting event, including
  - History of trauma
  - Position of the shoulder and arm
- Specifics regarding associated external forces should also be elicited.
- Underlying laxity should be evaluated in the absence of trauma, including
  - Patient history of shoulder or other joint instability
  - Family history of instability or other diagnosed collagen disorders
- Any history of prior surgical procedures, including anterior stabilizations, especially those performed on the injured shoulder, should be ascertained and reviewed.
- Although it is frequently difficult to discriminate between purely voluntary and traumatic instability, any history regarding previous instability including chronic voluntary dislocation may be useful in this regard.

Physical Examination

- Aids to supplement the information acquired during the patient history may be focused based on this information.
- In addition to a detailed shoulder examination, previous history suspicious for laxity should prompt a general examination for hypermobility. Use of the Beighton criteria for hyperlaxity is most helpful in this regard.
- Physical exam tests include
  - Approximating the thumb to the volar surface of the forearm
  - Hyperextension of the second metacarpophalangeal (MCP) greater than 90°
  - Hyperextension of the elbow
  - Recurvatum/hyperextension of the knee
  - The ability to lay the palm of the hand flat on the floor with the knees straight
- If at least three of these five test results are positive, then laxity is likely present.
- The sulcus test is an important test that can be used to assess for inferior glenohumeral laxity/instability of the shoulder.
- To perform this test
  - Apply downward traction to the patient's elbow or wrist.
  - Observe the shoulder for dimple (sulcus) lateral or inferior to the acromion.
- If the size of the sulcus does not reduce with ER, a defect in the rotator interval may be present.[10]
- Side-to-side comparisons should always be performed for accurate diagnosis.
- A thorough shoulder examination should begin with observation.
  - Contour should first be inspected.
  - Any prior incisions should be thoroughly reviewed.
- Muscle atrophy is not typically present except in chronic cases of rotator cuff tear or nerve palsy.
- Tenderness to palpation may be elicited along the posterior GHJ line.
- Evaluate
  - Range of motion (ROM; both active and passive)
  - Motor strength
- Compare with the contralateral side.
- Useful provocative tests for suspected posterior instability include
  - The posterior stress test
  - The jerk test
  - The load and shift
  - The modified load and shift
  - The Kim test (Figure 2-1)[11]



FIGURE 2-1. The load and shift test should be performed with the patient in a supine position to stabilize the scapula. The arm should then be placed in the plane of the scapula with an axial load placed on the elbow while the humerus is shifted on the glenoid as demonstrated here.

- The current authors suggest performing these provocative tests with the patient in the supine position to stabilize the scapula and isolate the GHJ.
- The posterior stress test is performed with the examiner applying a posterior force to the humerus with the arm flexed and internally rotated in an attempt to subluxate or dislocate the joint.
- The jerk test is performed with the patient seated or standing; the shoulder is flexed to 90° and internally rotated. With the elbow flexed the examiner applies a load posteriorly—the test result is positive if a sudden "jerk" occurs when the subluxated humeral head relocates into the glenoid fossa.
- The load and shift (patient seated) and modified load and shift (patient supine) are also useful to gauge the degree of posterior humeral head translation across the glenoid.
- Finally, the Kim test was recently described and has been shown, in conjunction with the jerk test, to have sensitivity for detecting posterior instability as high as 97%.[12] To perform the Kim test, the examiner should abduct the affected arm 90°, forward flex 45°, and then apply a posteroinferior load to the humerus. The exam is positive if pain is elicited with this maneuver.

Any prior history of cervical pathology or neuropathic symptoms should prompt a more focused examination of dermatomal sensation and motor strength.

Imaging

- Plain radiographs should be obtained in all patients, such as
  - An anteroposterior view of the GHJ (Grashey view)[13]
  - Scapular-Y view
  - Axillary view
- Specific views including the West Point or Stryker-Notch views may be included if clinical concern exists for a glenoid rim or a reverse Hill-Sachs lesions, respectively.
- These images should be critically evaluated for
  - Evidence of posterior glenoid rim fractures (reverse bony Bankart lesions)
  - Anterior humeral head impaction fractures (reverse Hill-Sachs lesions)
  - Bennett lesions
  - Early osteoarthrosis
  - Increased humeral or glenoid retroversion
  - Dynamic radiographs may also be indicated in patients with voluntary instability.[10]
- A computed tomography (CT) scan may be used to more clearly delineate the osseous morphology and identify previously unrecognized humeral and glenoid fractures (Figure 2-2).
- Calculation of the glenoid and humeral version and the degree of glenoid bone loss can be performed on axial cross-sectional images at the level of the mid-glenoid.[14]

Some authors have also used CT arthrography to evaluate the posterior and superior labrum and the capsule.[15] However, the intracapsular injection that is required to perform CT arthrography may artificially distend the glenohumeral capsule and hinder identification of a patulous capsule. Although the current authors routinely used CT to evaluate the glenohumeral osseous morphology, magnetic resonance imaging (MRI) with cartilage sensitive sequences is preferred for evaluation of soft tissue structures.

- MRI and MR arthrography (MRA) is used to evaluate the associated soft tissues, including
  - Labrum and capsule
  - Rotator cuff
  - Biceps complex
  - Rotator interval
- Care should be placed on complete evaluation of the images, including humeral-based injuries such as a posterior humeral avulsion of the glenohumeral ligament (PHAGL), especially when no glenoid-based pathology is identified (Figure 2-3).

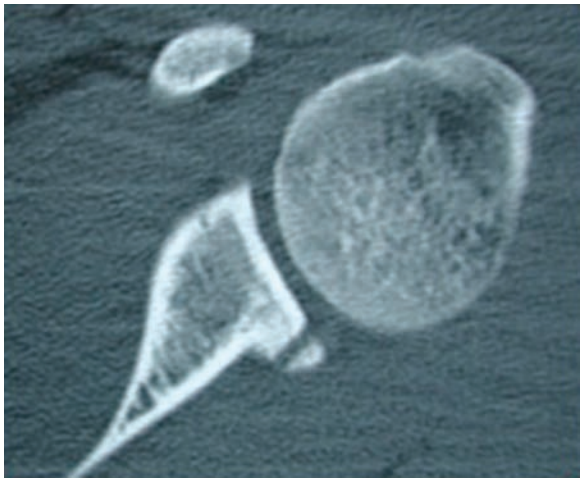


FIGURE 2-2. Axial CT image demonstrating a reverse bony Bankart injury. Care should be placed on complete evaluation of these injuries to ensure adequate preservation of bone stock before surgical stabilization.

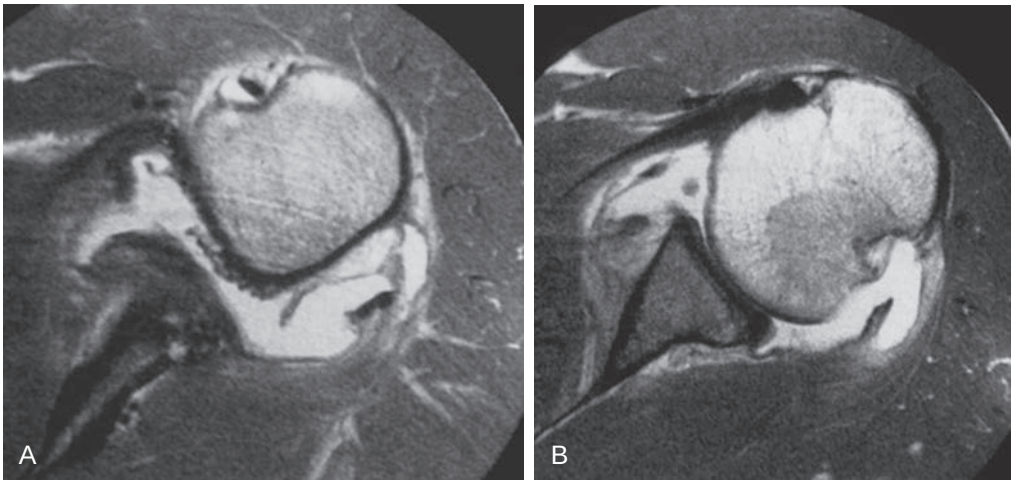


FIGURE 2-3. Axial MRI images demonstrating a posterior humeral avulsion of the glenohumeral ligament. **A,** Periosteum and subchondral bone can be seen attached to the capsule and (**B**) the donor defect in the humerus can be visualized.

- The presence and extent of posterior labral injury should also be identified, including extension of injury to the anterior labrum. In this regard, Kim et al.[16] have suggested a classification scheme for posterior labral tears. Preoperative identification of all associated pathology will facilitate planning and optimize postoperative outcomes.

Differential Diagnosis

- As previously described, posterior glenohumeral instability presents with
  - Complaints of posterior shoulder pain
  - Sensation of instability with the arm in the following position
    - Forward flexed
    - Adducted
    - Internally rotated
- Pain in this position may mimic pathology with the acromioclavicular joint or superior labrum, including a SLAP lesion.
- Nevertheless, this complete constellation of symptoms may not exist, but rather, the patient may demonstrate only a subset of signs and symptoms.
- In this vein, the differential diagnosis and fundamental differences among these diagnoses should be considered.

The following pathologies must be included in the differential diagnosis of posterior shoulder pain in addition to traumatic or atraumatic posterior glenohumeral instability:

- Posterior osteoarthritis
- Tear of the superior labrum from anterior to posterior (SLAP)
- Subluxating tendon of the long head of the biceps
- Acromioclavicular pathology
- Rotator cuff tear
- Proximal humerus fracture
- Scapular fracture
- Cervical radiculopathy
- Oncological lesions

The vast majority of these etiologies may be eliminated with a

- Careful history
- Physical examination
- Plain radiographic imaging

Nevertheless, more subtle differentials exist such as posterior instability with concomitant radiculopathy. In these circumstances, both diagnoses should be completely evaluated, including

- Imaging
- Electromyography
- Nerve conduction studies, if applicable, such that management and patient outcome can be optimized

Additionally, differentiating between multidirectional instability (MDI) and atraumatic unidirectional instability with mild generalized laxity can be difficult. In this circumstance, the data obtained during the aforementioned history and physical examination can significantly aid the surgical or nonsurgical options, which are detailed in the following.

- Adding to the diagnostic difficulty of posterior instability is the fact that the patient may present with anterior shoulder pain, particularly with shoulder adduction and have no sensation of posterior pain.
- Finally, concomitant or previously unappreciated pathology may be identified at the time of the arthroscopic or open surgery and may confirm or alter the preoperative plan. For this reason, the current authors perform a diagnostic arthroscopy before any posterior stabilization procedure to augment the preoperative plan and ensure that all contributing pathology is appropriately addressed.

Treatment

- In general, an initial course of nonoperative management including the following should be attempted before surgical intervention.[6,17]
  - Physical therapy
  - Rehabilitation for posterior glenohumeral instability

Strengthening dynamic muscular stabilizers allow patients to compensate for damaged or deficient static stabilizers, resulting in improved stability and pain control in a majority of those with posterior subluxation.[6,17]

- This approach is successful in 65% to 80% of atraumatic patients with MDI.[17,18]
- However, prior data have demonstrated that this nonoperative approach is less successful in patients with a history of trauma, with 70% to 89% success rate in atraumatic patients compared with 16% success in patients with a traumatic history.[17]
- Patients with a specific identified injury or posterior labral tear can also have documented recurrent instability following nonoperative management.[19]

Nonoperative Management

Nonoperative management represents the mainstay for primary treatment of posterior shoulder instability.[6,17]
Physical therapy, including

- Improving scapular stability
- Strengthening the dynamic stabilizers surrounding the GHJ will facilitate postoperative recovery and may obviate the need for surgical management in some cases. Physical therapy and rehabilitation has been particularly effective in patients with atraumatic posterior instability and MDI.
- Prior studies have documented success rates between 65% and 80% in patients with MDI and up to 89% in those with atraumatic, unidirectional posterior instability.[17,18,20]
- Nonoperative management of patients with traumatic, unidirectional posterior instability, however, has demonstrated success in only 16% of cases.[20]
- High recurrence rates following nonoperative management have also been documented in patients with a specific identified injury or radiographic evidence of a posterior labral tear.[19]

These data are in accordance with the current authors' clinical experience; thus, the suggested nonoperative treatment algorithm is similar. Nonoperative treatment is suggested as the first management modality in patients with an atraumatic instability etiology or with clinical evidence of MDI. Athletes competing in contact sports, however, typically exist in the traumatic, unidirectional posterior instability category; thus, early operative management is often recommended for this population.

Surgical Indications

The principal indication for open or arthroscopic surgical management of posterior glenohumeral instability is pain or perceived instability that is refractory to nonoperative measures.

- Although the main etiology of both symptoms is underlying glenohumeral instability, pain represents the most common presenting symptom.
- Optimal surgical outcomes have been associated with patients who have posttraumatic, unidirectional recurrent instability.
- Nevertheless, these patients represent a subset of patients with posterior glenohumeral instability, which also includes MDI, voluntary instability, and atraumatic posterior instability, among others.
- Surgical management may include either arthroscopic or open approaches, and both approaches may be combined in some situations depending on the identified pathology.
- Open surgical stabilization has been previously recognized as the gold standard for recurrent posterior instability with excellent outcomes[21–23]; however, recent advancements in arthroscopic techniques and instrumentation have resulted in many surgeons using this approach as the primary treatment method.
- It is the current authors' opinion that at this time posterior instability can be more effectively managed with an arthroscopic approach.
- Open surgical stabilization, on the other hand, may be indicated in cases including
  - Contact athletes
  - Revision stabilization
  - Significant generalized laxity or poor tissue quality
  - Excessive capsular insufficiency
  - Bony deficiency
  - Glenohumeral retroversion
- Open posterior stabilization has many advantages over an arthroscopic approach, including a complete visualization of the posterior capsule, which provides the opportunity for the treating surgeon to address labral pathology as well as perform a full posterior capsular shift.
- In addition, bone loss that is identified at the time of surgery can be addressed with a variety of osseous procedures in combination with the posterior capsular shift.
- Pollack et al.[24] suggested the capsular shift as the workhorse procedure for addressing posterior glenohumeral instability, with good to excellent results in up to 80% to 90% of patients.[6]
- These authors also noted that concomitant procedures should be used when necessary to address all apparent pathology.
- They suggested using bone block augmentation only in the setting of revision surgery with bony deficiency or glenoid hypoplasia.[24]
- This suggestion is based on the higher incidence of recurrent instability following posterior stabilization in patients with
  - Large posterior bony Bankart lesions
  - Glenoid hypoplasia
  - Significant humeral or glenoid retroversion
- Increased failure because of recurrent instability has also been identified in contact athletes and patients with significant capsular laxity or engaging reverse Hill-Sachs lesions.[24]
- Notably, although open surgical stabilization has been suggested in these patient populations, recent data have demonstrated improved outcomes following arthroscopic posterior stabilization in contact athletes.[25]
- Contraindications to surgery include voluntary instability with a psychogenic etiology and poor patient compliance.

Following appropriate patient indication for surgical stabilization, the surgeon must decide among the various

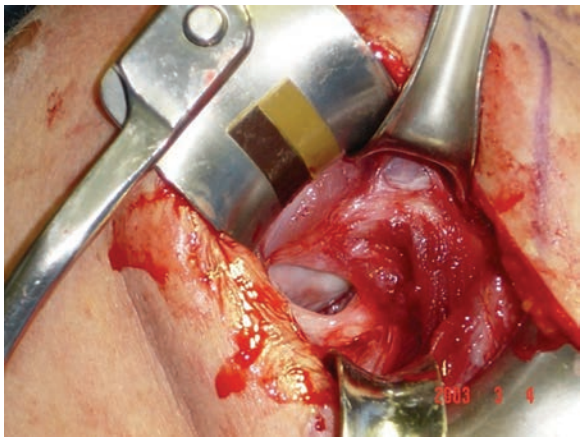


FIGURE 2-4. Open posterior stabilization may be required in the setting of significant capsular deficiency, as seen in this image.

stabilization options. As previously mentioned, the posterior capsular shift is commonly used as the principal stabilization procedure.[3,19,26–28] This capsular shift is performed through an open approach. The arthroscopic capsular plication and posterior labral repair can also be used in a similar fashion to effectively address soft tissue deficiency and laxity (Figure 2-4).[29] Other soft tissue procedures may include

- Posterior biceps tendon transfer[4,16]
- Subscapularis transfer[18,31]
- Posterior capsule reconstruction with the tensor fascia lata[30]
- Posterior Putti-Platt repair[17,22]

If the aforementioned indications for bony procedures are identified pre- or intraoperatively, then the following may be performed for bony deficiency greater than 20%, glenoid retroversion greater than 15°, or humeral retroversion greater than 60°, respectively:

- Bone block augmentation[1,11–13,15,21]
- Glenoid opening wedge osteotomy[30–34]
- A humeral rotational osteotomy[9,24]

Despite the multitude of treatment options, however, the current authors use an arthroscopic posterior capsular plication and labral repair with suture anchor fixation in the vast majority of patients, including contact athletes with recurrent posterior instability (Figure 2-5). Bony procedures are very rarely used and only in revision cases or patients with significant bony deficiency or glenoid retroversion.

Complications

Although surgical management of posterior glenohumeral instability has been associated with excellent patient outcomes, complications also have been reported, including

- Stiffness
- Neurological injury to the suprascapular and axillary nerves
- Early osteoarthritis
- Recurrent instability and subcoracoid impingement

Recurrent instability represents the most common complication, with reported rates up to 23% following open posterior capsular shift, and may require revision surgical stabilization.[21,35] Recurrence may be caused by failed index stabilization or recurrent trauma.[6,22] If revision stabilization is necessary, postoperative outcomes have been improved in posttraumatic patients compared with failure of the index stabilization.[6,22]

- Axillary and suprascapular nerve injury has also been reported, mainly following open posterior stabilization.[36,37] Fortunately, these injuries are rare and have been associated with
  - Excessive dissection
  - Retraction
  - Suture entrapment

Stiffness has been reported in up to 36% of patients with reduced ROM in IR and abduction.[3,13,33] Fortunately, the majority of these patients do not require intervention, except for athletes, who require increased ROM, including overhead-throwing athletes such as football quarterbacks. In this circumstance, stiffness may impede return to play, and intervention may be required, including

- Manipulation under anesthesia
- A capsular release at 6 months postoperatively

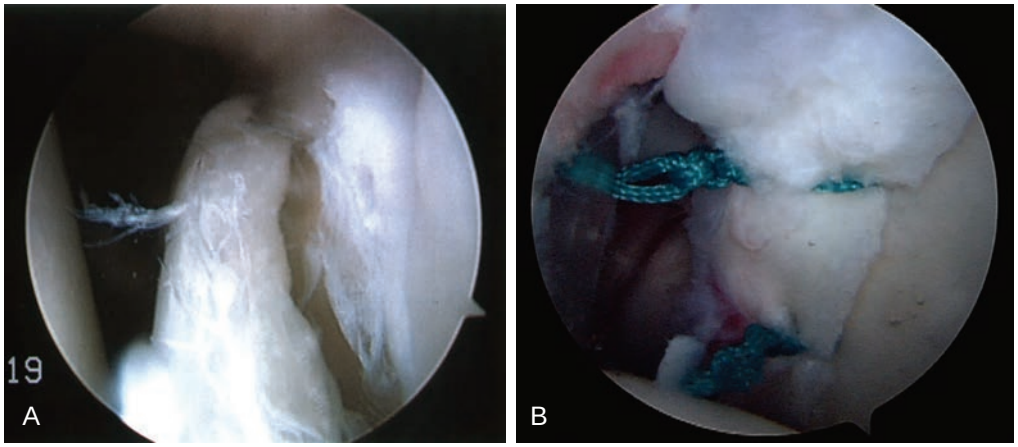


FIGURE 2-5. Arthroscopic posterior stabilization represents the current authors' preferred treatment method for posterior shoulder instability. **A,** The posterior labral tear can be easily visualized from the anterior portal and (**B**) repaired with suture anchor glenoid fixation.

Care should be taken, however, to perform a minimal release and not produce recurrent instability.

- Stiffness owing to overtightening during the posterior capsular shift or plication may not only produce decreased IR and abduction but may also lead to
  - Increased GHJ reaction forces
  - Altered mechanics
  - Scapular winging
  - Arthropathy
- Previous data have hypothesized that postcapsulorrhaphy arthropathy may be caused by increased shear forces that are concentrated at the posterior glenoid rim. These forces may lead to
  - Chondral injury
  - Early glenohumeral osteoarthritis[38]
- On the other hand, post-stabilization osteoarthritis has also been associated with iatrogenic etiologies, including
  - Bone block humeral head impingement
  - Prominent intraarticular hardware
  - Glenoid fracture

Evidence

Bigliani LU, Pollock RG, McIlveen SJ, et al: Shift of the posteroinferior aspect of the capsule for recurrent posterior glenohumeral instability. *J Bone Joint Surg Am* 77:1011–1020, 1995.

This study used open posterior capsulorrhaphy to manage patients with posterior shoulder instability and reduced the preoperative instability in 83% of patients. Subjective 5-year follow-up good to excellent results were obtained in 80% of shoulders and 71% of these patients returned to full activity. An 11% recurrence rate was documented and revision outcomes were noted to be worse than primary stabilization procedures. (Level IV evidence)

Fuchs B, Jost B, Gerber C: Posterior-inferior capsular shift for the treatment of recurrent, voluntary posterior subluxation of the shoulder. *J Bone Joint Surg Am* 82:16–25, 2000.

A unique subset of patients with recurrent, voluntary posterior shoulder instability was treated with open posterior capsulorrhaphy. Good to excellent results were reported in 93% of these patients, although a recurrent instability rate of 23% was documented. (Level IV evidence)

Kim SH, Park JS, Jeong WK, et al: The Kim test: A novel test for posteroinferior labral lesion of the shoulder—a comparison to the jerk test. *Am J Sports Med* 33:1188–1192, 2005.

A prospective cohort study of 172 painful shoulders was conducted, of which 33 had a positive Kim test result demonstrating a posteroinferior labral lesion. Twenty-four of these patients had radiographic evidence of a posteroinferior labral lesion. Among the remaining 133 shoulders with a negative Kim test, only six had radiographic evidence of a posteroinferior labral tear. Sensitivity of the Kim test was 80%, and specificity of the test was 94%.

Provencher MT, Bell SJ, Menzel KA, et al: Arthroscopic treatment of posterior shoulder instability: Results in 33 patients. *Am J Sports Med* 33:1463–1471, 2005.

Thirty-three consecutive patients with posterior instability caused by traumatic and atraumatic etiologies were treated with arthroscopic posterior stabilization with suture anchor technique. Seven failures were reported because of recurrent instability or pain. Significant improvements were noted in multiple outcome measures; however, worse outcomes occurred with patients with voluntary instability or prior shoulder surgery. (Level IV evidence)

Wolf BR, Strickland S, Williams RJ, et al: Open posterior stabilization for recurrent posterior glenohumeral instability. *J Shoulder Elbow Surg* 157–164, 2005.

Open posterior capsulorrhaphy was used to successfully treat 84% of patients with posterior shoulder instability and produce a 74% rate of return to play at the baseline level. Additionally, only 19% of patients experienced postoperative instability symptoms, and no evidence of radiographic arthrosis was identified. (Level IV evidence)

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Multiple Choice Questions

QUESTION 1. Posterior glenohumeral joint instability accounts for what percent of all shoulder instability cases?

A. 90%
B. 60%
C. 30%
D. 10%

QUESTION 2. Patients with posterior glenohumeral instability often report symptoms when the shoulder is placed in

A. extension, adduction, and external rotation.
B. extension abduction, and internal rotation.
C. flexion, adduction, and external rotation.
D. flexion, adduction, and internal rotation.

QUESTION 3. Intrinsic causes of posterior glenohumeral instability include

A. glenoid hypoplasia.
B. collagen disorder (e.g., Ehlers-Danlos).
C. humeral retroversion.
D. all of the above.

QUESTION 4. What is the most common complication after surgical management of posterior shoulder instability?

A. Axillary nerve palsy
B. Axillary artery laceration
C. Recurrent instability
D. Intraoperative fracture

QUESTION 5. All of the following provocative tests can be used to help diagnose posterior instability except:

A. Jerk test
B. Kim test
C. Martin test
D. Load and shift

Answer Key

QUESTION 1. Correct answer: **D** (see Epidemiology)

QUESTION 2. Correct answer: **D** (see Pathophysiology)

QUESTION 3. Correct answer: **D** (see Pathophysiology)

QUESTION 4. Correct answer: **C** (see Treatment)

QUESTION 5. Correct answer: **C** (see Clinical Presentation)

POSTOPERATIVE REHABILITATION AFTER OPEN OR ARTHROSCOPIC POSTERIOR SHOULDER STABILIZATION

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Michael D. Rosenthal, PT, DSc, SCS, ECS, ATC, CSCS, CAPT, and
Matthew T. Provencher, MD, MC, USN

Indications for Surgical Treatment

- Failure of nonoperative treatment
- Persistent activity-related pain and/or pain with instability with desire to continue in these sports/activities
- Optimized nonoperative care, especially optimization of the scapular stabilizers, pectoralis minor stretching, and subscapularis strengthening
- In the nonathletic population, conservative treatment is recommended for a minimum of 3 to 6 months and would discern their level of symptoms and activities in which they are limited before deciding on surgery.
- Surgery may be recommended earlier in an athlete.

Brief Summary of Surgical Management

Major Surgical Steps

- General anesthesia and shoulder arthroscopy
- Patient in lateral decubitus position
- Diagnostic arthroscopy to document all pathology
- Keep scope posterior and start preparation of the posterior labrum
- Preparation of the glenoid labrum at the labrum–bone junction for adequate healing after repair (Figures 2-6 and 2-7).
- Arthroscopic capsulolabral repair with suture anchors (usually 2.4 to 3.0 mm in diameter) and repair of the capsule and labral structures (Figures 2-8 and 2-9).
- Reduction of glenohumeral joint (GHJ) volume, especially in the posteroinferior quadrant (noting that posterior instability most commonly occurs at the 7 o'clock position), with capsular imbrication and repair with sutures.
- Padded abduction sling postoperatively for a total of 5 to 6 weeks. Consider use of an external rotation (ER) sling to reduce strain on repaired posterior capsular structures.

Factors That May Affect Rehabilitation

Anesthetic

- For regional anesthesia: the block may wear off 8 to 24 hours after the case. Be cognizant of rebound pain and use subsequent modalities.
- *Surgical*
- Amount of capsulolabral repair:
  - Posterior only (centered at 7 o'clock): 90° posterior quadrant repair versus more extensive repair
  - Posterior with some anterior augmentation (if tear extends anteriorly): will need to work on anterior capsule and note that an anterior repair was done for rehabilitation considerations. It is key to understand that the pathology of posterior instability is at 7 o'clock as the shoulder subluxes posteroinferiorly out of the joint.

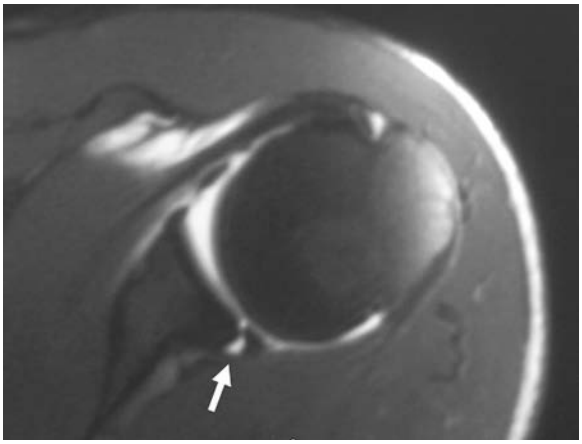

FIGURE 2-6. Magnetic resonance arthrogram of a posterior labral tear.

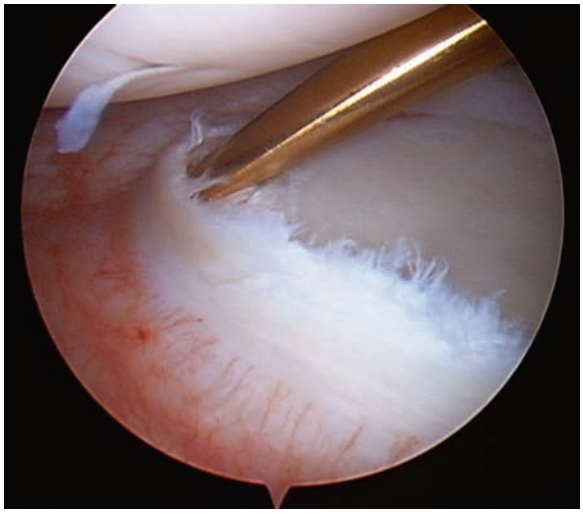

FIGURE 2-7. Posterior labral tear. Preparing the tear for surgical repair with an elevator device.

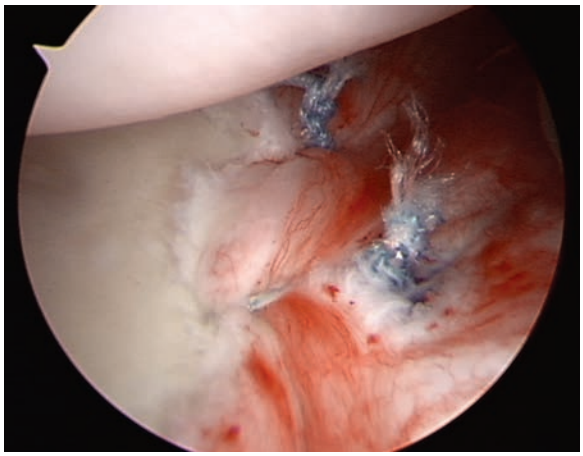

FIGURE 2-8. Posterior labral repair.

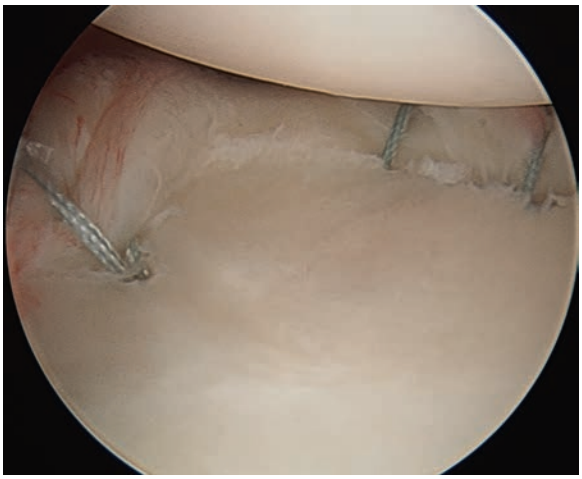

FIGURE 2-9. If the tear extends anteriorly, this is repaired posteriorly and then extended anteriorly for a balanced inferior 180° repair of the glenoid labrum.

- Additional repair construct (e.g., rotator interval closure): may lead to a tighter shoulder with ER at the side (Figure 2-10).
- If case is performed open, the posterior rotator cuff (infraspinatus and teres minor) will need to be protected for 6 weeks.

Before Surgery: Overview of Goals, Important Milestones, and Guidelines

Steps to Minimize Debilitation and Atrophy

Clinical Pearl

Pursuit of normal motor patterns, correction of scapular dyskinesis, and restoration of glenohumeral and scapulohumeral arthrokinematics preoperatively will aid in postoperative recovery. Thorough movement-pattern evaluation is a key component to preoperative posterior instability rehabilitation. Recognition of faulty motor patterns associated with pain complaints will assist the therapist in developing a treatment program that will effectively and efficiently address movement pattern dysfunctions.

Supervised Exercises

- Open and closed chain scapular stability: Scapular clocks with and without manual resistance, scapular depression (manual, resisted with tubing, Graviton).
- Rotator cuff isokinetic/progressive resistive exercises (PREs): tubing, Thera-Band, cable column IR/ER at 0, 45°, and 90° of abduction
- Serratus anterior exercises: wall slides (Figure 2-11) with and without resistance, supine punch (Figure 2-12), standing cable/band punch. (Care should be taken to avoid posterior-directed forces during traditional serratus anterior strengthening exercises such as plank-plus and pushup-plus.)
- Scapular stability: prone Y, T, W, I (Figure 2-13), closed chain Swiss ball movement patterns, standing shoulder flexion/scaption (open can position with scapular setting)
- PNF patterns and rhythmic stabilization

Modalities During Treatment

- Transcutaneous electrical nerve stimulation (TENS) to control pain as well as inhibit muscular guarding when performing both passive (PROM) and active (AROM) ROM exercises
- Interferential current (IFC) electrical stimulation to assist with pain and inflammation following treatment sessions

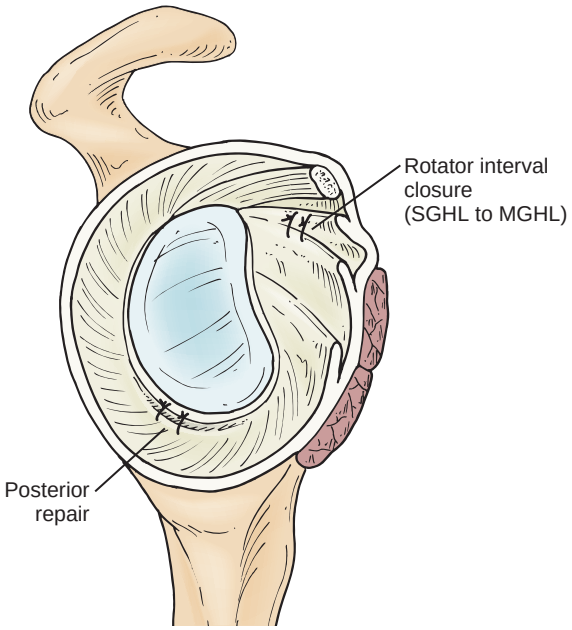

FIGURE 2-10. Typical arthroscopic rotator interval closure: Two sutures are placed to arthroscopically imbricate the superior to middle glenohumeral ligaments after the posterior instability repair is completed.

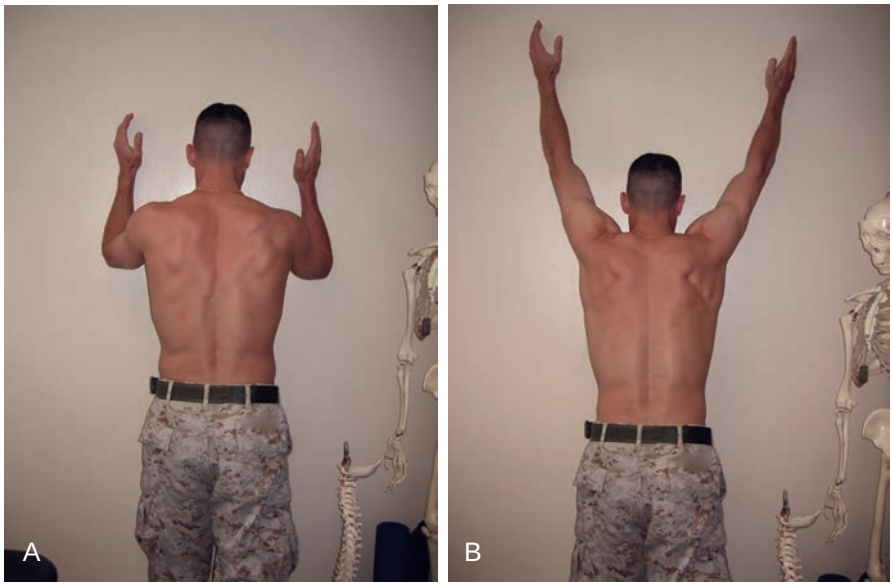

FIGURE 2-11. A,B, Wall slides.

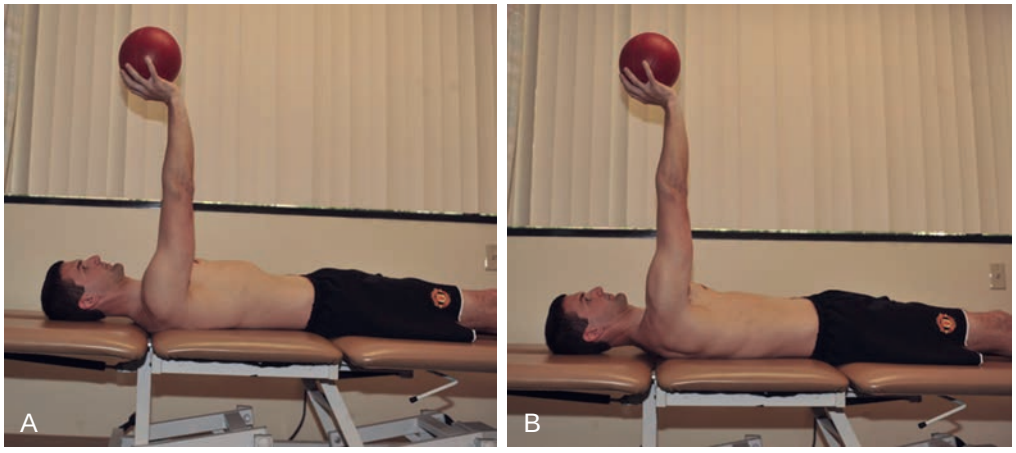

FIGURE 2-12. A,B, Supine punch.

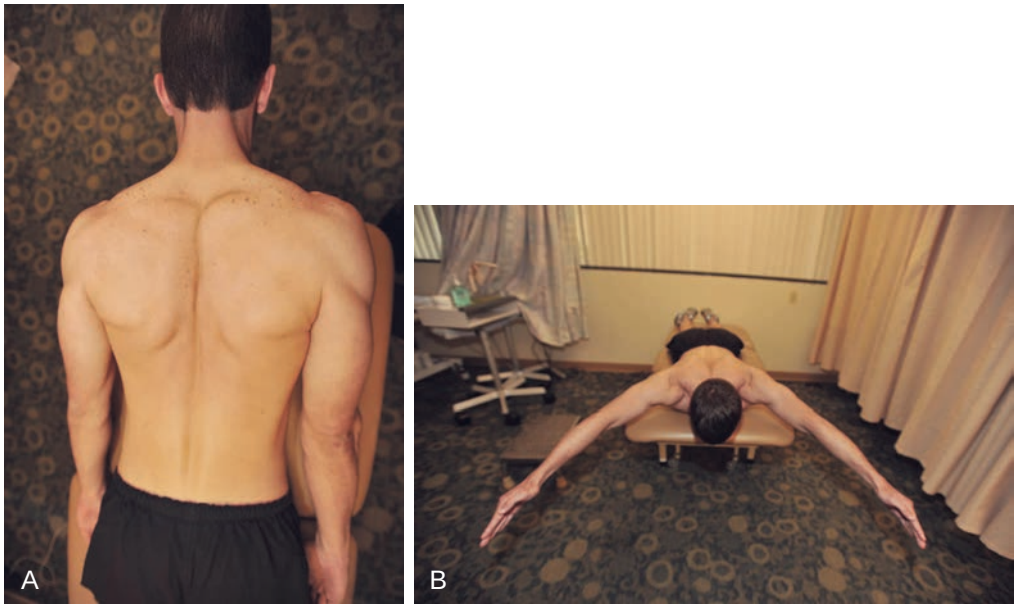

FIGURE 2-13. A,B, Prone Y, T, W, I.

- Thermal agents and/or cryotherapy for muscle guarding and inflammation[1]
- Neuromuscular electrical stimulation (NMES) in patients with a concomitant nerve injury such as suprascapular nerve neurapraxia

Steps to Relieve Disability of Acute Injury

Exercise

- Joint protection following an acute traumatic subluxation or posterior dislocation via sling for comfort
- Supported Codman's pendulum exercises for passive and active assisted ROM with the modification of elbow support of the contralateral side (Figure 2-14)
- Rest, ice, compression, and elevation (RICE) for 7 to 10 days
- Gradual return to AROM activities: pulleys, wands, wall walks, table slides
- Progressive strengthening and motor control per preceding recommendations
- Continuation of cardiovascular activities
- Pain should be respected and thereby serve as an indication of safe progression during this phase.

Modalities

- IFC electrical stimulation for pain and inflammation
- Cryotherapy for pain and spasm reduction

Steps to Relieve Disability of Chronic Injury

Exercise

- Avoid instability and pain-producing activities. Educate the patient about positions and activities likely to create episodes of instability, such as cross-chest horizontal adduction and posterior axial loading with the arm elevated greater than 90°.
- Posterior rotator cuff (infraspinatus/teres minor) exercises are essential, as is eccentric control of the subscapularis.
- Emphasis on scapulohumeral rhythm

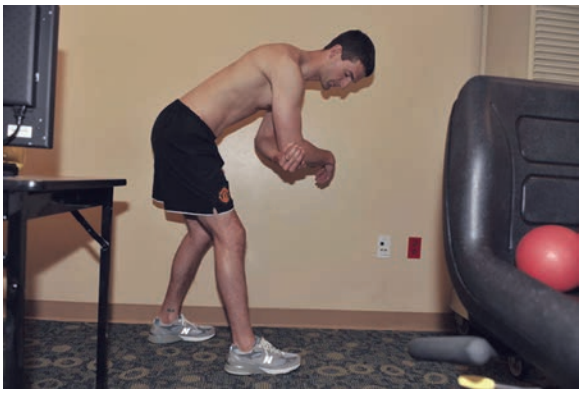

FIGURE 2-14. Supported Codman's pendulum exercises.

- Concomitant injuries of the rotator cuff must be recognized and accurately diagnosed to avoid undue stresses on other injured tissues during rehabilitation of chronic injuries
- See the preceding for supervised and home exercises for rehabilitation recommendations.

Modalities

- IFC electrical stimulation and/or TENS to reduce pain
- Biofeedback and NMES to assist in restoring motor control
- Thermal agents and cryotherapy to reduce spasm, pain, and inflammation

Phase I (days 0 to 14 postop)

Protection

- Postoperative immobilization is achieved via sling use with the arm in slight abduction and neutral rotation.
- A sling with an abduction pillow is preferred because of patient comfort and proper positioning to prevent stress to the healing posterior structures.
- Sling is to be used at all times, including sleep.

TIMELINE 2-1: **Postoperative Rehabilitation After Open or Arthroscopic Posterior Shoulder Stabilization**

PHASE I (weeks 0 to 2)	PHASE II (weeks 2 to 6)	PHASE III (weeks 6 to 10)
• Sling • PT modalities • ROM: scapular plane elevation to 90° • Active assistive Codman's exercises • TBS/TAS/TLS activities as recommended and tolerated	• Sling d/c at 4–5 weeks • PT modalities • ROM wk 4: scapular plane elevation to 120° • ROM wk 6: scapular plane elevation to 160° • ROM wk 4: start flexion to 90° • ROM wk 6: ER to 30° • ROM wk 6: IR to 0° • TBS/TAS/TLS activities as recommended and tolerated • Scapular exercises • Week 4: AROM exercises • Week 4: submax isometrics for GHJ muscles • Week 6: submax isometrics for ER	• PT modalities as needed • PROM: full • Mobilizations as needed • TBS/TAS/TLS activities as recommended and tolerated • Scapular exercises: PREs • TAS: biceps/triceps PREs • GHJ exercises: PREs • Rotator cuff exercises: PREs • Limit IR exercises to minimize strain to posterior capsule • PNF exercises • OKC rhythmic stabilization exercises • CKC exercises • Week 10: seated pressups and increased weight-bearing through joint • CKC manual perturbation exercises

Management of Pain and Swelling

- Regional anesthetic block or a regional pain pump (not intraarticular)
- Oral pain medications
- Therapeutic modalities for pain and inflammation to include TENS, Hi-Volt, and IFC electrical stimulation
- TENS to control pain as well as inhibit muscular guarding when performing PROM
- Continuous cryotherapy for pain and inflammation reduction[2]
- Patient education: using pillows or bolsters to find a "position of comfort" to reduce stress on contractile structures of the shoulder as well as repaired structures

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- ROM precautions: IR 0°, humeral elevation in scapular plane 90° (precautions adjusted for other concurrent surgical repairs such as SLAP or Bankart repairs)
- PROM: manual range of humerus (per precautions) as well as affected elbow, wrist, and scapula. Muscular guarding should be considered and manual therapy adjusted as necessary to facilitate relaxation to avoid undue stresses on the posterior capsulolabral complex.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Shoulder stretching is not to be performed during this stage with the exception of the cervical musculature (i.e., levator scapula, upper trapezius) as needed.

Other Therapeutic Exercises

- Athletes are encouraged to participate in low-intensity cardiovascular conditioning activities such as stationary biking or treadmill walking. The sling must be worn during these activities, and if there is increased pain or muscle guarding, the activity should be adjusted.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Hand gripping and active wrist flexion-extension ROM activities initiated
- Codman's pendulum exercises to maintain passive motion at the GHJ. Because of improper technique, which is often observed clinically, the authors recommend the use of assisted Codman's with sound-side support of the affected arm (see Figure 2-14).

Milestones for Progression to the Next Phase

Goals of the immediate postoperative phase:
- Protect the repaired structures.
- Minimize the effects of immobilization.
- Decrease pain and inflammation.

Assuming the athlete is progressing without complications (signs of infection, frank signs and symptoms of instability or repair failure, or intractable pain limiting ROM tolerance), progression to the next phase is allowed.

Phase II (weeks 2 to 6 postop)

Protection

- Use of the sling is continued. If arthroscopic labral repair was performed without involvement of the rotator cuff musculature or biceps tendon, the sling may be discontinued at 4 to 5 weeks postoperatively depending on surgeon preference and patient compliance with ROM restrictions.

TIMELINE 2-1: **Postoperative Rehabilitation After Open or Arthroscopic Posterior Shoulder Stabilization** (Continued)

PHASE IV (weeks 10 to 14)	PHASE V (weeks 14 to 24)	PHASE VI (weeks 24 to 52)
• PT modalities as needed • PROM: full • Mobilizations as needed • Week 12: IR sleeper stretch • TBS/TAS/TLS activities as recommended and tolerated • Scapular exercises: PREs • TAS: biceps/triceps PREs • GHJ exercises: PREs • Rotator cuff exercises: PREs • Thrower's 10 • Limit IR exercises to minimize strain to posterior capsule • PNF exercises • OKC rhythmic stabilization exercises • CKC exercises • CKC manual perturbation exercises	• PROM: maintain full motion • Mobilizations as needed • TBS/TAS/TLS activities as recommended and tolerated • Scapular exercises: PREs • TAS: biceps/triceps PREs • GHJ exercises: PREs • Rotator cuff exercises: PREs • Thrower's 10 progress intensity • PNF exercises • OKC rhythmic stabilization exercises • CKC exercises • CKC manual perturbation exercises • Plyometrics: two-arm progressing to one-arm • Overhead strengthening exercises • Sport-specific exercises begin • Overhead throwing athletes can begin an easy interval throwing program • 20 weeks: begin full-windup throwing	• PROM: maintain full motion • Mobilizations as needed • TBS/TAS/TLS activities as recommended and tolerated • Scapular exercises: PREs • TAS: biceps/triceps PREs • GHJ exercises: PREs • Rotator cuff exercises: PREs • IR/ER exercises at 90° • Thrower's 10 progress intensity • PNF exercises • OKC rhythmic stabilization exercises • CKC exercises • CKC manual perturbation exercises • Plyometrics: two-arm chest passes progressing to 90/90 one-arm plyos • Overhead strengthening exercises • Sport-specific exercises progressed • Overhead throwing athletes progress through an interval throwing program

Table 2-1 Postoperative Range of Motion Guidelines

	Range of Motion					
Postoperative Time	*Scaption*	*Flexion*	*Adduction*	*Abduction*	*ER*	*IR*
0–14 days*	90	30	0	90	60	0
2–4 weeks*	120	90	0	100	30	0
4–6 weeks*	140	120	0	120	45	0
6–10 weeks**	160	160	20	160	90	70
10–14 weeks	***	***	***	***	***	***

*PROM only
**A/AROM no limitations
***Full AROM

Management of Pain and Swelling

- Electrotherapy (TENS and IFC electrical stimulation) is continued for pain and muscle guarding
- Oral pain medications are usually continued
- Continuous cryotherapy with compression
- Hi-Volt electrical stimulation

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- ROM precautions: IR 0°, ER 30°, horizontal adduction 0°, scapular plane elevation to 120° at week 4, scapular plane elevation to 140° at week 6, sagittal plane flexion 90° at week 4, and sagittal plan flexion 120° at week 6 (Table 2-1).
- PROM: manual ROM of the humerus (per preceding precautions) while ensuring quality of glenohumeral and scapulothoracic motion and avoidance of excessive/compensatory scapular mobility to impingement. Scapular elevation, depression, and abduction.
- Grades I and III GHJ mobilizations may improve available PROM and also contribute to pain management.
- Posterior capsular stress should be avoided.

Soft Tissue Techniques

- Scar mobilization to postsurgical incisions once closed

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Patients may begin table slides or physio ball rolling for passive techniques within the ROM precautions.
- AROM: Scapular clocks are continued and scapular dumps (performing thoracic rotation while protracting the scapula) are initiated to emphasize thoracic and lumbar mobility.
- Elbow and wrist ROM is encouraged and can be done as part of the home exercise program.
- Pulleys for AAROM may begin during the fourth postoperative week as long as correct technique is demonstrated. As patients gain PROM to 120° in the scapular plane without guarding or pain, AAROM techniques are begun to include flexion and abduction via wands and wall walks with cues to avoid compensatory shoulder shrugs.
- Careful observation for compensation and emphasis on restoring scapulohumeral mechanics is important while increasing ROM during this phase to avoid subacromial impingement.

Other Therapeutic Exercises

- Submaximal isometrics are begun in neutral rotation and less than 30° abduction with the elbow flexed to 90° for flexion, abduction, ER, and extension.
- Scapular squeezes/pinches without resistance may also be added during this phase.
- Lower extremity exercises during this phase may include use of the stationary cycle, stair climber, elliptical, and machine-based lower extremity strength training equipment.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Unsupported Codman's pendulum exercises are continued.
- AROM may be initiated as to include wall walks and standing shoulder raises (arm flexion and scaption in the open can position).
- Patients are reminded to avoid horizontal adduction or IR until postoperative week 6.
- Well-arm exercises are begun to promote the neuromuscular crossover effect.

Sensorimotor Exercises

- Begin active angular replication exercises, for motor control, in the range of 0° to 90° scaption.

Techniques to Increase Muscle Strength, Power, and Endurance

- Lower body strengthening such as wall sits or bodyweight squats and lunges

Neuromuscular Dynamic Stability Exercises

- Lower extremity balance activities such as single-leg balance, BOSU ball (Figure 2-15), star excursion
- Manual rhythmic stabilization of trunk and core

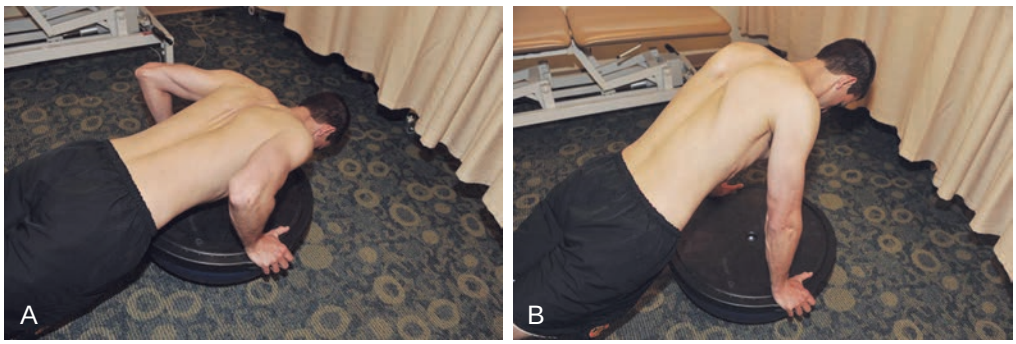

FIGURE 2-15. BOSU ball.

Functional Exercises

- Seated and standing trunk rotation combined with flexion and extension while wearing sling may be performed to maintain thoracolumbar mobility.

Milestones for Progression to the Next Phase

Goals of this phase
- Protect repaired structure.
- Minimize effect of immobilization.
- PROM glenohumeral elevation in scapular plane of 140°, ER 30°
- No marked pain at the posterior GHJ
- No signs or symptoms of instability

Phase III (weeks 6 to 10 postop)

Protection

- Sling use is discontinued.

Management of Pain and Swelling

- Oral analgesic use is continued as needed.
- NSAID therapy may be prescribed for persistent pain.
- IFC electrical stimulation for pain control as needed
- Cryotherapy is used post-therapy to mitigate postexercise inflammation and soreness.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- ROM precautions: IR 70°, ER 90°, horizontal adduction 20°, scapular plane elevation 160°, sagittal plane flexion 160°, abduction 160° (see Table 2-1)
- PROM: techniques continue in the scapular plane. Sagittal flexion and IR/ER at 45° of abduction are introduced while respecting pain complaints.
- Joint mobilizations: If adhesions are noted, capsular joint mobilizations may begin in reduced ranges, such as oscillatory techniques grade I to II for inferior and anterior capsule. Care must be taken when assessing posterior capsular structures. Scapular mobilizations continue, including scapular lifts if necessary.

Clinical Pearl

Gradual introduction of posterior and posterior-inferior capsule stretching using skilled manual therapy techniques beginning at the end of Phase III is important to assist with proper scapulohumeral rhythm and restore the glenohumeral arthrokinematics. Often, patients present with biceps tendinopathy or subacromial impingement caused by faulty movement patterns of which the tight posterior and inferior capsule play large roles because of the obligate translation.[3] Therefore, introduction of joint mobilizations grades II to III to the posterior capsule during this timeframe, as long as there is no pain with these techniques or rebound guarding, will aid in restoration of optimal scapulohumeral rhythm and glenohumeral arthrokinematics.

Soft Tissue Techniques

- Scar mobilization techniques including cross-friction are performed to assist with full tissue mobility around the shoulder region.
- Soft tissue techniques may be applied to the biceps tendon at this time as indicated.

Stretching/Flexibility Techniques for the Musculotendinous Unit

- Pulleys (with caution for correct technique to avoid impingement), table slides, wall walks, and wand exercises

Other Therapeutic Exercises

- Cardiovascular: Treadmill walking and stationary biking with increased resistance. Add upper-body ergometer (UBE) within pain-free ranges without resistance. Performing the UBE standing, if possible, provides an integrated conditioning exercise involving the trunk and hip girdle musculature.
- The potential need for upper-body support and loading during the use of stair climbers and elliptical machine activities restricts safe implementation of these conditioning options until 8 weeks postop.

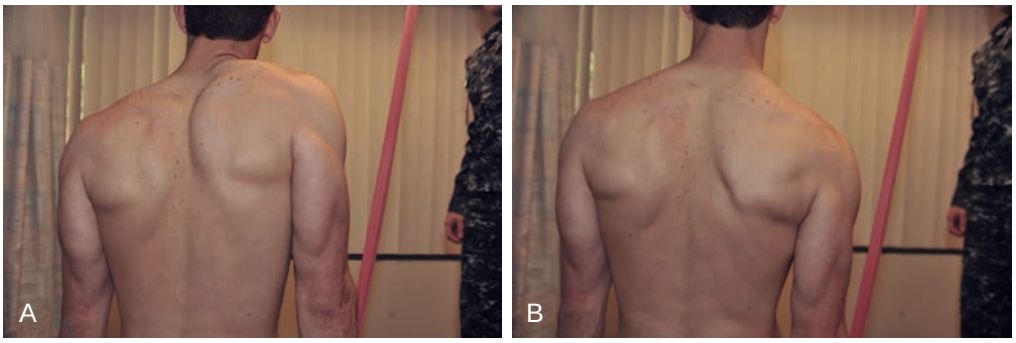

FIGURE 2-16. A,B, Scapular depression using manual cueing with light resistance bands.

- Lower-body strengthening is progressed and may include closed kinetic chain exercises (i.e., lunges, tubing resistance, hip flexion/extension/abduction, wall sits, body weight squats) and open chain resistance exercises.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- The scapulohumeral and scapulothoracic muscles should be the primary focus during this phase. Starting to isolate middle and lower trapezius, rhomboid, serratus anterior as well as the rotator cuff musculature is imperative for successful rehabilitation following posterior stabilization.
- Begin scapular depression using manual cueing as needed with light resistance bands (Figure 2-16)
- Progressive resistance exercises (PREs) for scapulothoracic muscles: Prone W, I, Y, and Ts (see Figure 2-13), prone rows, standing forward, and lateral raises (open can position in scapular plane), supine punches (see Figure 2-12), standing facing wall shoulder flexion (wall slides) (see Figure 2-11), scapular pinches, and bilateral shoulder ER with elbow flexed to 90° at neutral abduction.
- Rotator cuff strengthening: side-lying humeral ER (Figure 2-17), standing IR/ER with light resistance tubing may begin. The humerus should not exceed 30° abduction or IR when performing resisted IR because of excessive stress on the posterior capsule.
- Biceps and triceps strengthening with light resistance may begin.

Sensorimotor Exercises

Clinical Pearl

A strategic component to successful *proprioceptive neuromuscular facilitation* (PNF) is patient education for proper positioning throughout: cueing to stabilize scapula before generating upper extremity motion or accepting resistance. In addition, PNF is used to restore movement patterns common to athletes; this includes tracking the upper extremity movement with the eyes, as well as cervical and trunk rotation. This will also prepare the patient for more functional PNF patterns to be performed with tubing or cable resistance later in the treatment progression. PNF patterns are also performed on the nonaffected arm for crossover effect. Scapular PNF patterns are continued throughout this phase progressing from side lying to seated (Figure 2-18) and standing.

- Rhythmic stabilization and manual strengthening of the upper extremity while the patient is supine, seated, or standing
- Progress manual strengthening to include the serratus anterior, rotator cuff, and scapular muscles (i.e., repeated contractions of serratus anterior in supine, side-lying D1 and D2 patterns of scapula, slow reversals)
- The Bodyblade is an effective tool to incorporate (beginning at 8 weeks postop) at 0° abduction as well as 90° scapular elevation (Figure 2-19).
- Active joint repositioning throughout the available pain-free ranges of motion

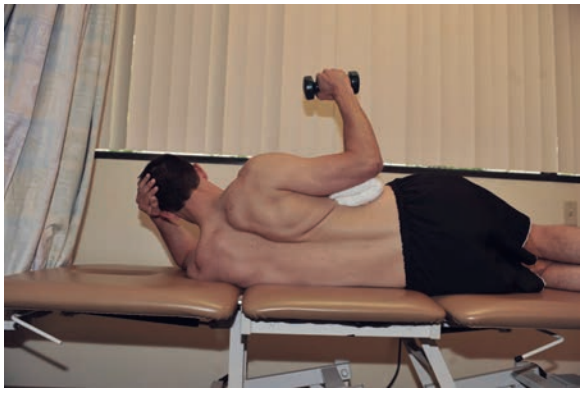

FIGURE 2-17. Side-lying humeral ER.



FIGURE 2-18. Seated proprioceptive neuromuscular facilitation.



FIGURE 2-19. Bodyblade

Open and Closed Kinetic Chain Exercises

- Closed chain proprioception activities: Lightweight medicine ball rotations at 90° scapular plane elevation progressing to 90° forward flexion against a wall and standing upper extremity weight-bearing with weight shifting on a table with the hands at least 1.5 times the bicoronial width to minimize direct posterior shear stresses through the GHJ.
- Beginning at week 10: Seated press ups for the latissimus dorsi as well as increased weight-bearing/loading through the joint is added.
- Pool-based exercises using the water for resistance may be incorporated during this phase if the incisions are well healed. Exercises should include reciprocal motions of IR/ER, flexion/extension, and abduction/adduction.

Techniques to Increase Muscle Strength, Power, and Endurance

- Progress biceps and triceps exercises in standing
- Add light weights to shoulder flexion and scapular plane elevation in the open can position at 8 to 10 weeks postop.
- Progression of lower extremity strength training exercises
- Progress to elliptical and stair stepper for cardiovascular conditioning at week 8.

Neuromuscular Dynamic Stability Exercises

- Progress manual rhythmic stabilization drills for the upper extremity in neutral and advance in varying degrees of abduction (0 to 90°) as ROM allows. Performing these exercises in sitting and standing will increase core recruitment and integrated work with the shoulder complex.

Milestones for Progression to the Next Phase

- AROM 150° scapular plane elevation
- AROM 45° degrees ER at neutral abduction
- AROM IR thumb to L1 reaching behind back
- PROM IR 70° at 90° abduction (In the overhead athlete, IR at 90° abduction is expected to be slightly less in the dominant arm, so full symmetry may not be the goal depending on specific patient demands.)
- Normal glenohumeral and scapulothoracic mechanics

Phase IV (weeks 10 to 14 postop)

Management of Pain and Swelling

- Oral NSAIDs may be continued. If pain continues to be a limiting factor to progression, the patient should return to the surgeon for reassessment.
- IFC electrical stimulation may also be used to assist with pain.
- Cryotherapy is used post-treatment sessions to mitigate muscle soreness or exercise-induced inflammation.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- PROM to full ROM (see Table 2-1)
- Graded GHJ mobilizations progressing to include grades III to IV may be incorporated to ensure full capsular mobility by the end of week 14.

Soft Tissue Techniques

- Assess the need for soft tissue mobilization to the pectoralis major/minor, subscapularis, and latissimus dorsi.



FIGURE 2-20. Sleeper stretch.

- Scar mobilizations are also included to minimize incisional adhesions.
- Monitor for development of biceps tendon and posterior rotator cuff pain and direct soft tissue mobilization to these tissues as indicated

Stretching and Flexibility Techniques for the Musculotendinous Unit

- PROM focusing on gentle end-range stretching
- Latissimus dorsi, pectoralis major/minor stretching
- IR stretching beginning 12 weeks postop via activities such as cross chest stretching and the "sleeper stretch" (Figure 2-20)
- Hot packs may be used prior to stretching and tissue flexibility to facilitate muscle relaxation

Clinical Pearl

Posterior capsule stretching should be closely monitored to ensure stabilization of the scapulothoracic joint. Without stabilization of this joint, stretching may impact the most "willing" tissue, which will equate to an increase in scapular mobility/scapulothoracic muscle stretching more so than the posterior capsule. Maintenance of posterior capsule integrity is paramount; therefore, patient education on restoration of mobility, avoidance of pain, and reporting any feelings of shoulder instability are important.

BOX 2-1 Thrower's 10 Exercises

- Diagonal pattern (D2) flexion
- Diagonal pattern (D2) extension
- Humeral ER at 0° abduction
- Humeral IR at 0° abduction
- Humeral ER at 90° abduction
- Humeral IR at 90° abduction
- Shoulder flexion to 90°
- Shoulder scaption
- Prone horizontal abduction at neutral
- Prone horizontal abduction with full ER at 100°
- Prone row
- Pressups
- Pushups
- Bicep curls/elbow flexion
- Triceps extension/elbow extension
- Wrist extension/wrist flexion
- Wrist supination/wrist pronation

Other Therapeutic Exercises

- The thrower's 10 exercises (Box 2-1) are implemented for strengthening of the shoulder complex.
- Resistance is increased within pain tolerance and the precautions of avoiding forced horizontal adduction and sagittal plane axial loading with the arm past neutral horizontal adduction.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Humeral IR/ER rotator cuff strengthening exercises are progressed to 90° abduction.
- Lat pulldowns in front of head are introduced.
- Bent-over rows with light dumbbell or kettle bell (Figure 2-21)

Sensorimotor Exercises (Proprioception, Kinesthesia)

- GHJ PNF D1 and D2 patterns while seated or standing (see Figure 2-18)

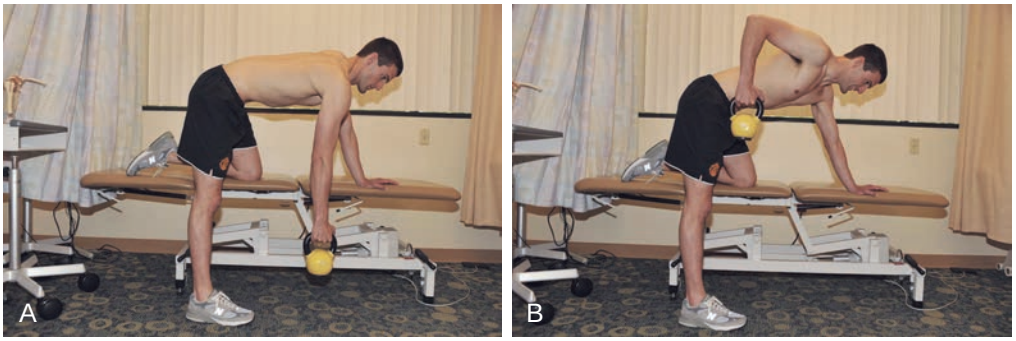

FIGURE 2-21. A,B, Bent-over rows with a light dumbbell or kettle bell.

Open and Closed Kinetic Chain Exercises

- Closed-chain activities progress to include a pushup progression beginning with wall pushups advancing to table height pushups and finally floor pushups.
- Athletes are encouraged to avoid locking out the elbows during this phase to avoid excessive loading of the posterior capsule. Hand width during closed kinetic chain (CKC) exercises should remain slightly wider than the bisacromial distance.

Techniques to Increase Muscle Strength, Power, and Endurance

- Lower extremity single-leg balance activities are progressed.
- Front squats may be introduced initially with medicine ball hugs rather than bar.
- Alternating endurance sets (perform a static hold set with resistance at mid-to-end range) to all upper extremity resistance exercises (hypertrophic load in this phase, 12 to 25 repetition sets)

Neuromuscular Dynamic Stability Exercises

- Rhythmic stabilization is progressed to standing and in positions with decreased base of support, open chain or unstable surface.
- Axial compression drills: closed chain on unstable surface (i.e., Airex pad, weighted ball, tilt boards) (Figure 2-22)
- Manual perturbation to the trunk while in dynamic closed chain loaded position

Plyometrics

- Lower extremity plyometric drills (i.e., multidirectional lunge)
- Upper extremity wall dribble
- Plyoback/rebounder exercises to include chest pass, ER/IR ball toss, and catch

Functional Exercises

- Begin a walk-jog progression at 3 months postoperatively.



FIGURE 2-22. Closed chain on unstable surface.

Sport-Specific Exercises

- Lower extremity sport-specific drills in a controlled environment at 3 months postoperatively (i.e., hopping, jumping, changes in direction/agility drills)

Outcome Measures

- Patient-reported outcome scales should be implemented by the 12-week follow-up and administered at a minimum during the 3-, 6-, 9-, and 12-month follow-up appointments. Scales that have been used in the literature for posterior instability include the Western Ontario Shoulder Instability Index (WOSI); American Shoulder and Elbow Surgeons Rating Scale; Single Assessment Numeric Evaluation (SANE); Subjective Patient Shoulder Evaluation Score; Penn Shoulder Score; Simple Shoulder Test; and Disabilities of the Arm, Shoulder and Hand (DASH) Score.[4,5]

Milestones for Progression to the Next Phase

- Normal scapulohumeral rhyth
- Full PROM all planes
- AROM within functional limits, pain-free flexion and abduction
- Strength manual muscle testing grade IV to V throughout the scapulothoracic and scapulohumeral muscles

Phase V (weeks 14 to 24 postop)

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Continue as in the preceding to achieve full capsular mobility.
- Joint mobilization grade III to IV as indicated

Soft Tissue Techniques

- Scar mobilizations as necessary

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Athletes are instructed in full glenohumeral and scapulothoracic stretching techniques as well as cervical, thoracic, and lumbo-pelvic-hip mobility.

Other Therapeutic Exercises

- Progress thrower's 10 exercises with increased intensity and resistance as tolerated.
- Progress lower extremity, gluteal, and hip strength exercises.

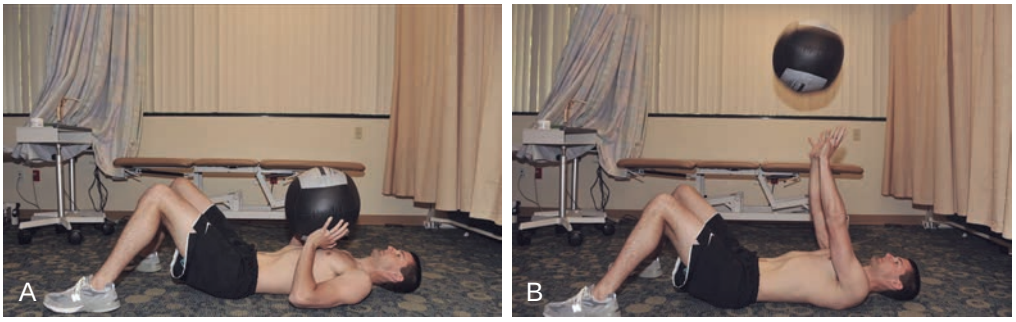

FIGURE 2-23. A,B, Overhead bilateral medicine ball slams and overhead medicine ball catching.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- As before with progressive resistance

Open and Closed Kinetic Chain Exercises

- OKC: upright rows, seated rows, lateral raises, front raises
- OKC: ER/IR at 0° and 90° abduction, isotonic/resistance bands, PNFs, diagonal lift, and wood chop resistance exercises
- OKC: tubing fencing, step and punch, plate push
- OKC: pool resisted motions
- CKC: side planks, front planks and weight shifts on stable and progress to unstable surfaces. Figure-of-8s on a slide board in quadruped or standing with pressure against a wall.
- The BOSU ball can be used for progression of pushups to uneven surfaces for CKC activities (Figure 2-22)
- CKC may also include slide board exercises in quadruped or pushup position.

Techniques to Increase Muscle Strength, Power, and Endurance

- Advance endurance sets to strength exercises (repetitions of 6 to 10 per set)
- Implement an undulating periodization model for strength training

Neuromuscular Dynamic Stability Exercises

- The pushup progression leads to dynamic bilateral upper extremity wall pushups and then to single-arm dynamic pushups on the wall.
- The progression then leads to dynamic floor pushups.
- Rhythmic stabilization performed in quadruped

Plyometrics

- Plyometrics are initiated using bilateral arm throwing patterns beginning with chest pass motions into a rebounder and progressing to single-arm tosses.
- Overhead bilateral medicine ball slams and overhead medicine ball catches are also added (Figure 2-23).
- These activities progress to single-arm activities.
- Rebounder IR/ER at 90° abduction as well as supine IR/ER ball catch and toss with the therapist is incorporated.

Functional Exercises

- Overhead strengthening is incorporated as well as lower extremity agility drills, including ladder and hurdle drills as well as running progression (intervals, sprints).
- Resistance exercises in standing progress from double leg to single leg stance, asymmetrical resistance, and unstable surfaces.
- Initiate lower extremity agility program.

Sport-Specific Exercises

- Throwing athletes may begin light tossing at shorter distances and are instructed to avoid full wind-up throws until 20 weeks postop. Progression of throwing intensity may begin at 20 weeks as long as the patient demonstrates normal mechanics. Throwing should be closely monitored and discontinued if the athlete exhibits any compensatory movement patterns or shoulder girdle discomfort.
- Progression to formal strength and conditioning commences when athletes have full gross strength and AROM and are pain free with activity.

Outcome Measures

- Patient-reported outcome scales (see Phase IV). Recommend utilization of scales that are most consistent with the patient population being evaluated. Utilization of two or three scales is reasonable.

Milestones for Progression to the Next Phase

- Full pain-free uncompensated AROM
- No episodes of instability
- Manual muscle testing grade 5/5 strength of rotator cuff, shoulder, and scapular stabilizers
- Isokinetic testing for assessment of dynamic strength, power, and endurance may be implemented.[6] Assessment may include motions of IR, ER, flexion, extension, abduction, and adduction. Side-to-side ratios

should be within 85%, same-side ratio for ER to IR should be within 70%, and abduction to adduction 80%.
- Outcome scores at 24 weeks should be greater than 80%.

Phase VI (weeks 24 to 52 postop)

Management of Swelling

- Ice application post exercise

Techniques for Progressive Increase in Range of Motion

- Patients should have achieved full AROM by 6 months.

Manual and Soft Tissue Techniques

- Manual therapy techniques as previously stated for Phase V if full mobility is not yet achieved
- Additional joint mobilizations will be directed towards restricted joints and may include the GHJ (grade III to IV), scapulothoracic joint (usually not necessary at this late stage), and thoracic spine.
- Instructing the patient in self-management techniques with commercially available products or simply using a tennis ball or racquet ball will provide long-term self-treatment options.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Home stretching for posterior capsule progression: supine horizontal stretch, supine horizontal stretch with IR, sleeper stretch, and sleeper stretch with rollover[7]
- Continued utilization of sustained end range stretching to achieve desired symmetrical or required mobility
- Pre-performance/exercise stretching should focus on functional movement patterns that prepare the athlete for return to sport activity

Other Therapeutic Exercises

- Integrated training activities at this stage should include multijoint movements (i.e., front squats, power or hang cleans, clean and press)

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Focus in the late stage of recovery is on establishing preinjury levels of function.

Sensorimotor Exercises

- Ball-toss exercises in standing
- D1/D2 movements with cables
- Medicine ball
- Progression to slosh ball
- Rapid repositioning drills and reaction movement drills

Open and Closed Kinetic Chain Exercises

- Advancing the previous exercises in accordance with sport-specific demands
- Examples of progression may include kettle bell swings and overhead lifts such as kettle bell snatches.
- More aggressive posterior axial loading in the sagittal place may begin in preparation for return to athletics.

Techniques to Increase Muscle Strength, Power, and Endurance

- Isokinetic training
- Refining and integrating the undulating periodization model to optimize recovery and return to athletics

Neuromuscular Dynamic Stability Exercises

- Resistance exercises in standing progress from double- to single-leg stance, asymmetrical resistance, and unstable surfaces as necessary to replicate anticipated performance demands

Clinical Pearl

Reinjury is more likely to occur when the athlete is overworked and receives posterior-directed stress on the fatigued GHJ complex. In order to optimally prepare the athlete for full return to sport, dynamic stability exercises and strength training must be taken to a sufficient level of stress to closely replicate the strength, power, and endurance demands that will be encountered.

Plyometrics

- Advanced to increasing level of difficulty (i.e., overhead tossing with a light-weight ball, dynamic pushups, hand-walking up and down over a step or ball)

Sport-Specific Exercises

- By 24 weeks postop, athletes may have begun light sport-specific training, such as short tossing for throwing athletes and limited overhead stroke work for swimmers, tennis, and volleyball players.
- A progression of throwing volume and intensity may begin at the 24th to 28th week mark in baseball and softball players.
- For athletes involved in sports with repeated anteroposterior axial stress to the GHJ, increased loading will begin during this phase
  - Weight training may now safely progress to include pressing exercises at bisacromial width at grip.
  - Wrestlers may progress to drills in the quadruped position with an increasing amount of partner drill work.
  - Football players may increase sport-specific activities, to include bag work (i.e., punches, swim techniques) for linemen and one-on-one drills.

Milestones for Progression to the Next Stage

- Less than 10% side-to-side deficit on isokinetic testing
- CKC testing may include the CKC upper extremity stability test and/or the upper extremity Y-balance test.
- Integrated power tests may include the vertical jump, standing backward overhead medicine ball throw, and standing rotational medicine ball throw. Preinjury test values would provide the best measure of functional recovery as sport-/position-specific normative data are limited.
- Patient-reported outcome scales at 36 and 52 weeks should be greater than 90%.

Criteria for Return To Sport

General

- Normal scapulothoracic and glenohumeral mechanics
- Full AROM without instability or scapular dyskinesis
- Minimum of 90% (side-to-side) symmetry on isokinetic testing of muscular strength, power, and endurance. ER to IR ratio at least 70%.
- CKC testing and integrated power tests with good quality of motion and maintenance of scapulothoracic and core stability throughout the tests with no report of shoulder pain or instability.

Sport Specific

- Implementation of return-to-sport criteria must include a demand/needs analysis of the chosen sport. The rehabilitation specialist should be able to analyze the demands on the shoulder complex and create a sufficient series of tests and exercises to ensure readiness for return to preinjury levels of activity.

After Return to Sport

Continuing Fitness or Rehabilitation Exercises

- Total-arm and total-body strengthening exercises

Exercises and Other Techniques for Prevention of Recurrent Injury

- Prevention of recurrence requires continued maintenance of dynamic neuromuscular control (strength, mobility, kinesthetic awareness, and proprioception). Degradation in any of these areas could put the athlete at risk for reinjury if a high degree of physical demands on the reconstructed posterior GHJ are continued.

Although sport-specific training is essential to ensure readiness for return to sport, a training program that does not include reactive drills and a diversity of training modalities can result in a shoulder complex unable to adapt to the ever-changing demands of athletic competition.

Evidence

Eckenrode BJ, Logerstedt DS, Sennett BJ: Rehabilitation and functional outcomes in collegiate wrestlers following a posterior shoulder stabilization procedure. *J Orthop Sports Phys Ther* 30(7):550–558, 2009.

This case series presents the rehabilitation approach and outcomes for five collegiate wrestlers. (Level IV evidence)

Ellenbecker TS, Davies GJ: The application of isokinetics in testing and rehabilitation of the shoulder complex. *J Athl Train* 35(3):338–350, 2000.

This manuscript provides a thorough review on the utilization of isokinetic training and testing for the shoulder complex. (Level V evidence)

McMullen J, Uhl TL: A kinetic chain approach for shoulder rehabilitation. *J Athl Train* 35(3):329–337, 2000.

The rationale for and description of a kinetic chain approach for restoration of optimal shoulder function is presented. (Level IV evidence)

Myers JB, Lephart SM: The role of the sensorimotor system in the athletic shoulder. *J Athl Train* 35(3):351–363, 2000.

The authors provide an overview of the relationship between glenohumeral stability and the sensorimotor system as well as recommendations to enhance sensorimotor and functional performance of the shoulder. (Level IV evidence)

Provencher MT, LeClere LE, King K, et al: Current concepts: Posterior instability of the shoulder diagnosis and management. *Am J Sports Med* 39(4):874–886, 2011.

This article provides a review of the anatomy and biomechanics associated with posterior shoulder instability. The authors discuss the radiographic and clinical presentation of this pathology and describe various treatment options. (Level V Evidence)

Radkowski CA, Chhabra A, Baker CL, III, et al: Arthroscopic capsulolabral repair for posterior shoulder instability in throwing athletes compared with nonthrowing athletes. *Am J Sports Med* 36(4):693–699, 2008.

Previous data regarding both throwing and nonthrowing athletes documented significant improvements in stability, range of motion, strength, pain, and function following stabilization. Good to excellent results were documented in 93% and 89% of throwers and nonthrowers, respectively. Throwing athletes were less likely than nonthrowing athletes to return to play with 55% versus 71%, respectively. (Level II evidence)

Voight ML, Thomson BC: The role of the scapula in the rehabilitation of shoulder injuries. *J Athl Train* 35(3):364–372, 2000.

This clinical update article contains information on the pathomechanics, evaluation, and thorough coverage of rehabilitation methods to optimize scapular function. (Level V evidence)

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Multiple Choice Questions

QUESTION 1. When should stretching of the posterior capsule to promote restoration of normal mobility commence following posterior reconstruction?

A. 2 to 6 weeks
B. 6 to 10 weeks
C. 10 to 14 weeks
D. 14 to 24 weeks

QUESTION 2. When is it safe to begin posterior axial loading in the sagittal plane following posterior capsule reconstruction?

A. 6 to 10 weeks
B. 10 to 14 weeks
C. 14 to 24 weeks
D. 24 to 52 weeks

QUESTION 3. When is it safe to incorporate low amplitude joint mobilizations following posterior capsule reconstruction?

A. 0 to 2 weeks
B. 2 to 6 weeks
C. 6 to 12 weeks
D. greater than 12 weeks

QUESTION 4. When should full GHJ PROM be achieved following posterior capsule reconstruction?

A. 2 to 6 weeks
B. 6 to 10 weeks
C. 10 to 14 weeks
D. 14 to 24 weeks

Answer Key

QUESTION 1. Correct answer: **B** (see Phase III: Clinical Pearl)

QUESTION 2. Correct answer: **C** (see Phase V: Neuromuscular Dynamic Stability Exercises)

QUESTION 3. Correct answer: **B** (see Phase II: Manual Therapy Techniques)

QUESTION 4. Correct answer: **C** (see Phase IV: Techniques for Progressive Increase in Range of Motion)

BEYOND BASIC REHABILITATION: RETURN TO FOOTBALL AFTER POSTERIOR SHOULDER STABILIZATION

Travis G. Maak, MD, and Russell F. Warren, MD

Introduction

Aspects of Football that Require Special Attention in Rehabilitation

Posterior shoulder instability may result from both traumatic and atraumatic etiologies.

This injury is particularly prevalent in football and may result from an acute, traumatic subluxation or dislocation from a high-energy posteriorly directed force on an outstretched arm or, more commonly, from multiple subluxations due to recurrent posterior load on a forward flexed, adducted, internally rotated shoulder.

This posterior loading and subsequent recurrent subluxation is particularly common in football linemen. Associated posterior labral injury and capsular laxity may be treated nonoperatively; however, continued instability frequently requires surgical stabilization.

Careful postoperative consideration should be given to the football player's position, specifically linemen, in regard to rehabilitation and return to play.

Rehabilitation following posterior shoulder stabilization and return to football participation typically occurs in four distinct phases:

- Recovery phase (weeks 2 to 4)
- Range of motion (ROM) phase (weeks 4 to 8)
- Strengthening phase (weeks 8 to 12)
- Sport-specific conditioning phase (weeks 12 to 18)

This phase-specific rehabilitation program is designed to ensure that the goal of each phase is achieved before progression to the next phase. The week intervals serve as suggestions but should not be rigid as the patient should complete each phase before advancement, even if increased time is required in a given phase.

The overall goal of this program is to allow recovery, return of full ROM, and restoration of normal strength, flexibility, and proprioception.

- Notably, contact athletes, including football players, will require activity restriction until the 4- to 6-month period and return to full participation is restricted until at least 6 months.



FIGURE 2-24. Pendulum exercises should begin immediately postoperatively to minimize stiffness while protecting the stabilization repair. The arm should hang with gravity and rotate in a circular fashion about the shoulder as shown here.

- Phase I begins 2 weeks following surgery; however, careful instruction should be given to the patient during this 2-week immediate postoperative period. Sling immobilization should be maintained at all times for the first 4 weeks except during periods of rehabilitation.
- It is the authors' experience that this position is well tolerated, although others have suggested that immobilization in external rotation (ER) may reduce stress on the posterior capsule.
- The patient should also be instructed to perform passive pendulum exercises (Figure 2-24) and active elbow and wrist ROM immediately postoperatively and until the first rehabilitation session.

Return to Football After Proximal Shoulder Stabilization: Literature

- Outcomes following posterior shoulder stabilization have been promising. Initial data in 1998 documented only one case of recurrent instability with 11 of 14 patients returning to a preinjury level of function.[1] Provencher et al.[2] documented an 88% success with stabilization and 94.6 mean score on the American Shoulder and Elbow Society (ASES) scale in 33 patients.
- A study of 27 throwing and 80 nonthrowing athletes documented only one failure by ASES score with a return to preinjury sport participation in 55% of throwers and 71% of nonthrowers.[3] These results, however, are a product not only of well-performed surgery, but also of a carefully constructed and directed rehabilitation program.

Phase I (weeks 2 to 4): Recovery Phase

- This phase is a continuation of the immediate postoperative instructions. Focus should be placed on protection of the posterior stabilization repair while incrementally restoring ROM.
- This phase also attempts to reduce postoperative pain and facilitate intraarticular motion with gentle, controlled ROM in a narrow arc. Continued instruction on pendulum exercises and elbow and wrist motion is given. Gripping exercises are also performed to encourage distal motion and circulation.
- Scapular exercises are also performed during this phase, including isometrics and side-lying stabilization (Figure 2-25). This scapular-based rehabilitation serves to establish a stable base and improved posture upon which future ROM and strengthening can occur.
- Finally, careful teaching regarding protection of the surgical stabilization, pain control, and cryotherapy to

TIMELINE 2-2: **Beyond Basic Rehabilitation: Return to Football After Posterior Shoulder Stabilization**

PHASE I		PHASE II (weeks 4 to 8)
(weeks 0 to 2)	(weeks 2 to 4)	
• Sling • PT modalities • Active assistive pendulum exercises • Active elbow and wrist ROM as tolerated	• Sling • PT modalities • Gentle passive ER to 30° with arm at side • Active elbow and wrist ROM as tolerated • Scapular exercises: isometrics and side-lying stabilization • Cryotherapy	• D/C sling • PT modalities as needed • ROM: forward flexion to 120° • ROM: abduction to 90° • ROM: IR to 45° • ROM: horizontal abduction limited to neutral • Scapular strengthening • Progress ROM from passive to active when full PROM achieved • Sub-max deltoid, IR and ER isometrics • Mobilizations as needed • CKC limited to plane of scapula to maintain GH congruency • Biceps/triceps PREs • Home exercise program teaching



FIGURE 2-25. Scapular stabilization exercises including side-lying stabilization should begin at Phase II and continue throughout the rehabilitation program. A stable scapular foundation is crucial for glenohumeral stability. In this figure, the therapist or trainer can be seen manually stabilizing the scapula while the patient performs an isometric contraction.



FIGURE 2-26. Shrugging should be avoided during shoulder abduction in the plane of the scapula because this signifies detrimental weakness and scapular compensation. The shrug can be visualized on the patient's right shoulder compared with a normal abduction motion on the left.

reduce inflammation is provided. Importance should also be placed on patient counseling regarding normal pain levels, activity limitation, and immediate expectations.
- The patient should advance to Phase II upon completion of passive ER to 30 degrees with minimal pain.

Phase II (weeks 4 to 8): Range of Motion Phase

- The patient may discontinue the use of the shoulder immobilizer at the end of the 4th postoperative week.
- This marks the beginning of progression of ROM to include passive forward flexion to 120° and abduction to 90°. ER may progress as tolerated by the patient's pain limitations. Internal rotation (IR) is limited to 45° to minimize stress on the posterior structures. Horizontal adduction is limited to neutral. Elevation in the plane of the scapula is allowed during the 4- to 6-week period, after which full flexion is advanced. These limitations are particularly important during forward flexion, as the forearm may attempt to internally rotate the shoulder in this position.
- Active and active-assisted ROM should begin when the patient has achieved full passive ROM within the prescribed guidelines. Notably, hydrotherapy may be used in this stage to facilitate ROM. Care should be given to avoid shrugging during shoulder abduction, as this will promote fatigue and rotator cuff inflammation (Figure 2-26).
- Scapular strengthening may also progress at this stage to continue securing a stable foundation for shoulder motion and strengthening.

TIMELINE 2-2: Beyond Basic Rehabilitation: Return to Football After Posterior Shoulder Stabilization (Continued)

PHASE III (weeks 8 to 12)	PHASE IV (weeks 12 to 18)	PHASE V (weeks 19+)
• PT modalities as needed • PROM: full • Mobilizations as needed • Scapular exercises: PREs • Biceps/triceps: PREs • GH joint exercises: PREs • Rotator cuff exercises: PREs • Thrower's 10 • Limit IR exercises to minimize strain to posterior capsule • PNF exercises • Upper extremity ergonometrics • OKC rhythmic stabilization exercises • CKC exercises • CKC manual perturbation exercises	• PROM: maintain full motion • Mobilizations as needed • Bench press: wide grip only • Scapular exercises: PREs • Biceps/triceps: PREs • GH joint exercises: PREs • Rotator cuff exercises: PREs • Thrower's 10: progress intensity • PNF exercises • OKC rhythmic stabilization exercises • CKC exercises • CKC manual perturbation exercises • Plyometrics: two-arm progressing to one-arm • Overhead strengthening exercises • Overhead throwing athletes can begin an easy interval throwing program • 20 weeks: begin full windup throwing • Upper and lower extremity endurance and proprioception exercise • Neuromuscular fatigue drills	• Continue Phase IV program • Advance sport-specific functional activities • Increase functional repetitions and interval program • Maintain activity restrictions • Full activity at 6 months for collision play

- Deltoid and IR and ER isometrics may also be used to facilitate stress-limited muscle contraction.
- Care should be taken to avoid closed chain exercises with the shoulder in a forward flexed position as these may place undue stress on the posterior stabilization. Instead, closed kinetic chain (CKC) shoulder exercises should be limited to the plane of the scapula to maintain glenohumeral congruency and minimize posterior stress.
- A home exercise program should also be discussed to ensure continued therapy throughout this phase.
- The patient should progress to Phase III upon completion of forward flexion to 120° and active internal and ER strength of at least 4/5 on manual muscle testing.

Phase III (weeks 8 to 12): Strengthening Phase

- Phase III is focused on maintaining full shoulder ROM and initiating a focused strengthening program. The patient should aim to achieve full ROM by the 8-week mark, at which point the emphasis may be shifted to strengthening.
- Pulleys and wand exercises may be used to maintain ROM during this phase (Figure 2-27). IR may be progressed as tolerated at this time, as the posterior structures are fully healed. Nevertheless, aggressive passive stretching, especially in IR, should be avoided.
- Scapular strengthening is progressed at this point with the goal to restore normal scapulothoracic motion and function. This function will aid to center the glenohumeral joint and facilitate shoulder strengthening. Isotonic strengthening of the trapezius, serratus, levator scapulae, and rhomboids are conducted. Scapular elevation, retraction, and protraction are also promoted with shrugs, rowing, and serratus punch, respectively (Figure 2-28).
- Latissimus dorsi strengthening should also be performed in a protective arc of 0° to 90° to optimize scapular function and improve glenohumeral compressive stability.
- Focused shoulder strengthening in internal and ER is initiated using elastic band resistance with the shoulder in a neutral position with the scapula stabilized.
- Active shoulder abduction in the plane of the scapula should also progress according to the relative strength of the rotator cuff. The shrugged scapular position should be avoided during shoulder abduction because this may promote rotator cuff inflammation and impede rehabilitation progress. In this circumstance, shoulder abduction should be delayed until scapula strengthening, active forward flexion, and IR and ER strength are sufficient to allow shrug-free shoulder abduction. Notably, active abduction should be performed with the shoulder in full ER to avoid impingement of the greater tuberosity under the acromion.
- Finally, proprioception and endurance rehabilitation should be incorporated when strength has sufficiently progressed in all planes of motion. Humeral head control drills, including rhythmic stabilization, may be used. Neuromuscular control patterns should be initiated in challenging positions.
- Upper extremity ergonometry and isokinetic training may facilitate speed, endurance, and muscular coordination. Isokinetic testing may also be used to identify deficient areas that may require selective rehabilitation.
- Patients should progress to Phase IV only with pain-free, full shoulder ROM, normal glenohumeral rhythm, and isokinetic strength in IR and ER equal to 85% of the contralateral shoulder.



FIGURE 2-27. Maintenance of glenohumeral range of motion during Phase III is crucial to minimize stiffness and reduce pain. Pulleys can be used in this regard as demonstrated here.

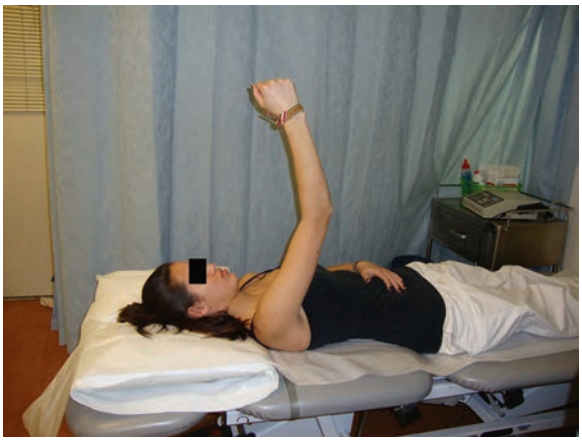

FIGURE 2-28. The serratus punch can be effectively used to allow scapular stabilization during active forward flexion of the shoulder in the supine position. The elbow should begin in the fully flexed position and should actively extend as the shoulder is forward flexed. This exercise facilitates deltoid strengthening and glenohumeral range of motion.

Phase IV (weeks 12 to 18): Sport-Specific Conditioning

- Return to football participation requires a carefully constructed reintroduction program. The athlete must be able to fully perform position-specific functional demands with no limitation in neuromuscular function before participation.
- Eccentric strengthening is particularly useful in this population to maximize strength and minimize the time required before return to play. A functional plyometric exercise program should be constructed including increasing stress and progressive overload. Bench press is instituted at this time with a wide grip requirement to minimize posteriorly directed forces (Figure 2-29).
- Endurance training is also progressed, including neuromuscular drills to fatigue completion. Lower extremity proprioception, strengthening, and endurance exercises are also incorporated in this phase to ensure that the athlete regains normal timing and endurance to minimize upper extremity compensation.
- Sport-specific exercises are also incorporated in this phase to gradually reintegrate the athlete into functional activities.
- Care should be taken throughout this phase to avoid overload or excessive fatigue of the shoulder. Increased pain or inflammation may hinder progress and predispose the athlete to developing a shoulder contracture. If increased pain occurs during this phase, the athlete should reduce the functional repetitions and avoid strengthening until the pain is well controlled. At this time, gradual incorporation of the prior program may once again begin.
- Activity restrictions are maintained for the football athlete for at least 4 to 6 months, and participation in collision play is restricted for at least 6 months.



FIGURE 2-29. Incorporation of the bench press as a strengthening exercise may begin in Phase IV (typically at week 12). A wide-based grip should be used to facilitate a concentric glenohumeral articulation, which will improve compressive forces and minimize posterior forces.

Evidence

Badge R, Tambe A, Funk L: Arthroscopic isolated posterior labral repair in rugby players. *Int J Shoulder Surg* 3:4–7, 2009.

A previous study conducted over a 5-year period of 142 elite rugby players with posterior shoulder capsulolabral injury and operative stabilization demonstrated constant score improvement from 66 to 99. Oxford instability score improved from 52.2 to 12.3. Return to play at the preinjury level was documented at a mean of 4.3 months following repair and a similar rehabilitation protocol. (Level IV evidence)

Eckenrode BJ, Logerstedt DS, Sennett BJ: Rehabilitation and functional outcomes in collegiate wrestlers following a posterior shoulder stabilization procedure. *J Orthop Sports Phys Ther* 39:550–559, 2009.

Five division I wrestlers with a mean age of 20.2 years were treated with focused physical therapy including range of motion, strengthening, plyometrics, neuromuscular re-education, and sport-specific training. Postsurgical outcomes improved from an immediate postoperative Penn Shoulder Score ranging from 37 to 74/100 to a score ranging from 81 to 91/100. Four of the five players were able to return to wrestling with no recurrence. (Level IV evidence)

Radkowski CA, Chhabra A, Baker CL, 3rd, et al: Arthroscopic capsulolabral repair for posterior shoulder instability in throwing athletes compared with nonthrowing athletes. *Am J Sports Med* 36:693–699, 2008.

Previous data regarding both throwing and nonthrowing athletes documented significant improvements in stability, range of motion, strength, pain, and function following stabilization. Good to excellent results were documented in 93% and 89% of throwers and nonthrowers, respectively. Throwing athletes were less likely than nonthrowing athletes to return to play with 55% versus 71%, respectively. (Level II evidence)

Savoie FH, 3rd, Holt MS, Field LD, et al: Arthroscopic management of posterior instability: evolution of technique and results. *Arthroscopy* 24:389–396, 2008.

One hundred and thirty-six shoulders in 131 patients with posterior instability who had failed at least 6 months of rehabilitation were studied following posterior stabilization and postoperative directed rehabilitation. Outcomes were documented with a 97% stability and success on the Neer-Foster scale. Similar rehabilitation techniques were employed in this study. (Level IV evidence)

Williams RJ, 3rd, Strickland S, Cohen M, et al: Arthroscopic repair for traumatic posterior shoulder instability. *Am J Sports Med* 31:203–209, 2003.

Mean follow-up 5.1-year outcome data from male patients (28.7 years) following arthroscopic stabilization for traumatic posterior shoulder instability documented 92% pain and instability elimination, with a mean L'Insalata shoulder score of 90.0 and 96% overall patient satisfaction. All patients were able to return to unlimited athletic activity at 6 months post-operatively. (Level IV evidence)

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2. Provencher MT, Bell SJ, Menzel KA, et al: Arthroscopic treatment of posterior shoulder instability: Results in 33 patients. *Am J Sports Med* 33:1463–1471, 2005.

3. Radkowski CA, Chhabra A, Baker CL, 3rd, et al: Arthroscopic capsulolabral repair for posterior shoulder instability in throwing athletes compared with nonthrowing athletes. *Am J Sports Med* 36:693–699, 2008.

Multiple Choice Questions

QUESTION 1. The patient should use the shoulder immobilizer immediately postoperatively and for the first _____ week(s).

A. 1
B. 2
C. 3
D. 4

QUESTION 2. During the range of motion phase of rehabilitation, closed kinetic chain exercises should be performed

A. with the shoulder in the forward flexed position.
B. with the shoulder in full internal rotation.
C. with the shoulder positioned in the plane of the scapula.
D. with the shoulder in full external rotation.

QUESTION 3. Scapular exercises should be performed

A. only during Phase IV—sport-specific conditioning.
B. throughout all of the phases.
C. during Phases III and IV but not during Phases I and II
D. during Phases I and II but not during Phases III and IV

QUESTION 4. During Phase IV—sport-specific conditioning, if the patient experiences mild pain and inflammation during repetition exercises, he or she should

A. take NSAIDs and continue to increase the repetitions because this is a normal response to rehabilitation.
B. stop repetition exercises until pain is absent and then reincorporate gradually to minimize inflammation.
C. change repetition exercises to strengthening only exercises.
D. obtain immediate radiograph because the athlete likely sustained an acute injury.

Answer Key

QUESTION 1. Correct answer: **D** (see Phase I: Rehabilitation)

QUESTION 2. Correct answer: **C** (see Phase II: Rehabilitation)

QUESTION 3. Correct answer: **B** (see Phase I–IV: Rehabilitation)

QUESTION 4. Correct answer: **B** (see Phase IV: Rehabilitation)

Chapter 3



Multidirectional Shoulder Instability

INTRODUCTION

Bryan Warme, MD, and Scott A. Rodeo, MD

Epidemiology

- Multidirectional instability (MDI) of the shoulder has various definitions in the literature. Shoulder instability can be categorized into anterior, posterior, or inferior directions. Generally speaking, instability in any two or more of these directions or combination of directions supports a diagnosis of MDI. Furthermore, instability without associated trauma is a characteristic of MDI.

Age

- MDI is a relatively rare condition, and it is unknown whether there is a specific age of an athlete during which there is increased vulnerability to manifesting the associated symptoms. This condition appears to be more common in younger individuals.

Sex

- It has been suggested that atraumatic MDI may be more common in female athletes, but this anecdotal evidence is not supported by formal studies.

Sport

- Swimming has been associated with a higher percentage of athletes with MDI than other sports. There may be a degree of acquired laxity that develops over time in swimmers due to repetitive overhead activity. There is likely also an element of congenital, underlying generalized ligamentous laxity in these athletes (Figure 3-1). Athletes with increased shoulder laxity may have a mechanical advantage in various swimming strokes, thus leading to selection for swimming.

Position

- Swimming strokes that require extremes of range of motion may increase the likelihood of having athletes with MDI.

Pathophysiology

Intrinsic Factors

- MDI is a complex shoulder condition that remains poorly understood. The underlying pathology is capsular laxity.
- Systematic connective tissue disorders can predispose an athlete to MDI. Examples of this include Ehlers-Danlos and Marfan syndromes.
- Abnormal muscle activation patterns of the deltoid and periscapular musculature adversely affect the dynamic shoulder stabilizers, leading to scapulothoracic dyskinesis and resultant abnormal kinematics, thereby contributing to MDI.

Extrinsic Factors

- It is unclear whether there is an etiologic relationship between competitive swimming and MDI, although it is possible that repetitive overhead activity can lead to glenohumeral laxity. Swimming is a unique sport in that there is constant shoulder motion against resistance (water) at extremes of shoulder motion.

Traumatic Factors

- Shoulder instability in general has a spectrum of causes from purely traumatic to completely atraumatic. MDI lies on the atraumatic end of the spectrum, but



FIGURE 3-1. Generalized laxity in a swimmer demonstrated by bilateral knee hyperextension.



FIGURE 3-2. Physical examination of a shoulder with MDI demonstrating a positive "Sulcus Sign," indicative of inferior instability. *(From Altchek DW, Warren RF, Skyhar MJ, Ortiz G: T-plasty modification of the Bankart procedure for multidirectional instability of the anterior and inferior types. J Bone Joint Surg Am 73:105–112, 1991.)*

traumatic causes can underlie shoulder instability in more than one direction.
- Matsen developed the "TUBS" and "AMBRI" acronyms to describe the two ends of this instability spectrum: Traumatic vs. MDI.

Traumatic	Atraumatic
Unidirectional	Multidirectional
Bankart lesion	Bilateral
Surgical stabilization	Rehabilitation
	Inferior capsular shift

Classic Pathological Findings

- Patulous, redundant, or dysfunctional capsule
- Scapular dyskinesis, which may be primary or secondary

Clinical Presentation

History

- Classically, there is no traumatic etiology underlying shoulder instability.
- A history of asymptomatic shoulder laxity may become symptomatic without an apparent traumatic event.
- The typical complaint is pain, although some athletes will report a sense that the shoulder "slips" or "feels loose."

Physical Examination

Abnormal Findings

- 2+ Instability (symptomatic laxity) in more than a single direction (anterior, posterior, or inferior). The shoulder should translate to and over the rim of the glenoid with testing and reproduce symptoms of "instability."
- Bilateral shoulder instability without a traumatic etiology.
- Sulcus sign suggesting inferior laxity (Figure 3-2).
- Jerk test suggesting posterior instability.
- Apprehension suggesting anterior instability.
- Generalized laxity can suggest underlying connective tissue disorder (e.g., elbow hyperextension or the ability to touch the thumb to the forearm).

Pertinent Normal Findings

- Normal neurological and vascular exams (which can be compromised during episodes of instability).
- Patient is not able to voluntarily dislocate.

Imaging

- Bony injuries such as Hill-Sachs or bony Bankart lesions seen on plain film suggest a traumatic etiology rather than atraumatic MDI.
- Magnetic resonance imaging (MRI) can show a "patulous" capsule in MDI. MRI may also show capsular thickening, which reflects adaptive remodeling due to repetitive episodes of plastic deformation of the capsule (Figure 3-3).

Arthroscopic Examination

- Capsular redundancy and a positive "drive through" sign are hallmarks of MDI on diagnostic arthroscopy (Figure 3-4).

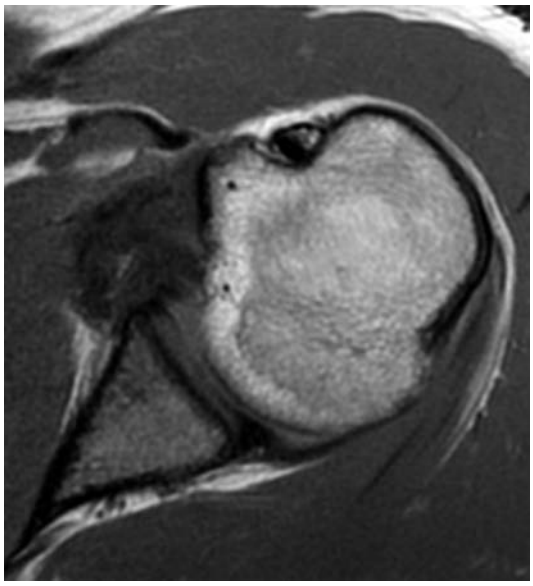

FIGURE 3-3. Capsular remodeling as seen on MRI can reflect repetitive plastic deformation.

Differential Diagnosis

- Traumatic unidirectional instability—look for traumatic lesions on radiographs and instability in only one direction.
- Posterior shoulder dislocation due to seizure/convulsion—again, confirm instability only in the posterior direction.
- Voluntary dislocation with or without underlying psychiatric condition—these patients may have MDI, but these underlying diagnoses can make it difficult to achieve a stable outcome, regardless of treatment modality.

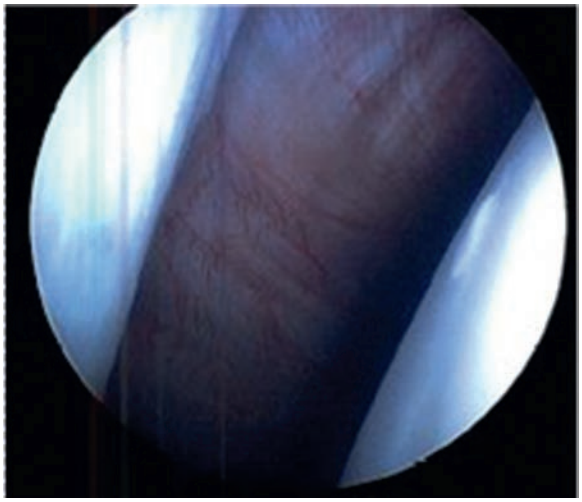

FIGURE 3-4. Postive "drive through" sign on arthroscopy indicative of shoulder laxity.

Treatment

Nonoperative Management

- Rehabilitation is the mainstay of treatment for MDI. Most treating physicians recommend a minimum of 6 to 12 months of rehabilitation before considering any surgical intervention in MDI.
- Pain-relieving modalities such as nonsteroidal antiinflammatory drugs (NSAIDs) and selective use of injections can be used adjunctively with rehabilitation if necessary.
- Exercises aimed at improving coordination of shoulder muscle activation can improve dynamic shoulder stability.
- Ultimately, activity modification may be necessary to exclude those shoulder positions for which subluxation events are most likely.

Guidelines for Choosing among Nonoperative Treatments

- Proprioception training and scapular stabilization exercises are important when the athlete is unable to actively control the humeral head concentrically on the glenoid.
- Cessation of the offending sport is at the discretion of the athlete.
- Pain-relieving modalities should be used conservatively, and opioid pain medication should only be used in acute settings for short periods of time.

Surgical Indications

- There are no absolute indications for surgical stabilization of MDI.
- Relative indications for surgery are failure of extended rehabilitation and trials of activity modification and/or cessation of the affecting sport.
- Ultimately, surgery for MDI is less predictable than for traumatic, unidirectional instability. The athlete must be an informed patient, appreciating the unpredictability of the surgery and the potential complications. Furthermore, the surgeon must be confident that improved stability can be achieved through an operation if surgery is to be indicated.

Aspects of History, Demographics, or Exam Findings That Affect Choice of Treatment

- History of voluntary dislocation, especially in the setting of an underlying psychiatric condition, predicts a poor surgical outcome. In these cases, treatment should consist of rehabilitation exclusively. If the underlying psychiatric condition resolves, then surgery can be considered if extended rehabilitation has failed to improve stability.
- If there is a traumatic injury underlying MDI, earlier surgical intervention can be considered to concomitantly address the traumatic injury (e.g., Bankart lesion) and the MDI (e.g., patulous capsule).

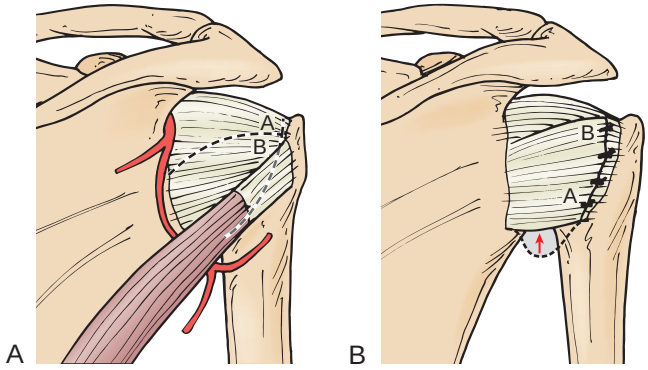

FIGURE 3-5. Open inferior capsular shift, as proposed by Neer. *(Redrawn from Neer CS 2nd, Foster CR: Inferior capsular shift for involuntary inferior and multidirectional instability of the shoulder. A preliminary report. J Bone Joint Surg Am 62:897–908, 1980.)*

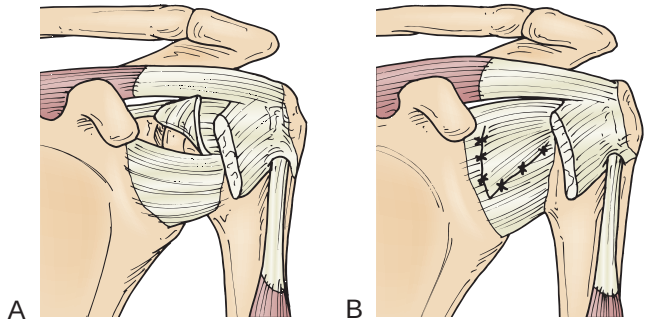

FIGURE 3-6. T-plasty modification of the inferior capsular shift, as proposed by Altchek. *(Redrawn from Altchek DW, Warren RF, Skyhar MJ, Ortiz G: T-plasty modification of the Bankart procedure for multidirectional instability of the anterior and inferior types. J Bone Joint Surg Am 73:105–*112, 1991.)

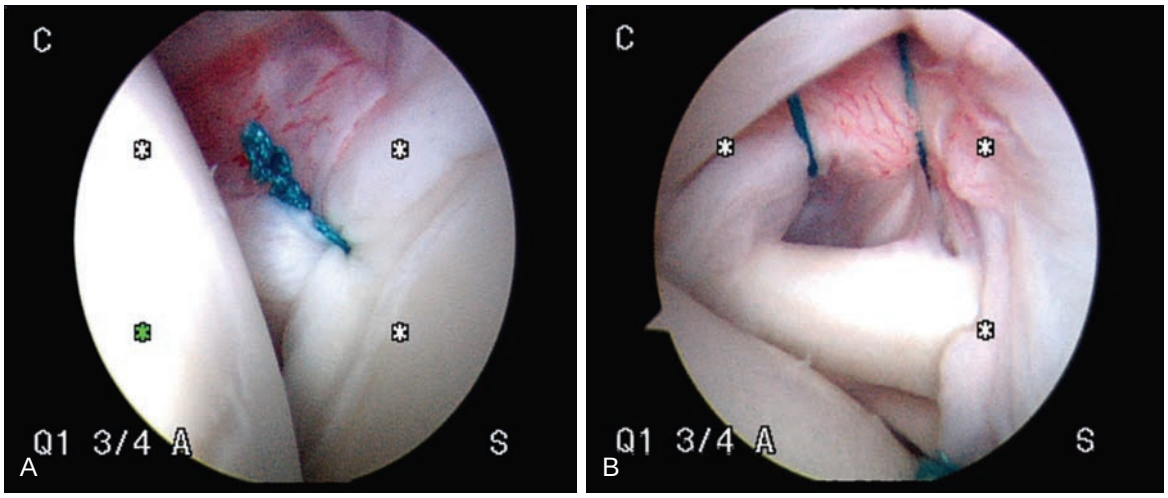

FIGURE 3-7. Arthroscopic capsular placation (**A**) and rotator interval closure (**B**).

Aspects of Clinical Decision Making When Surgery is Indicated

- The directions of instability are important to surgical planning. Although both open and arthroscopic techniques have been described for MDI, open techniques have traditionally been the mainstay of surgical intervention for MDI. The direction of instability influences the decision to open the shoulder either anteriorly or posteriorly. Most surgical repairs are now done arthroscopically.
- A combination of open and arthroscopic approaches can be used if both anterior and posterior instability are present to limit the open aspect of the surgery to a single incision. Alternatively, both anterior and posterior incisions can be used to allow open stabilization of both anterior and posterior stabilization (Figures 3-5, 3-6, and 3-7).

Evidence

Altchek DW, Warren RF, Skyhar MJ, et al: T-Plasty modification of the Bankart procedure for multidirectional instability of the anterior and inferior types. *J Bone Joint Surg Am* 73:105–112, 1991.

A retrospective study of 42 shoulders that underwent T-plasty modification of the capsular shift. Satisfaction was rated as excellent in 95% of cases. The average loss of external rotation after surgery was 4° with the arm at the side and 5° degrees with the arm abducted. (Level IV evidence).

Burkhead WZ, Jr, Rockwood CA, Jr: Treatment of instability of the shoulder with an exercise program. *J Bone Joint Surg Am* 74:890–896, 1992.

This study highlights the importance of differentiating "traumatic" instability of the shoulder from "atraumatic" instability. Only 12/74 (16%) cases of traumatic shoulder instability responded with a good/excellent result to rehabilitation alone, compared with 53/66 (80%) of shoulders with atraumatic instability. (Level IV evidence).

Matsen FA, 3rd, Thomas SC, Rockwood CA, Jr: Anterior glenohumeral instability. In Rockwood CA, Matsen FA, editors: *The shoulder*, Philadelphia, 1990, WB Saunders, pp 547–551.

The spectrum between traumatic and atraumatic causes of shoulder instability are discussed, and the acronyms "TUBS" and "AMBRI" are described in this reference. (Level V evidence).

McFarland EG, Kim TK, Park HB, et al: The effect of variation in definition on the diagnosis of multidirectional instability of the shoulder. *J Bone Joint Surg Am* 85:2138–2144, 2003.

This study evaluated four different classification systems of MDI and found that the criteria used to make the diagnosis of MDI significantly affected the distribution of the diagnosis. The study also demonstrated that the use of laxity testing tends to overestimate the diagnosis. (Level III evidence).

Morris AD, Kemp GJ, Frostick SP: Shoulder electromyography in multidirectional instability. *J Shoulder Elbow Surg* 13:24–29, 2004.

This study demonstrated abnormal muscle activation patterns in shoulders with MDI compared with controls. The paper supports the idea that impaired coordination of the shoulder muscles and inefficiencies of the dynamic stabilizers play a role in MDI. (Level III evidence).

Neer CS, 2nd, Foster CR: Inferior capsular shift for involuntary inferior and multidirectional instability of the shoulder. A preliminary report. *J Bone Joint Surg Am* 62:897–908, 1980.

This is the classic article that first described the condition and named it MDI. It is a retrospective study of 40 shoulders with MDI and describes Dr. Neer's inferior capsular shift technique for surgical stabilization. (Level IV evidence).

Rowe CR, Pierce DS, Clark JG: Voluntary dislocation of the shoulder. A preliminary report on a clinical, electromyographic, and psychiatric study of twenty-six patients. *J Bone Joint Surg Am* 55:445–460, 1973.

A clinical, radiographic, electromyographic, and psychiatric study that determined that patients with significant psychiatric problems did poorly after surgical or nonsurgical treatment unless their psychiatric problem had resolved. (Level IV evidence).

Multiple-Choice Questions

QUESTION 1. MRI of a shoulder with MDI often reveals:

A. Fatty infiltration of the rotator cuff
B. Bone edema adjacent to a Hill-Sachs lesion
C. Concomitant acromioclavicular (AC) joint arthrosis
D. Patulous capsule

QUESTION 2. According to Matsen et al., two factors that are more closely associated with MDI than traumatic shoulder instability include:

A. Bankart and Hill-Sachs lesions
B. Multidirectionality and bilaterality
C. Traumatic etiology and unidirectionality
D. Shoulder weakness and paresthesias

QUESTION 3. Which of the following patient attributes predicts a poor surgical outcome after MDI stabilization?

A. Age less than 20
B. Smoking history
C. Underlying psychiatric condition
D. BMI greater than 35

QUESTION 4. The mainstay of treatment for MDI should be:

A. Surgical stabilization
B. Rehabilitation
C. Pain medication
D. Benign neglect

Answer Key

QUESTION 1. Correct answer: **D** (see Clinical Presentation)

QUESTION 2. Correct answer: **B** (see Clinical Presentation and Evidence)

QUESTION 3. Correct answer: **C** (see Treatment)

QUESTION 4. Correct answer: **B** (see Treatment)

NONOPERATIVE REHABILITATION OF MULTIDIRECTIONAL SHOULDER INSTABILITY

John T. Cavanaugh, PT, MEd, ATC, SCS, and Scott A. Rodeo, MD

GUIDING PRINCIPLES OF NONOPERATIVE REHABILITATION

- Communicate with referring physician
- Treat patient as an individual
- Consider physiological healing restraints
- Develop strong base of support: Scapular strengthening
- Identify direction of greatest instability
- Incorporate exercises high in neuromuscular activation
- Functional progression

Clinical Pearls

- Patients referred for physical therapy with the diagnosis of MDI often present with varied symptoms. Some patients may present acutely following an episode of instability, whereas others present relatively asymptomatic with full range of motion (ROM) and normal strength on physical examination.
- Throughout the rehabilitation course an emphasis is placed on neuromuscular training to train the shoulder's dynamic stabilizers to engage when

needed to aid in stability. These neuromuscular exercises are encouraged as early as deemed appropriate in the rehabilitation program.
- The patient needs to be treated as an individual and treated based on information gained from their history, subjective complaints, radiographic imaging, physical examination, and the direction of the referring physician.

Phase I (weeks 0 to 8)

Clinical Pearls

- A thorough physical examination can identify deficits in ROM, flexibility, laxity, and strength. Scapular dyskinesis, winging, and atrophy can also be observed. Apprehension and stability testing provide the rehabilitation specialist with valuable information as it pertains to the direction of greatest instability (Figure 3-8).
- Patients may very well present with only symptoms in overhead sports activities; e.g., baseball and swimming. These patients may present on initial examination with full ROM and normal strength and scapulohumeral rhythm. Their laxity exam along with subjective complaints and history confirm their diagnosis.
- These patients begin their rehabilitation program at a more advanced level, incorporating exercise and activities found in Phases II and III of the general guideline.



FIGURE 3-8. Load and shift laxity testing.

Protection

- During the first phase of rehabilitation, care is taken to allow for healing and recovery from trauma (if applicable). The patient/athlete who complains of microinstability is treated predominantly based on symptoms.
- For the first-time dislocator, sling immobilization may be indicated for up to 4 weeks after an instability episode.
- Immobilization for less than 2 weeks for patients who report an episode of subluxation or recurrent dislocation.
- Patient/athlete is advised to avoid symptomatic positions that provoke apprehension.
- Modification of daily activities is emphasized: i.e., no heavy lifting or overhead activities of daily living (ADL).

TIMELINE 3-1: Nonsurgical Rehabilitation after Treatment of Multidirectional Shoulder Instability

PHASE I (weeks 0 to 8)	PHASE II (weeks 8 to 14)	PHASE III (weeks 14 to 20)
• Treatment-based on evaluation • Sling immobilization less than 2 weeks after episode of instability • Ice, electrical stimulation as needed • NSAIDs • Activity modification • AROM/AAROM • Flexibility exercises • Scapular stabilization/strengthening exercises (PRE) • CKC manual perturbation exercises • Humeral head control exercises • Deltoid/rotator cuff isometrics • Scaption (PRE as tolerated) • Upper-body ergometer • Soft tissue massage • Total body strengthening (TBS)/total arm strengthening (TAS)/total leg strength (TLS) activities as recommended and tolerated	• Treatment based on evaluation • Ice, electrical stimulation as needed • Flexibility exercises • Scapular stabilization/strengthening exercises (PRE) • Rhythmic stabilization exercises • Scaption (PRE) • IR/ER TheraBand/isokinetic exercises • PNF exercises • CKC manual perturbation exercises • Functional exercises: Keiser/pulley systems • BodyBlade • Upper-body ergometer • Plyometrics • Soft tissue massage • TBS/TAS/TLS activities as recommended and tolerated	• Treatment based on evaluation • Ice, electrical stimulation as needed • Flexibility exercises • Scapular stabilization/strengthening exercises (PRE) • Rhythmic stabilization exercises • Scaption (PRE) • IR/ER TheraBand/isokinetic exercises • IR/ER TheraBand 90/90 • PNF exercises • CKC manual perturbation exercises • BOSU® ball CKC stabilization with perturbations • Military press • Chest press • Functional exercises: Keiser/pulley systems • Bodyblade (overhead) • Upper-body ergometer • Plyometrics (overhead) • Soft tissue massage • Sport-specific training • TBS/TAS/TLS activities as recommended and tolerated

Management of Pain and Swelling

- During the posttraumatic period the daily use of cryotherapy and antiinflammatory medication are recommended.
- Electrical stimulation in the form of transcutaneous electrical nerve stimulation (TENS) can be used to assist in pain control.
- NSAIDs as needed.

Techniques for Progressive Increase in Range of Motion

Clinical Pearl

- ROM deficits are addressed with respect to the direction of instability and the timetable set forth by the referring physician. For example, for patients whose recent episode entailed an anterior subluxation, external rotation (ER) will be initially limited to 30° and forward flexion (scapular plane) limited to 90°. Full ROM should be restored by 8 weeks after trauma.

Manual Therapy Techniques

- Gentle active assisted range of motion (AAROM) in scapular plane (if needed).

Soft Tissue Techniques

- Soft tissue massage: scapular musculature.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- ER is regained via a supine wand exercise.
- Forward flexion by supine active-assistive exercise, at first with the assistance of the noninvolved upper extremity, progressing to using a wand.
- Internal rotation (IR) via a towel-pass exercise while the patient attempts to pass a towel around his/her back. IR is then progressed to a towel-stretch exercise.

Other Therapeutic Exercises

- Core-stability exercises.
- Lower-extremity strengthening without use of upper extremity.
- Distal upper-extremity strengthening (forearm, wrist, hand) exercises.

Activation of Primary Muscles Involved

- Exercises are performed for the following muscle groups:
  - Serratus anterior, rhomboids
  - Trapezius muscles
  - Levator scapulae
  - Deltoid muscles
  - Rotator cuff musculature
  - Humeral positioners

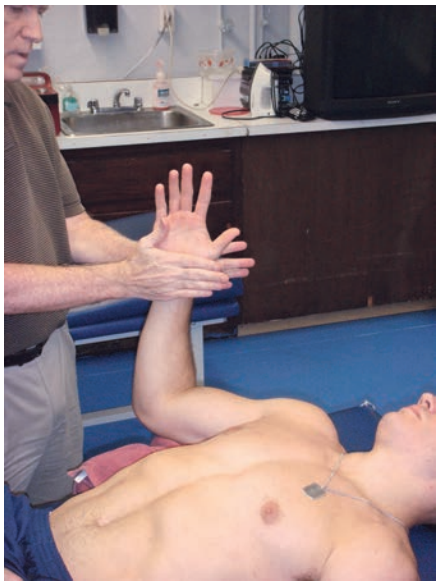

FIGURE 3-9. Neuromuscular dynamic stability exercises.

Sensorimotor and Neuromuscular Dynamic Stability Exercises

- Manual humeral head control exercises where the patient needs to react to the direction of force provided by the rehabilitation specialist (perturbation exercises) attempt to reestablish neuromuscular pathways to provide dynamic stability of the glenohumeral joint (Figure 3-9).

Open and Closed Kinetic Chain Exercises

- Closed kinetic chain (CKC) stabilization exercises using a physioball are included for patients whose symptomatic direction of instability is anterior (Figure 3-10).

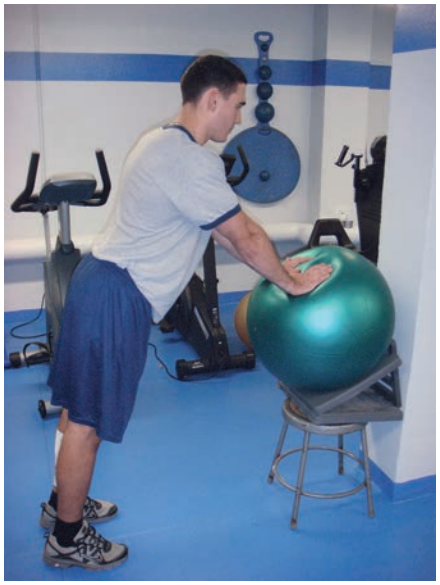

FIGURE 3-10. CKC stabilization exercises using a physioball.



FIGURE 3-11. Manual scapular stabilization exercises performed sidelying with the humerus positioned in neutral rotation.

Techniques to Increase Muscle Strength, Power, and Endurance

- Deltoid isometrics are initiated as symptoms allow.
- Early scapular strengthening is initiated as soon as these exercises are asymptomatic. Specific techniques used include manual resistance and rhythmic stabilization to scapular musculature. This technique can be started early on with the patient sidelying and the involved upper extremity supported in a neutral rotated position (Figure 3-11).
- As symptoms subside during this phase, scapular retraction isometrics and isotonic exercises are introduced as supine "serratus" punches (Figure 3-12).
- When scapulothoracic rhythm normalizes, scapular plane elevation "scaption" is performed and advanced in a progressive resistive exercise (PRE) fashion (Figure 3-13).
- IR and ER isometrics are initiated in a modified neutral position and performed submaximally.
- Upper-body ergometer (as symptoms allow).



FIGURE 3-12. Serratus anterior exercise performed supine.



FIGURE 3-13. Forward elevation in the scapular plane ("scaption").

Milestones for Progression to the Next Phase

- Full AROM and passive ROM.
- Scapulohumeral rhythm normalized throughout AROM as measured by visual observation, assuring symmetry, lack of dynamic scapula winging, and hiking.
- Sufficient scapular strength base: Demonstration of strength gains via PRE in proportion to body type/size.
- 5/5 Manual muscle testing throughout involved upper extremity (scapular muscles, humeral head positioners, and rotator cuff muscles).

Phase II (weeks 8 to 14)

Clinical Pearls

- Many patients/athletes with MDI may very well enter their rehabilitation program at an advanced level as described here in Phase II. This advanced phase emphasizes the need to clinically evaluate the athlete to properly challenge the shoulder complex.
- Dynamic neuromuscular control about the glenohumeral joint is crucial for optimal performance in sports. EMG studies have demonstrated that patients with MDI exhibit altered functioning of the humeral head positioners and dynamic stabilizers of the glenohumeral joint during functional and complicated movements.
- Because ROM and muscle strength have been normalized before this phase is entered, a greater emphasis is placed on training the neuromuscular structures throughout the shoulder complex during this phase.

Protection

- Activity modification in ADL, avoiding motions that bring on symptoms (pain, instability) e.g., overhead movements.

Management of Pain and Swelling

- Ice and electrical stimulation (TENS) as needed.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Continue humeral head control/rhythmic stabilization exercises.
- Proprioceptive neuromuscular facilitation (PNF) patterns with manual resistance (D1, D2) (Figure 3-14).

Soft Tissue Techniques

- Soft tissue massage to scapular musculature.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Address inflexibility issues on an individual basis: e.g., pectoralis minor tightness, glenohumeral IR deficits (GIRD) (thixotrophy of the infraspinatus and teres minor).

Other Therapeutic Exercises

- Lower-extremity strengthening program, running, plyometrics specific to sport.
- Core-stability program.
- Wrist and elbow strengthening, especially for throwing athletes.

Activation of Primary Muscles Involved

- Scapular stabilizers (serratus anterior; rhomboids; upper, middle, and lower trapezius; levator scapulae).

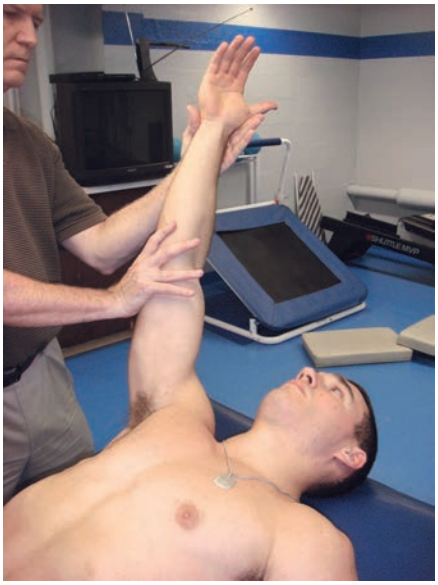

FIGURE 3-14. Manual resistance with PNF D2 pattern.

- Glenohumeral stabilizers (deltoid, humeral head positioners, rotator cuff musculature).

Sensorimotor and Neuromuscular Dynamic Stability Exercises

- Rhythmic stabilization.
- Humeral head control exercises.
- PNF exercises.
- Scapular stabilization exercises, CKC using a physioball on wall: bilateral → unilateral → manual perturbations.
- Bodyblade (below horizontal).

Techniques to Increase Muscle Strength, Power, and Endurance

Open and Closed Kinetic Chain Exercises

- IR/ER TheraBand (modified neutral).
- IR/ER isokinetics (modified neutral).
- Scaption with weights (PRE).
- Ball stabilization on wall.
- Serratus "punches" (PRE).
- Prone "hitch-hiker" (middle trapezius muscle strengthening).
- Prone lower-trapezius strengthening (PRE).
- Biceps/triceps (PRE).
- Row machine (PRE).
- Chest press machine (PRE) (limit arc) to symptom-free ROM.
- Latissimus dorsi pulldown machine (PRE) (limit arc) to symptom-free ROM.
- Upper-body ergometer.

Functional Exercises

- D1/D2 PNF patterns with TheraBand or resistance exercise machines.
- Resistance exercise machine or pulley system: reciprocal flexion.

Plyometrics

- Two-handed chest press toss vs. plyoback.

Sport-Specific Exercises

- Baseball, tennis, volleyball, golf: scaption, trunk rotation exercises seated on physioball.
- Swimming: prone PRE exercises; e.g., lower trapezius, "hitch-hiker," shoulder extension on physioball (Figure 3-15).

Milestones for Progression to the Next Phase

- Lack of apprehension with overhead movements.
- IR/ER isokinetic test greater than 75% limb symmetry.
- 0/10 pain in all ADL.



FIGURE 3-15. "Hitch-hiker" exercise performed prone on physioball.

Phase III (weeks 14 to 20)

Clinical Pearls

- With the athlete relatively asymptomatic and having achieved a sufficient strength base, he/she is now ready to challenge the shoulder complex with more demanding exercises that mimic the demands of their individual sport.
- During this phase, emphasis is placed on increasing strength, power, and endurance as well as a gradual return to sport.
- Valuable information can be gained from isokinetic testing, so that any deficits or muscle imbalances across the glenohumeral joint can be addressed in the final phase of rehabilitation.
- Intensity and volume should be structured and closely monitored to avoid overuse symptoms from developing.

Management of Pain and Swelling

- Ice and electrical stimulation (TENS) as needed.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Continue humeral head control/rhythmic stabilization exercises.
- PNF patterns with manual resistance (D1, D2).

Soft Tissue Techniques

Continue soft tissue massage to upper extremity as needed.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Continue to address inflexibility issues on an individual basis: e.g., pectoralis minor tightness, GIRD (thixotrophy of the infraspinatus and teres minor).

Other Therapeutic Exercises

- Lower-extremity strengthening program, running, plyometrics specific to sport.
- Core-stability program.
- Wrist and elbow strengthening, especially for throwing athletes.

Activation of Primary Muscles Involved

- Scapular stabilizers (serratus anterior; rhomboids; upper, middle, and lower trapezius; levator scapulae), glenohumeral stabilizers (deltoid, humeral head positioners, rotator cuff musculature).

Sensorimotor and Neuromuscular Dynamic Stability Exercises

- Rhythmic stabilization.
- Humeral head control exercises (give some specific examples of exercises to accomplish this).
- PNF exercises.
- Scapular stabilization exercises, CKC using a physioball on wall: unilateral with manual perturbations.
- Bodyblade (above horizontal).
- BOSU ball upper-extremity stabilization, bilateral → unilateral with perturbations (Figure 3-16).

Techniques to Increase Muscle Strength, Power, and Endurance

Open and Closed Kinetic Chain Exercises

- IR/ER TheraBand (modified neutral and 90°/90°).
- IR/ER isokinetics (modified neutral).
- Scaption with weights (PRE).
- Unilateral ball stabilization on wall.
- Serratus "punches" (PRE).
- Prone "hitch-hiker" (middle trapezius).
- Prone lower-trapezius strengthening (PRE).



FIGURE 3-16. Upper-extremity stabilization using BOSU® ball (foot taps for perturbations).

- Biceps/triceps (PRE).
- Row machine (PRE).
- Chest press machine (PRE).
- Latissimus dorsi pulldown machine (arc) (PRE).
- Military press (PRE).
- Bench press (wide grip).
- Upper-body ergometer.

Plyometrics

- Advance to overhead "soccer throw," diagonal toss (overhead) vs. plyoback.
- D2 deceleration with plyoball off wall (throwers).
- Unilateral plyoball toss: supine → standing (90/90) vs. plyoback.

Functional Exercises

- D1/D2 PNF patterns with TheraBand or resistance exercise machines.
- Resistance exercise machine or pulleys system: reciprocal flexion.

Sport-Specific Exercises

- Baseball, tennis, volleyball, golf: Scaption, military press, trunk rotation exercises seated on physioball.
- Swimming: Prone PRE exercises; e.g., lower trapezius, "hitch-hiker," shoulder extension on physioball.
- Resistance exercise machine or pulley system to replicate sport-specific movements: e.g., forehand/backhand tennis, polling cross-country skiing movement.
- Interval throwing program (baseball).
- Tennis: ground strokes → overhead volleys/serving (monitor volume).
- Volleyball: Overhead serving/spiking (monitor volume).
- Swimming: breaststroke → freestyle before advancing to backstroke/butterfly (monitor volume).

Milestones for Progression to Advanced Sport-Specific Training and Conditioning

- Asymptomatic (apprehension/pain) with overhead sport-specific ovements.
- IR/ER isokinetic test greater than 90% limb symmetry.
- Independent with home/gym therapeutic exercise program for maintenance and progression of strength, power, endurance gains made in physical therapy.

Criteria for Abandoning Nonoperative Treatment and Proceeding to Surgery or More Intensive Intervention

- Continued pain, apprehension, or complaints of instability during ADL and/or sport-specific exercises and movements.
- Poor compliance with rehabilitation resulting in continued symptoms.

Tips and Guidelines for Transitioning to Performance Enhancement

- Care is taken to avoid overtraining and incorporating rest and cross training into the treatment regimen.
- The athlete should take note to initially avoid combining weight training and sport-specific training, e.g., throwing, swimming, tennis strokes on the same day. As symptoms allow, sport-specific training can be performed on consecutive days.
- Communication with the athlete's strength and conditioning coach or whoever will be responsible for the continuation of care is vital to ensure a safe, noncomplicated return to sport.

Performance Enhancement and Beyond Rehabilitation: Training/Trainer and Optimization of Athletic Performance

- It is vital to communicate with the athlete's coach that upon to return to team practice, the athlete returning from injury is not be treated the same as team players who are otherwise deemed healthy.
- Volume and repetitions need to be modified for the individual who has returned to the team following his/her course of rehabilitation.
- Bracing for sports such as football and lacrosse may be recommended by the physician on an individual basis (Figure 3-17).



FIGURE 3-17. Shoulder stabilizer brace (Breg Inc., Vista, CA).

Specific Criteria for Return to Sports Participation: Tests and Measurements

- Asymptomatic (apprehension/pain) with overhead sport-specific movements.
- IR/ER isokinetic test > 90% limb symmetry (muscular strength, power, and endurance).
- Isokinetic test: ER to IR ratio > 70%.
- Independent with home/gym therapeutic exercise program for maintenance and progression of strength, power, and endurance gains made in physical therapy.
- Physician clearance.

Evidence

Burkhead WZ, Jr, Rockwood CA, Jr: Treatment of instability of the shoulder with an exercise program. *J Bone Joint Surg Am* 74:890–896, 1992.

Authors reported that when using a conservative rehabilitation program for atraumatic shoulder instability, 66 (86%) of their patients obtained good to excellent results. (Level III evidence).

Cordasco FA, Wolfe IN, Wootlen ME, et al: An electromyographic analysis of the shoulder during a medicine ball rehabilitation program. *Am J Sports Med* 24:386–392, 1996.

The authors studied the electromyographic activity of the shoulder girdle musculature during a two-handed medicine ball throw. High levels of activity were identified during the acceleration phase of the throw. Their findings support the use of medicine ball training as a bridge between static resistive training and dynamic throwing in the rehabilitation of the throwing athlete. (Level IV evidence).

Hawkes DH, Alizadehkhaiyat O, Fisher AC, et al: Normal shoulder muscular activation and co-ordination during a shoulder elevation task based on activities of daily living: an electromyographic study. *J Orthop Res* 30:53–60, 2012.

Upper-limb functional status was assessed in 12 healthy male volunteers using the Functional Impairment Test-Hand, Neck, Shoulder and Arm test (FIT-HaNSA). Electromyography was then used to study the activity and coordination of 13 muscles around the shoulder during a dynamic movement task based on the shelf-lifting task in FIT-HaNSA. The study concluded that the deltoid, adductor, and rotator cuff muscles all contribute to the muscular component of glenohumeral joint stability. (Level IV evidence).

Illyes A, Kiss RM: Electromyographic analysis in patients with multidirectional shoulder instability during pull, forward punch, elevation and overhead throw. *Knee Surg Sports Traumatol Arthrosc* 15:624–631, 2007.

This study compared the EMG activity from eight different muscles of patients with multidirectional shoulder instability and a control group during pull, forward punch, elevation, and overhead throw activities. Test results suggested that, in patients with multidirectional shoulder instability, the various motions are performed in a different way. The results give rise to the assumption that the centralization of the glenohumeral joint and the reduction of instability are attempted to be ensured by increasing the role of rotator cuff muscles and decreasing the role of the deltoid, biceps brachii, and pectoralis major muscles. The time difference between the peaks of normalized voluntary electrical activity was shown to be significantly greater in the patients with MDI than in the control group. (Level III evidence).

Morris AD, Kemp GJ, Frostick SP: Shoulder electromyography in multidirectional instability. *J Shoulder Elbow Surg* 13:24–29, 2004.

The study examined shoulder muscle activity in MDI and multidirectional laxity (MDL) of the shoulder. Six muscles (supraspinatus, infraspinatus, subscapularis, anterior deltoid, middle deltoid, and posterior deltoid) were investigated by use of intramuscular dual fine-wire electrodes in seven normal shoulders, five MDL shoulders, and six MDI shoulders. Each subject performed five types of exercises on an isokinetic muscle dynamometer. Abnormalities in the deltoid rather than the muscles of the rotator cuff were demonstrated. Altered patterns of shoulder girdle muscle activity and imbalances in muscle forces support the theory that impaired coordination of shoulder girdle muscle activity and inefficiency of the dynamic stabilizers of the glenohumeral joint are involved in the etiology of MDI. (Level III evidence).

Multiple-Choice Questions

QUESTION 1. For athletes who have sustained a recurrent episode of instability, sling immobilization should be used for no greater than:

A. 2 weeks
B. 4 weeks
C. 6 weeks
D. 8 weeks

QUESTION 2. For athletes who have sustained an episode of anterior instability, which motion will initially be limited?

A. IR
B. ER
C. Horizontal adduction
D. Flexion to 45°

QUESTION 3. All of the following exercises strengthen in isolation one of the scapular muscles, except:

A. Supine "punch"
B. Prone "hitch-hiker"
C. Shrugs
D. CKC ball stabilization on wall

QUESTION 4. In determining strength assessment for return to sport, IR/ER isokinetic testing should reveal a limb symmetry of:

A. 70%
B. 80%
C. 90%
D. 100%

QUESTION 5. Toward the latter stages of rehabilitation, an athlete transitions into a sport-specific training (throwing, swimming, etc.) program. Such training should initially be performed.

A. Every day
B. Every other day
C. Every 3 days
D. Once a week

Answer Key

QUESTION 1. Correct answer: **A** (see Phase I)

QUESTION 2. Correct answer: **B** (see Phase I)

QUESTION 3. Correct answer: **D** (see Phase II)

QUESTION 4. Correct answer: **C** (see Phase III)

QUESTION 5. Correct answer: **B** (see Phase III)

POSTOPERATIVE REHABILITATION AFTER TREATMENT OF MULTIDIRECTIONAL SHOULDER INSTABILITY

John T. Cavanaugh, PT, MEd, ATC, SCS, and Scott A. Rodeo, MD

Indications for Surgical Treatment

- Persistent symptoms of instability with ADL and/or sports activity following a comprehensive rehabilitation program
  - Symptoms may include either pain or apprehension
- Generalized ligamentous laxity may increase risk of failure of conservative management
- Glenoid bone loss increases risk of persistent instability and need for surgical treatment

Brief Summary of Surgical Treatment

Major Surgical Steps

- Basic principle of surgery is to address the underlying pathology
  - Labral reattachment as needed
  - Appropriate capsular tensioning and glenohumeral joint capsular volume reduction
  - Address glenoid or humeral head bone loss as indicated

Factors That May Affect Rehabilitation

- Open vs. arthroscopic approach
- Subscapularis tenotomy will require postoperative protection
- Glenoid bone grafting (Latarjet or Bristow procedure) should be considered
- Remplissage (infraspinatus tenodesis for large Hills-Sachs lesion) requires delayed initiation of active ER to allow tendon-to-bone healing

GUIDING PRINCIPLES OF POSTOPERATIVE REHABILITATION

- Protect surgical correction
- Early controlled ROM
- Patient education
- Treat patient/athlete as an individual
- Follow a functional progression of therapeutic exercise
- Criteria-based guideline

Phase I (days 0 to 14): Immediate Postoperative Period[1]

Clinical Pearls

- This first phase of rehabilitation is designed to allow maximal protection to the surgical correction performed.
- Postoperative pain is controlled with the use of cryotherapy, analgesics, and NSAIDs.
- The patient is educated to use his/her sling at all times, with the exception of self-care and distal AROM exercises.
- Proper donning and doffing of the sling is instructed as to aid in the protection of the surgical correction.
- It is very important for the patient to perform elbow AROM so as to avoid the development of a flexion contracture.

Goals

- Pain control
- Decrease swelling
- Independent donning/doffing of sling
- Prevent elbow flexion contracture

Protection

- Sling immobilization with an abduction pillow (so as to approximate neutral rotation in the scapular plane) is used at all times, except for self-care, hygiene, etc.

Management of Pain and Swelling

- Analgesic and NSAID medications
- Cryotherapy: Game-ready cryotherapy system (Figure 3-18).
- Electrical stimulation for pain control, i.e., TENS, interferential current (IFC) estim (as needed)
- Patient education
- Proper sling donning/doffing
- Positioning for comfort/sleeping

[1]*Prehabilitation, if appropriate, is described in the Nonoperative Rehabilitation section of this chapter.*



FIGURE 3-18. Game-ready cryotherapy system.

Therapeutic Exercises

- AROM exercises for elbow, wrist, and hand
  - Elbow ROM exercises: Flexion/extension, supination/pronation performed supine with involved upper arm supported with rolled towel approximating plane of the scapula. Emphasis on full active extension is encouraged
  - Hand gripping and active wrist flexion/extension AROM exercises
- Cardiovascular exercise using a stationary bicycle is encouraged, particularly for the athletic patient.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

Biceps/triceps/supinators/pronators/wrist extensors and flexors/hand intrinsic via distal AROM exercises

Milestones for Progression to the Next Phase

- Postoperative pain decreased
- Incisions well healed/no sign of infection
- No reported incidence of trauma that would indicate disruption of surgical correction

Phase II (weeks 2 to 6 postoperatively)

Clinical Pearls

- ROM is achieved via active-assisted and passive exercises.
- Any PROM exercises are performed without complaints of pain.
- Care is given to ensure patient performs these exercises in the scapular plane.
- As ROM improves, hydrotherapy using exercises in water at/below the patients shoulder level ensures a safe environment for ROM gains.

Goals

- Protect surgical correction
- Decrease pain/swelling
- Improve glenohumeral ROM (scapular plane): ER/IR → 30°, forward flexion (FF) → 120°
- Reestablish humeral head and scapula control
- Independent home exercise program

Protection

- Sling immobilization is continued at all times except for therapeutic exercises, self-care, hygiene, etc. At 4 to 5 weeks postoperatively, the sling may be discontinued in areas deemed to ensure a safe environment (home, office, etc.). This lifted restriction will be

TIMELINE 3-2: **Postoperative Rehabilitation after Treatment of Multidirectional Shoulder Instability**

PHASE I (weeks 0 to 2)	PHASE II (weeks 2 to 6)	PHASE III (weeks 6 to 12)

• Sling immobilization
• PT modalities:
  • Game-ready cryotherapy system
• TBS/TAS/TLS activities as recommended and tolerated
	• Sling immobilization
	• PT modalities
	• AAROM exercises, scapular plane:
	  • ER → 30°
	  • IR → 30°
	  • FF → 120°
	• Codman's exercises
	• Scapular exercises, manual/isometrics
	• Week 4:
	  • Pool therapy
	  • Deltoid isometrics (submaximal)
	  • IR/ER isometrics (submaximal)
	• TBS/TAS/TLS activities as recommended and tolerated
		• D/C sling
		• PT modalities as needed
		• AAROM exercises:
		  • ER → 60°
		  • IR → 45°
		  • FF → 160°
		• Joint mobilizations (gentle) as needed
		• TBS/TLS activities as recommended. and tolerated
		• Scapular exercises (PREs)
		• FF (scapular plane) "scaption": PREs
		• Biceps/triceps PREs
		• Glenohumeral extension: theraband/PREs (below 90° elevation)
		• IR/ER strengthening: Theraband/PREs
		• Humeral head control exercises: Rhythmic stabilization
		• Airdyne/upper-body ergometer
		• Scapular stabilization exercises: CKC (below 90° elevation)
		• CKC perturbation exercises

determined by gains in ROM, patient comfort level, and physician's preference.

Management of Pain and Swelling

- Cryotherapy: Ice packs, game ready
- Moist heat packs before mobilization exercises
- Electrotherapy (TENS, IFC) if indicated
- Analgesic/NSAID medication as needed

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- ROM precautions: IR 30°/ER 30° (scapular plane), horizontal adduction 0°, scapular plane elevation to 120°
- PROM (pain-free) exercises to glenohumeral joint (limitations as mentioned above), PROM exercises performed supine with scapula stabilized, gentle grade I glenohumeral joint mobilizations
- Careful attention to protect posterior capsule from unnecessary stress
- Side-lying scapula AROM, AAROM, and PROM exercises (scapular elevation, depression, retraction, and protraction) to restore normal scapulothoracic mobility

Soft Tissue Techniques

- Scar mobilization to postsurgical incisions once closed.
- Soft tissue massage (scapular musculature)

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Codman's exercise, emphasizing proper techniques.
- Wand exercise ER, performed supine (scapular plane) (Figure 3-19)
- AAROM exercise FF (scapular plane) performed supine using noninvolved upper extremity. Exercise progressed to using wand as ROM and humeral head control is established.
- AAROM forward flexion (scapular plane) using pulleys as ROM approximates 120° technique emphasized to discourage compensatory shrugging of shoulder girdle.

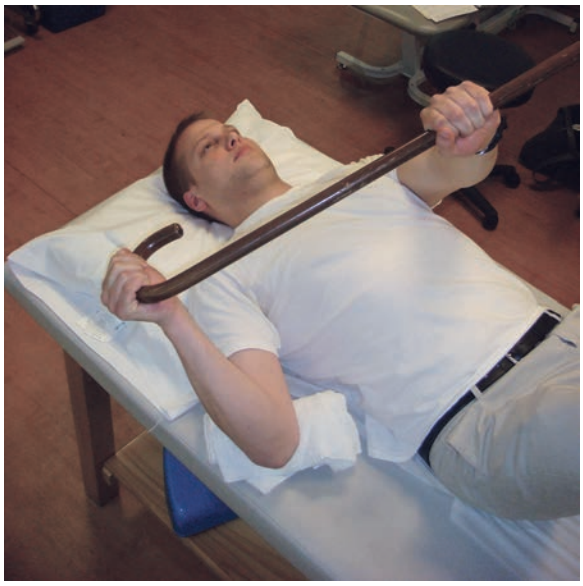

FIGURE 3-19. Wand exercise for ER in scapular plane.

Other Therapeutic Exercises

- Cardiovascular exercise using a stationary bicycle and/or elliptical machine
- Distal strengthening: wrist flexors/extensors with PRE
- Core-stabilization exercises
- Lower-extremity strengthening: CKC (body weight)/open kinetic chain (OKC) (PRE)
- Pool therapy exercises are initiated: AAROM scaption, scapular retraction/protraction, horizontal abduction/adduction (0°)

TIMELINE 3-2 Postoperative Rehabilitation after Treatment of Multidirectional Shoulder Instability (Continued)

PHASE IV (weeks 12 to 20)	PHASE V (weeks 20 to 30)

• PT modalities as needed
• AAROM exercises:
  • ER → 75°
  • IR → 60° (protect posterior capsule)
  • FF → 170°
• Mobilizations as needed:
  • Scapular exercises (PREs)
• FF, scapular plane, ("scaption"): PREs
• Biceps/triceps PREs
• Glenohumeral extension: Theraband/PREs (greater than 90° elevation)
• IR/ER strengthening: Theraband/PREs/isokinetics
• Humeral head control exercises: Rhythmic stabilization
• Scapular stabilization exercises: CKC
• CKC perturbation exercises
• Airdyne/upper-body ergometer
• Chest press (arc)
• PNF exercises: Manual/theraband/PRE
• TBS/TAS/TLS activities as recommended and tolerated
• Upper-extremity sport-specific activities
	• PT modalities as needed
	• Progress ROM to WNL
	• Flexibility exercises
	• Mobilizations as needed
	• Sleeper stretch IR
	• Scapular exercises (PREs)
	• FF (scapular plane) "scaption": PRE
	• Biceps/triceps PRE
	• Glenohumeral extension theraband/PRE (greater than 90° elevation)
	• IR/ER strengthening: Theraband/PRE/isokinetics: 90/90
	• Isokinetic test
	• Humeral head control exercises: Rhythmic stabilization
	• Scapular stabilization exercises: CKC/unilateral
	• CKC perturbation exercises
	• Airdyne/upper-body ergometer
	• Chest press
	• Military press: PRE
	• PNF exercises: Manual/TheraBand/PRE
	• Plyometrics: Below horizontal, progressing to overhead
	• TBS/TAS/TLS activities as recommended and tolerated
	• Sport-specific training/monitor volume
	• Interval throwing program
	• Swimming



FIGURE 3-20. Side-lying AROM and resisted scapula exercises.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Side-lying AROM and resisted scapula exercises to initiate the reestablishment of scapular stability (Figure 3-20)
- Humeral head control exercise IR/ER (supine/scapular plane) to reeducate rotator cuff musculature to reestablish neuromuscular control of dynamic stabilizers
- Submaximal isometrics: Anterior/middle/posterior deltoid performed in neutral rotation (short lever arm/elbow at 90° flexion)
- Submaximal isometrics: Rotator cuff musculature. ER/IR performed in modified neutral (scapular plane), once 30° of passive ER/IR is attained.
- Scapular retraction isometrics
- Postural exercises/awareness

Sensorimotor Exercises

- Humeral head control exercises/rhythmic stabilization (manual)

Neuromuscular Dynamic Stability Exercises

- Lower-extremity balance activities: stable surface → unstable surface, bilateral support → unilateral support. Add perturbations when appropriate

Phase III (weeks 6 to 12 postoperatively)

Clinical Pearls

- Gradual restoration of IR and horizontal adduction is begun in this phase.
- The clinician should continue to respect the healing response of the posterior capsule.
- ROM exercise should continue to be performed in the scapular plane throughout this phase.
- Scapular musculature strengthening is emphasized during this phase to develop a stable/strong base for the more demanding exercises and sport-specific activities to follow in later stages of this rehabilitation program.

Goals

- Improve PROM: (scapular plane) elevation → 160°, ER → 60°, IR → 45°, horizontal adduction → 20°
- Improve scapulohumeral rhythm to within normal limits (WNL) less than 90° elevation (scapular plane)
- Independent with home therapeutic exercise program

Protection

- Sling is gradually discontinued from week 6 to week 8, depending on functional status and living/working environment

Management of Pain and Swelling

- Moist heat (before exercise)
- Cryotherapy (after exercise and as needed)
- NSAIDs
- Oral analgesics as needed

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- ROM Precautions: IR 45°/ER 60° (scapular plane), horizontal adduction 20°, scapular plane elevation to 160° PROM (pain-free) exercises to glenohumeral joint (limitations as mentioned above) PROM exercises performed supine with scapula stabilized.
- Gentle grade I glenohumeral joint mobilizations
- Careful attention to protect posterior capsule from unnecessary stress

Soft Tissue Techniques

- Continue soft tissue massage: scapular musculature, latissimus dorsi, and pectoralis major/minor
- Continue scar mobilization to post surgical incisions as needed

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Wand exercise for forward elevation is advanced to pulleys when athlete demonstrates PROM of 120° elevation and good humeral head control. Proper technique is emphasized so as to avoid any compensatory shoulder shrugging
- Pool exercises incorporate horizontal abduction to 20°

Other Therapeutic Exercises

- Lower-extremity strengthening continues with OKC and CKC exercises with PRE
- Upper-extremity strengthening (besides specific exercises listed below) include airdyne bicycle and upper-body ergometers
- Cardiovascular conditioning includes treadmill walking, stationary bicycle, elliptical trainer, StairMaster and versa climber

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Humeral head control exercises: IR/ER (supine/scapular plane) to reeducate rotator cuff musculature to re-establish neuromuscular control of dynamic stabilizers.
- Rhythmic stabilization of humeral positioners at 110° elevation (scapular plane)

  Strengthening emphasis during this phase is placed on the scapular musculature. Isolated strengthening of the trapezius muscles, rhomboids, and serratus anterior are performed via PRE, such as scapular retraction on a row machine, supine punches (Figure 3-21), prone horizontal abduction, and bilateral ER with TheraBand (elbows bent to 90°/at side). Closed-chain exercises are initiated with weight shifts (wide-based hand position to approximate scapular plane and avoid direct load to posterior capsular), progressing to physioball stabilization against a plyoback (below 90°elevation).
- Forward plane elevation in the scapular plane (scaption) is initiated upon the athlete demonstrating normal scapulothoracic rhythm. Progressive resistance is applied and progressed as tolerated (Figure 3-22).
- Isolated rotator cuff strengthening for ER/IR is progressed to TheraBand once 60° of ER and 45° of IR are attained. This exercise is performed in a modified neutral position. (towel in axilla)
- Resisted bicep and tricep muscular strengthening

Sensorimotor Exercises

- Rhythmic stabilization, supine (scapular plane, progressing to multiangle humeral positioning)
- CKC stabilization exercises (physioball stabilization below 90° on a plyoback), progressing to perturbations.

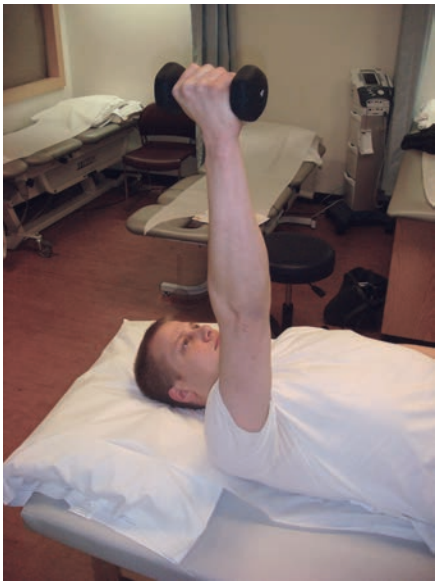

FIGURE 3-21. Supine "punches" for serratus anterior muscle strengthening.



FIGURE 3-22. Forward plane elevation in the scapular plane (scaption).

Open and Closed Kinetic Chain Exercises

- Described above

Techniques to Increase Muscle Strength, Power, and Endurance

- Progressive resistance for the exercises discussed above
- Aggressive strengthening as tolerated for scapula musculature
- Light resistance for isolated rotator cuff exercises and scaption exercise (respecting long lever arm)

Neuromuscular Dynamic Stability Exercises

- Described above

Milestones for Progression to the Next Phase

- PROM: (scapular plane) elevation → 160°, ER → 60°, IR → 45°, horizontal adduction → 20°
- Scapulohumeral rhythm to WNL less than 90° elevation (scapular plane)

Phase IV (weeks 12 to 20 postoperatively)

Clinical Pearls

- It is imperative that full ROM be attained during this phase of rehabilitation in order for the athlete to safely return to sport on schedule.
- This is achieved via PROM, AAROM, and flexibility exercises.
- Not only will full ROM be required for sports participation, particularly in the overhead athlete, but full ROM will be needed for aggressive strengthening (isokinetics, plyometrics), which will be introduced to the rehabilitation program in this phase.

Goals

- Improve ROM to WNL
- Improve muscle strength to 5/5 throughout involved upper extremity
- Restore scapulohumeral rhythm throughout ROM
- Full ADL

Management of Pain and Swelling

- Cryotherapy (after exercise and as needed)
- NSAIDs as needed
- Oral analgesics as needed

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Progress ROM to full PROM as tolerated
- Glenohumeral joint mobilizations

Soft Tissue Techniques

- Continue soft tissue massage: scapular musculature, latissimus dorsi, and pectoralis major/minor
- Continue scar mobilization to postsurgical incisions as needed
- Massage therapist consult if needed

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Wand ER stretching 90°/90°
- End-range FF stretch (doorway)
- Towel stretch (IR)
- Posterior capsule stretch
- "Sleeper" stretch (IR) (Figure 3-23)

Other Therapeutic Exercises

- Lower-extremity strengthening continues with OKC and CKC exercises with PRE
- Upper-extremity strengthening/conditioning: airdyne, upper-body ergometers, rowing ergometer



FIGURE 3-23. "Sleeper" stretch" for IR.



FIGURE 3-24. ER/IR Isokinetic strengthening (modified neutral position).

- Cardiovascular conditioning includes treadmill running, stationary bicycle, elliptical trainer, StairMaster, and versa climber

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Progress upper-extremity strengthening (PRE): Row (scapular retraction), chest press, latissimus dorsi pulldown, biceps, triceps
- Progress scapular musculature strengthening (PRE) via OKC (isolated) and CKC (stabilization) exercises: Physioball stabilization is progressed to 90° elevation, then to unilateral (involved) stabilization with a plyoball
- Scaption (long lever arm) PRE, monitoring correct form
- ER/IR strengthening using isokinetics (moderate → fast speeds/modified neutral positioning) (Figure 3-24)
- ER/IR strengthening progressed to 90/90 position using TheraBand when ROM is WNL
- PNF (D2/D1) patterns with manual resistance progressing to TheraBand

Sensorimotor Exercises

- Continue humeral head control and rhythmic stabilization exercises at various ROM positions
- CKC scapular stabilization with perturbations

Open and Closed Kinetic Chain Exercises

- Pushup progression (CKC) is initiated using wide base of support (protect posterior capsule from direct sagital plane load) wall pushups → pushups (angle) → floor pushups.

Techniques to Increase Muscle Strength, Power, and Endurance

- Consider changing repetitions/program should athlete participate more than 5 days/week, i.e., strengthening sets 3 × 10, 2 × 10, 1 × 10 to prevent overuse symptoms from presenting and to add variety to program.
- Continue lower-extremity strengthening, flexibility balance programs
- Progress core strengthening

Neuromuscular Dynamic Stability Exercises

- Rhythmic stabilization exercises as described above. Progress to less stable positioning, i.e., sitting/standing

Plyometrics

- Initiate chest pass below 90° on plyoback
- Lower-extremity plyometrics

Sport-Specific Exercises

- Lower-extremity drills (sport-specific), i.e., agility, hopping, bounding
- Upper-extremity sport-specific activities permitted at 4 months should ROM and muscle strength be WFL, e.g., baseball (fielding ground balls/hitting; noninvolved lead shoulder before involved lead shoulder), golf (chipping/putting), volleyball (bumping/setting), swimming (breaststroke), tennis (ground strokes)

Milestones for Progression to the Next Phase

- Full ROM
- Muscle strength 5/5 throughout involved upper extremity
- Normal scapulohumeral rhythm throughout ROM

Phase V (weeks 20 to 30 postoperatively)

Clinical Pearls

- Having met the goals of restoring full ROM throughout the earlier phases, the goal in this last phase of rehabilitation is to ensure that the athlete has the sufficient amount of strength, power, endurance, and flexibility to meet the demands of his/her specific sport.
- A periodization approach to rehabilitation is taken, whereas the athlete performs varied workouts throughout the week.
- Sport-specific training one day (throwing, swimming, etc.), weight training on another day.
- Volume of weight training should be monitored, as should volume of sport-specific activity (throws, yardage swam, etc.).
- The athlete needs to be closely monitored for signs of overuse.
- Rehabilitative programs often need to be adjusted if and when subjective complaints present.

Goals

- Improve muscle strength, power, and endurance greater than 90% limb symmetry via isokinetic testing ER/IR
- ER/IR ratio within 85% of contralateral upper extremity
- Maximize flexibility so as to meet the demands of specific sport
- Lack of apprehension, instability, and pain with sport-specific movements
- Independent with home and gym therapeutic exercise programs

Management of Pain and Swelling

- Cryotherapy (after exercise and as needed)
- NSAIDs as needed
- Oral analgesics as needed

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Continue above treatment strategies to maintain ROM and enhance flexibility
- Glenohumeral joint mobilizations
- Cervical/thoracic mobilizations as needed

Soft Tissue Techniques

- Continue soft tissue massage: Scapular musculature, latissimus dorsi, and pectoralis major/minor
- Continue scar mobilization to postsurgical incisions as needed

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Continue upper-extremity stretching program as part of warmup and cool-down portions of rehabilitation program.

Other Therapeutic Exercises

- Lower-extremity strengthening continues with OKC and CKC exercises with PRE and plyometrics
- Upper-extremity strengthening/conditioning: Airdyne, upper-body ergometers, rowing ergometer
- Cardiovascular conditioning includes running, stationary bicycle, elliptical trainer, StairMaster and versa climber

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Continue PRE to involved upper extremity

Sensorimotor Exercises

- Continue rhythmic stabilizations at different angles

Open and Closed Kinetic Chain Exercises

- Continue exercises as listed earlier (PRE)
- Front raises (below 90°), lateral raises (below 80°)
- Pushups on BOSU® ball
- PNF patterns with TheraBand sitting on physioball → perturbations

Techniques to Increase Muscle Strength, Power, and Endurance

- Incorporate training programs to days specific to strength (low reps), power (speed), and endurance (high reps), i.e., periodization
- Velocity spectrum training with isokinetics
- Initiate bench press (wide grip) PRE. It is not realistic for the athlete to match their personal best with bench pressing until greater than 1 year after operation

Neuromuscular Dynamic Stability Exercises

- CKC stabilization on BOSU® ball: Bilateral support (eyes open → eyes closed) → perturbations → unilateral support (eyes open → eyes closed) → perturbations

Plyometrics

- Bilateral overhead throws ("soccer throws") against plyoback
- 90/90 toss/catch (supine) of plyoball with rehabilitation specialist
- Unilateral (involved extremity) throws with plyoball 90/90 against plyoback
- Deceleration D2 PNF pattern off wall with plyoball (throwing athletes)

Sport-Specific Exercises

- Continue lower-extremity drills (sport-specific), i.e., agility, hopping, bounding
- Upper-extremity sport-specific activities progressed to overhead activities, e.g., interval throwing program (baseball), high irons → middle irons → low irons (golfer), serving/spiking (volleyball), freestyle → backstroke → butterfly (swimming), and serving (tennis). These activities should not be performed on consecutive days, with symptoms and volume closely monitored

Milestones for Progression to the Next Phase

- Muscle strength, power, and endurance greater than 90% limb symmetry via isokinetic testing ER/IR
- ER/IR ratio within 85% of contralateral upper extremity
- Flexibility in line with the demands of specific sport
- Lack of apprehension, instability, and pain with sport-specific movements
- Independent with home and gym therapeutic exercise programs

Criteria for Return to Sport

General

- Muscle strength, power, and endurance greater than 90% limb symmetry via isokinetic testing ER/IR (dominance corrected)
- ER/IR ratio within 85% of contralateral upper extremity
- Flexibility in line with the demands of specific sport
- Lack of apprehension, instability, and pain with sport-specific movements
- Independent with home and gym therapeutic exercise programs

Sport-Specific

Return to sports should follow a progression protecting the surgical correction. ROM and muscle strength should approach near normal ranges before initiating sport-specific activities. Dominance should be taken into consideration when evaluating isokinetic measures because dominance has been shown to yield 10% greater torque values.

- Baseball: Hitting will preclude throwing. A right-handed hitter with a surgically repaired right shoulder will be allowed to hit before a right-handed hitter with a surgically repaired left shoulder.
- Tennis: Ground strokes with proper technique are allowed before overhead volleys and serving
- Swimming: Breaststroke will be allowed before freestyle. Volume of activity closely monitored

After Return to Sport

Continuing Fitness or Rehabilitation Exercises

- Upper- and lower-extremity strengthening exercises
- Flexibility exercises
- Core-stabilization program

Exercises and Other Techniques for Prevention of Recurrent Injury

- Continue to challenge the neuromuscular/proprioceptive element of the rehabilitation program to better condition the dynamic shoulder stabilizers so that they are prepared to provide stability to the glenohumeral joint during joint loading
- Compliance with home/gym therapeutic exercise program for maintenance and advancement of strength and flexibility gains.

Evidence

Baker CL, 3rd, Mascarenhas R, Kline AJ, et al: Arthroscopic treatment of multidirectional shoulder instability in athletes: a retrospective analysis of 2- to 5-year clinical outcomes. *Am J Sports Med* 37:1712–1720, 2009.

The authors evaluated 40 patients (43 shoulders) with MDI of the shoulder treated via arthroscopic means at a mean of 33.5 months postoperatively. Postoperative rehabilitation with early ROM was used. Ninety-one percent of patients had full or satisfactory ROM, 98% had normal or slightly decreased strength, and 86% were able to return to their sport with little or no limitation. (Level IV evidence).

Ellenbecker TS, Davies GJ: The application of isokinetics in testing and rehabilitation of the shoulder complex. *J Athl Train* 35:338–350, 2000.

Clinical use of upper-extremity isokinetic training and testing reviewed. (Level IV evidence).

Nyiri P, Illyés A, Kiss R, et al: Intermediate biomechanical analysis of the effect of physiotherapy only compared with capsular shift and physiotherapy in multidirectional shoulder instability. *J Shoulder Elbow Surg* 19:802–813, 2010.

This study compared the kinematic parameters and activity pattern of muscles around the glenohumeral joint in MDI treated by only physiotherapy (N-32) and by capsular shift and physiotherapy (N-19), before and after treatment. (N-50) healthy shoulders were used as the control. The physiotherapy strengthened the muscles, but regression lines remained monolinear. Capsular shift and physiotherapy resulted in bilinear regression lines, and normal relative displacement between the rotation center of scapula and humerus was restored. After surgery and physiotherapy the activity pattern of muscles was almost normal. (Level III evidence).

Speer KP, Cavanaugh JT, Warren RF, et al: A role for hydrotherapy in shoulder rehabilitation. *Am J Sports Med* 21:850–853, 1993.

Clinical rationale for using a hydrotherapy rehabilitation program in the early postsurgical rehabilitation period.(Level IV evidence).

Voigt C, Schulz AP, Lill H: Arthroscopic treatment of multidirectional glenohumeral instability in young overhead athletes. *Open Orthop J* 3:107–114, 2009.

This prospective case series of nine young overhead athletes (10 shoulders) evaluates the outcome and the return to sports of young overhead athletes with a persistent, symptomatic, MDI with hyperlaxity treated with an arthroscopic anteroinferior capsular plication and rotator interval closure. At the final follow-up all patients were satisfied; Rowe Score showed 7 "excellent" and "good" results; Constant Score was "excellent" and "good" in 6 and "fair" in 1 patient. Seven of nine patients returned to their previous sports, three of nine at a reduced level. (Level IV evidence).

Voight ML, Thomson BC: The role of the scapula in the rehabilitation of shoulder injuries. *J Athl Train* 35:364–372, 2000.

This clinical update article contains information on the pathomechanics, evaluation, and thorough coverage of rehabilitation methods to optimize scapular function. (Level V evidence).

Multiple-Choice Questions

QUESTION 1. Following surgical correction for MDI, sling immobilization is continued at all times except for therapeutic exercises, self-care, hygiene, etc., until how many weeks postoperatively?

A. 1 to 2 weeks
B. 2 to 3 weeks
C. 3 to 4 weeks
D. 4 to 5 weeks

QUESTION 2. Following surgical correction for MDI, glenohumeral elevation ROM exercises are limited to which of the following planes for the first 12 postoperative weeks?

A. Frontal
B. Scapular
C. Sagital
D. Coronal

QUESTION 3. Following surgical correction of MDI, the posterior capsule is protected from undue stress. IR is limited to 30° in the scapular plane until:

A. 2 weeks
B. 6 weeks
C. 10 weeks
D. 12 weeks

QUESTION 4. Isolated rotator cuff strengthening for ER is progressed from isometric to TheraBand once ____ of ER is achieved.

A. 20°
B. 40°
C. 60°
D. 80°

QUESTION 5. Muscle strength criteria for return to sport of the involved external and internal rotators should exceed ____ limb symmetry.

A. 60%
B. 70%
C. 80%
D. 90%

Answer Key

QUESTION 1. Correct answer: **D** (see weeks 2 to 6)

QUESTION 2. Correct answer: **B** (see weeks 6 to 12)

QUESTION 3. Correct answer: **B** (see weeks 2 to 6)

QUESTION 4. Correct answer: **C** (see weeks 6 to 12)

QUESTION 5. Correct answer: **D** (see weeks 20 to 30)

BEYOND BASIC REHABILITATION: RETURN TO SWIMMING AFTER TREATMENT OF MULTIDIRECTIONAL SHOULDER INSTABILITY

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Introduction

ASPECTS OF SWIMMING THAT REQUIRE SPECIAL ATTENTION IN REHABILITATION

- Repetitive movement in an overhead position that requires:
  - Full ROM
  - Adequate muscle strength of the core, scapula, and rotator cuff muscles to meet the demands of swimming
  - Adequate neuromuscular control of the glenohumeral joint
- Large training volumes, year round
- The shoulder is inherently susceptible to injury in overhead sports. For swimmers, shoulder pain is the most common musculoskeletal complaint. It has been reported that competitive swimmers may undergo as many as 16,000 shoulder revolutions per week. Microtrauma is thereby inevitable, with 66% of elite swimmers reporting a shoulder injury at one point in their career.[1]
- Shoulder surgery in the management of "swimmers shoulder" to include debridement, partial release of the coracoacromial ligament, and bursectomy have yielded less than remarkable results.[2]
- Stabilization surgery in swimmers who have failed a nonoperative course of treatment has been reported to be a viable intervention. Return to preinjury training volume, however, is questionable.[3]

Phase I: Advanced Strength and Conditioning Programs (Box 3-1)

Periodization

- Linear
  - Linear periodization will allow the athlete to reestablish a base of strength and endurance in the

BOX 3-1 Advanced Rehabilitation Program

- Prone scapula strengthening for middle and lower trapezius muscles (Figure 3-25).
- IR and ER isokinetic strengthening in a 90/90 position (Figure 3-26).
- Closed kinetic chain stabilization exercises using perturbations (Figure 3-27).
- Prone 90/90 ball catches emphasizing posterior rotator cuff eccentric strengthening (Figure 3-28).



FIGURE 3-25. Prone scapula strengthening for middle and lower trapezius muscles.



FIGURE 3-26. IR and ER isokinetic strengthening in a 90/90 position.



FIGURE 3-27. Closed kinetic chain stabilization exercises using perturbations.



FIGURE 3-28. Prone 90/90 ball catches emphasizing posterior rotator cuff. Eccentric strengthening.

hypertrophy and strength phase followed by the development of power. Undulating periodization programs may be appropriate in subsequent training macrocycles.
- Macrocycles
- The return to swimming macrocycle may take 6 to 12 months depending on the response of the individual athlete to the progressions in each mesocycle.
- Mesocycles
  - Hypertrophy/endurance phase, 3 to 5 weeks
  - Strength phase, 3 to 5 weeks
  - Power phase, 3 to 5 weeks
- Microcycles
  - Gradual increase in sets/reps over the 3- to 5-week cycle
  - Recovery built in to each week, e.g., recovery day following hard training day

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- The goal is to return the athlete to a full training load and successful return to competition. Because muscle weakness, muscle imbalances, lack of flexibility, and faulty mechanics may all place the athlete at risk of injury, it is critical to keep the following principles in mind when designing the training plan.
- Performance enhancement training techniques require a solid foundation of overall strength, core stability, mobility, and cardiorespiratory fitness to prevent possible injury.
- All swimming strokes involve the entire body and require generating force against water. Building the components of mobility, strength, and neuromuscular control will allow the athlete to generate power while reducing drag. This requires a training program that integrates the following concepts.
- Training continuum
  - A gradual progression will give the athlete the best chance to be able to tolerate the high volume of shoulder revolutions involved in training for competitive swimming by creating a base of overall muscular strength and endurance before progressing to higher intensity and sport-specific performance enhancement techniques.
- Training with optimum posture
  - The streamline position is a key factor in reducing drag in the water, so all dry-land exercises should be done with attention to optimum posture.
- Core training
  - Core strength is essential for good swimming technique—rotation in the water, propulsion from the kick and streamline position
- Cardiorespiratory training
  - The volume of cardiorespiratory training done on land would gradually transition to swim training as the upper extremity and trunk musculature gains strength and endurance and can tolerate increasing volume of repetitions.

Olympic Lifts Used in the Training Program

- Snatch
- Clean

Training Principles Used in the Design of the Program

- Because the athlete may have lost overall conditioning as a result of the injury and recovery, a gradual progression will allow the athlete to reestablish a foundation of overall fitness before sport-specific training. The following principles would apply to both the dry-land and water programs.
  - Principle of progression
  - Principle of overload
  - Principle of variation
  - Principle of individualization
  - Principles of specific adaptations to imposed demands (SAID)

Application of Acute Training Variables

- Repetitions
  - Hypertrophy/endurance phase: 10 to 20 reps
  - Strength phase: 4 to 8 reps
  - Power phase: 2 to 5 reps
- Sets
  - Hypertrophy phase: 3 to 6 sets
  - Strength phase: 3 to 5 sets
  - Power phase: 3 to 5 sets
- Rest interval
  - Hypertrophy/endurance: less than 60 seconds
  - Strength phase: 2 minutes
  - Power: 2 minutes
- Intensity
  - Hypertrophy/endurance: 60% to 85% of one-repetition maximum (1RM)
  - Strength: less than 85% of 1RM
  - Power: 75% to 85% of 1RM
- Repetition tempo
  - Hypertrophy: moderate tempo (2/0/2)
  - Strength: moderate/fast
  - Power: fast/explosive
- Training frequency
  - 3 to 4 days



FIGURE 3-29. Unilateral pulldown prone on stability ball.

- Training duration
  - Less than 60 minutes per session
  - 3 to 5 weeks per cycle
- Training volume
  - Hypertrophy: 36 to 75 repetitions/exercise
  - Strength: 18 to 24 repetitions/exercise
  - Power: 12 to 20 repetitions/exercise
- Specific exercises used in the training
  - Latissimus dorsi pulldown
  - Standing pulldown
  - Unilateral pulldown prone on stability ball or with rotation in side plank position (Figures 3-29 and 3-30)
  - Pullups
  - Chinups
  - Row
  - Bench press
  - Unilateral incline press
  - Pushups
  - Serratus punch
  - Upper-body step-up (Figure 3-31) or crab walk
  - Scapular retraction with ER
  - Standing IR/ER
  - IR/ER in catch position
  - Scaption
  - Prone Y, T



FIGURE 3-30. Unilateral scapula strengthening with trunk rotation in plank position.



FIGURE 3-31. Upper-body step-ups.

  - Wrist flexion and extension
  - Standing triceps extensions (bi- and unilateral)
  - Lower body
    - Squats/lunges (with rotation), step-ups
    - Calf raises/dorsiflexion
  - Cleans
  - Snatch
  - Push press
  - Core
    - Planks/planks on stability ball
    - Side planks
    - Ball rotations against wall
    - Dead bug
    - Bird dog
    - Leg drop to each side
    - Crunches, with rotation
    - Russian twists
    - Supermans
  - All exercises are not performed in each session. Loads are at the level that allows the athlete to complete the desired repetitions with proper form.

Application of Chronic Training Variables

- Volume is increased before intensity in both water and dry-land training.
- In the dry-land strength and conditioning program, the hypertrophy phase would be performed early preseason followed by strength/power.
- During the competition phase, the volume of dry-land training is decreased and more power-based exercises are included. The decreased volume of dry-land training allows for the increase in sport-specific swim training.
- In all phases of training, loads should be adjusted to allow the athlete to maintain optimal form during each repetition of each exercise.
- Because maintaining a streamline position is critical for swimmers, postural alignment is essential in all dry-land training exercises. If excessive lordosis or kyphosis occurs when performing any exercise, the set should be terminated and the load adjusted to allow the athlete to perform the recommended number of repetitions with good form.
- When body weight exercises (pushups, pull-ups, or chinups) are performed, assistance may be provided to

ensure optimal alignment for the recommended number of repetitions.
- All dry-land training should lead to improvements in the swimmer's ability to apply force in a streamlined position.

Phase II: Performance Enhancement Training Techniques

Periodization

- Linear
  - This phase would follow the linear progression from hypertrophy/endurance to strength to power.
  - This linear progression would reestablish a base of conditioning needed to perform the higher intensity performance enhancement exercises with proper form.
- Macrocycles
  - The return to swimming macrocycle may take 6 to 12 months depending on the response of the individual athlete to the progressions
- Mesocycles
  - Hypertrophy/endurance phase 3 to 5 weeks
  - Strength phase, 3 to 5 weeks
  - Power phase, 3 to 5 weeks
  - Performance enhancement techniques, 2 to 4 weeks
- Microcycles
- Gradual increase in sets and reps over each week
- Training should be performed on nonconsecutive days to allow adequate recovery

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- Training continuum
- Flexibility/joint mobility for joint stability
- Training with optimum posture
- Sensorimotor and balance training
- Core training
- Cardiorespiratory training
- Multiplanar training activities
- Training for optimum muscle balance
- Training for optimum muscle functional strength
- Training for optimum muscle functional power
- Neuromuscular dynamic stability exercises
- Training for speed, agility, quickness (SAQ)
- Plyometric training
- Functional training
- Sport-specific training
- Stength: Power supersets. The resistance exercises are high intensity to increase the "force" side of the power equation.
- The plyo exercises focused on enhancing the "velocity" side of the power equation.

Olympic Lifts Used in the Training Program

- Snatch
- Power clean

Training Principles Used in the Design of the Program

- Principle of progression
- Principle of overload
- Principle of variation
- Principle of individualization
- Principles of SAID

Application of Acute Training Variables

See Phase 1: Advanced Strength and Conditioning leads to Performance Enhancement. Plyometric and strength/power training would be included to further enhance performance as well as further improve proprioception and kinesthesia. These techniques focus on both high force and high velocity to increase power.
- Repetitions
  - Plyo: 8 to 12
  - Superset of strength and power exercise:
    - Strength: 1 to 5
    - Power: 8 to 10
- Sets
  - Plyo: 2 to 3
  - Strength: 3 to 5
  - Power: 3 to 5
- Rest interval
  - Plyo: 0 to 60 seconds
  - Strength: 1 to 2 minutes
  - Power: 3 to 5 minutes
- Intensity
  - Plyo: body weight, medicine ball
  - Strength: 85% to 100% 1RM
  - Power: 10% BW or 30% to 45% 1RM
- Repetition tempo
  - Plyo: As fast as possible
  - Strength: controlled
  - Power: as fast as possible
- Training frequency
  - 2 to 3 times/week on nonconsecutive days
- Training duration
  - Less than 60 minutes
  - 2 to 4 weeks
- Training volume
  - Plyo: 16 to 36 repetitions per exercise
  - Strength: 3 to 20 reps per exercise
  - Power: 24 to 40 reps per exercise
- Specific exercises used in the training
  - Plyo:
    - 90° to 180° jump turn
    - Bounding
    - Streamline jump (Figure 3-32)
    - Tuck jumps
    - Figure-of-eight medicine ball pass and throw (Figure 3-33)
    - Plyo sit up with chest pass
    - Explosive rotational medicine ball wall throw
    - Medicine ball squat with chest throw
    - Medicine ball supine catch and throw
    - ER catch and toss
    - 90/90 ball drop
    - Overhead medicine ball throw



FIGURE 3-32. Streamline jump.

- Strength: Power
  - Barbell squat: Jump squat or power step up
  - Dumbbell Split squat: Power lunges
  - Bench press: Medicine ball chest pass double or single arm
  - Lat pulldown: Medicine ball soccer throw (Figure 3-34)

Application of Chronic Training Variables

- The focus of this phase of training would focus on increasing power.
- The preceding mesocycles should have established a solid base of strength.
- The resistance exercises in this phase would be high intensity to increase the "force" side of the power equation.

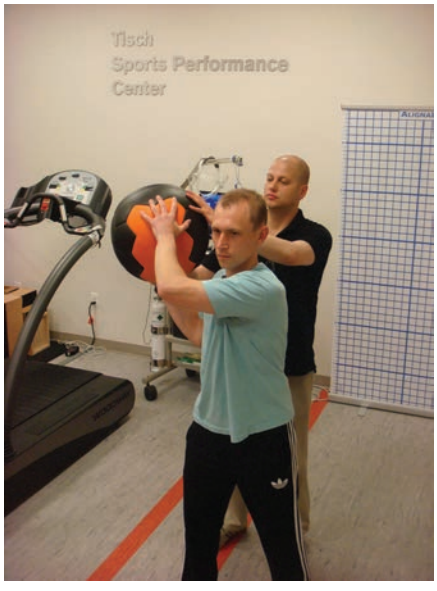

FIGURE 3-33. Figure-of-eight medicine ball catch and throw.



FIGURE 3-34. Medicine ball soccer throw.

- The plyo exercises as well as the power exercises that superset with the strength exercises are focused on enhancing the "velocity" side of the power equation.
- This phase of training would be done leading up to competition.

Phase III: Sport-Specific Training

Periodization

- Linear
  - A linear progression in return to swimming is aimed at establishing ideal technique and sport-specific endurance before progressing to higher intensity swim sets and the use of hand paddles.
- Macrocycles
  - The return to swimming macrocycle may take 6 months or more depending on the athlete's tolerance for the increases in training volume and intensity
- Mesocycles
  - General endurance: 6 to 8 weeks
  - Anaerobic development: 3 to 5 weeks
  - Event-specific training: 2 to 4 weeks
- Microcycles
  - In the endurance phase, there would be a gradual increase in frequency and volume of swim workouts, with the intensity remaining fairly low. Each workout should include technique drills to establish proper form as the training load increases. Greater focus on kick sets in the early weekly microcycles can allow for a gradual increase in training load for the shoulder. A lower volume recovery/adaptation microcycle can be used before transitioning to the next mesocycle or as needed during the mesocycle if the athlete develops soreness or loses form during the training session.
  - In the anaerobic development cycle, the athlete will be working on maintaining form at race pace. Beginning with 25-yard sprints will allow the coach to assess the tolerance for high intensity work before progressing the reps and distance of the high-intensity sets.

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- Training continuum
- Flexibility/joint mobility for joint stability
- Training with optimum posture: Streamline position that has been incorporated into all dry-land training exercises should be the focus in sport-specific training to reduce drag
- Core training: Core strengthening exercises done in dry-land training should translate to the ability to maintain optimal form while swimming
- Cardiorespiratory training: The linear progression provides for establishing a base of cardiorespiratory endurance before focusing on anaerobic development. The aerobic base allows for quicker recovery between anaerobic sets.
- Multiplanar training activities
- Training for optimum muscle balance
- Training for optimum muscle functional strength
- Training for optimum muscle functional power
- Neuromuscular dynamic stability exercises
- Training for SAQ
- Plyometric training
- Functional training
- Sport-specific training

Training Principles Used in the Design of the Program

- Principle of progression: the athlete will progress volume (total yardage, % of swim- vs. kick-only yardage, and intensity)
- Principle of overload: The volume and intensity are gradually increased to create a stimulus adequate to elicit training adaptations without overloading the athlete to the point of injury or overtraining. The optimal rate of overload will vary with each athlete and in the return to swimming after injury phase; this will demand frequent and close communication between the athlete and coach.
- Principle of variation: Varying drills, volume, intensity, and strokes will result in greater overall conditioning as well as limit the possibility of creating muscle imbalances and overload
- Principle of individualization: Athletes will have individual rates of adaptation to training loads and will require careful supervision to return to high volumes of training without a further injury
- Principles of SAID: The training program will gradually become more event specific. The initial sport-specific training will focus on general endurance and technique development and gradually transition to higher intensity and event-specific training.

Application of Acute Training Variables

- Use of fins, paddles, tubing, baskets, and swim ergometers may be incorporated into sport-specific drills.
- This would be highly individualized depending on the swimmer's stroke, event, training history, age, and level of fitness.



FIGURE 3-35. Unilateral power assessment on swim ergometer.

- The use of hand paddles should be discouraged until shoulder strength is at or near preinjury levels.
- As with all previous phases, progression of volume and intensity of swim training is dependent on the ability to complete a given training session with good form and without pain before, during, or after the session.
- Repetitions
- Sets
- Rest interval
- Intensity
- Repetition tempo
- Training frequency
- Training duration
- Training volume
- Specific exercises used in the training
  - Sculling
  - Swimming against elastic tubing
  - Vertical kicking
  - Swim bench or swim ergometer (Figure 3-35)
    - Unilateral intervals for comparison of peak power, mean power, and power decay
  - Fins, hand paddles, pull-buoys

Application of Chronic Training Variables

Throughout season

Sports Performance Testing

General Information

- General history
- Subjective questionnaires
- Medical history
- Sports injury history
- Surgical history
- Chronic conditions/medications

Specific Criteria for Progression to the Next Stage to Determine Readiness for Swimming

Objective tests

- Physiological assessments
  - Lactate
    - Throughout season

  - Heart rate
    - Resting, submaximal at target velocities, maximal
    - Throughout season
- Body-composition tests
  - Preseason
  - Midseason
  - Precompetition
- Static/dynamic postural assessments
  - Video stroke analysis
  - Throughout season
  - Dynamic muscle performance testing
    - Isokinetic swim bench
    - 4, 8, and 12 weeks after return to swimming
- Sport-specific testing
  - Stroke count
  - Stroke length
  - Start time
  - Turn time
  - Finish time
  - Split time
  - Velocity

Criteria to Determine Readiness for Sport

- Absence of pain
- Full symmetrical ROM as evaluated by the coach or certified athletic trainer (ATC); visual physical exam.
- Ability to maintain form throughout training session (both water and dry land)
  - The coach should observe mechanics during the training session; (videotaped analysis both above and underwater can be helpful here) to detect changes in form with fatigue. The point at which any asymmetries in form develop during a training session should be noted and the volume and intensity limited to the level at which the athlete can maintain form.
- Adaptation to training load—able to increase volume, intensity, or velocity within each phase of training

Specific Criteria for Release to Unsupervised Complete Participation in Swimming

- *Strength:* At or near preinjury levels or symmetrical with unaffected side MMT by trainer; ability to perform equal sets, reps, and load in unilateral upper-body strength-training exercises
- *Power:* Symmetrical with unaffected side (isokinetic swim bench testing; if swim bench is available, side-to-side measures of peak power, mean power output, and power decay in a 30-second sprint can be compared[4])
- *ROM:* At or near preinjury levels or symmetrical with unaffected side
- *Joint stability:* No instability (evaluated by coach or team trainer)
- No tenderness, inflammation, swelling, or effusion on affected side
  - Assessed by observation, examination, and regular interview with athlete
- Ability to consistently maintain proper shoulder mechanics despite a fatiguing workout assessed by close observation during workouts and over- and underwater videotaped analysis if available
- Asymptomatic after full training session
- At or near preinjury level of sport-specific skills

Recommended Ongoing Exercises

- ER/IR standing and in catch position
- Scapular retraction
- Shoulder extension
- Prone T, Y
- Latissimus dorsi pulldown
- Serratus punch
- Core strengthening

Evidence

Bak K, Magnusson SP: Shoulder strength and range of motion in symptomatic and pain-free elite swimmers. *Am J Sports Med* 25:454–459, 1997.

Differences in shoulder strength and ROM were examined in two matched groups of elite swimmers: Group 1 with unilateral shoulder pain related to swimming and a control group with no current or history of shoulder pain. Concentric and eccentric IR torques were reduced in painful shoulders. Both groups exhibited increased external ROM and reduced internal ROM. (Level IV evidence).

Brushøj C, Bak K, Johannsen HV, et al: Swimmers' painful shoulder arthroscopic findings and return rate to sports. *Scand J Med Sci Sports* 17:373–377, 2007.

Retrospective study of 18 competitive swimmers who all had undergone shoulder arthroscopy for therapy-resistant shoulder pain were evaluated with respect to operative findings and ability to return to swimming. Most common finding at arthroscopy: Labral pathology [11 (61%)] and subacromial impingement [5 (28%)]. Operative procedures included debridement in 11 swimmers, partial release of the coracoacromial ligament in 4, and bursectomy in 4. Sixteen (89%) responded to the follow-up evaluation. Nine swimmers (56%) were able to compete at preinjury level after 4 (2 to 9) months. (Level IV evidence).

Creighton DW, Shrier I, Schultz R, et al: Return-to-play in sport: a decision-based model. *Clin J Sport Med* 20:379–385, 2010.

A three-step decision-based return-to-play model is proposed including health status, participation risk, and decision modifiers. (Level V evidence).

Crewther B, Cronin J, Keogh J: Possible stimuli for strength and power adaptation: acute mechanical responses. *Sports Med* 35:967–989, 2005.

This article reviews the metabolic responses to different training regimens (hypertrophy vs. power). Hypertrophy sessions elicit greater blood lactate responses than do dynamic power sessions. The authors conclude that mechanisms underpinning muscular adaptation remain highly speculative.

Lorenz DS, Reiman MP, Walker JC: Periodization: current review and suggested implementation for athletic rehabilitation. *Sports Health* 2:509–518, 2010.

This review article of 91 articles related to periodization discusses relevant training variables, methods of periodization, and periodization program outcomes. The authors conclude that despite the evidence in the strength-training literature supporting periodization programs, there

is a considerable lack of data in the rehabilitation literature about program design and successful implementation of periodization into rehabilitation programs. (Level IV evidence).

McCarty EC, Ritchie P, Gill HS, et al: Shoulder instability: return to play. *Clin Sports Med* 23:335–351, 2004.

This review article focuses on the return to play for competitive individuals after a glenohumeral dislocation or reconstructive surgery for shoulder instability. (Level IV evidence).

Montgomery SR, Chen NC, Rodeo SA: Arthroscopic capsular plication in the treatment of shoulder pain in competitive swimmers. *HSS J* 6:145–149, 2010.

Retrospective study of 18 shoulders in 15 competitive swimmers treated with arthroscopic capsular plication 80% (12/15) of patients who returned to competitive swimming; 20% (3/15) were able to return to their preinjury training regimen volume. All patients subjectively reported improved pain after surgery. The average American Shoulder and Elbow Society score was 78±16 (average, standard deviation). The average L'Insalata score was 82±11. (Level IV evidence).

Newton RU, Hakkinen K, Hakkinen A: Mixed-methods resistance training increases power and strength of young and older men. *Med Sci Sports Exerc* 34:1367–1375, 2002.

Effects of 10 weeks of a periodized resistance-training program designed to increase muscle size, strength, and maximal power on isometric squat strength; time course of force development; muscle fiber characteristics; muscle activation (iEMG); and force and power output during squat jumps were compared in young men (30 ± 5 years, N = 8) and older men (61 ± 4 years, N = 10). Although the results of this study confirm age-related reductions in muscle strength and power, the older men did demonstrate capacity similar to that of young men for increases in these variables via an appropriate periodized resistance-training program that includes rapid, high-power exercises. (Level IV evidence).

Pabian PS, Kolber MJ, McCarthy JP: Postrehabilitation strength and conditioning of the shoulder: an interdisciplinary approach. *J Strength Cond Res* 33:42–55, 2011.

This article outlines the entire spectrum of recovery from common shoulder pathologies from injury to postrehabilitation program design. (Level IV evidence).

Pink MM, Tibone JE: The painful shoulder in the swimming athlete. *Orthop Clin North Am* 31:247–261, 2000.

This article reviews mechanisms of injury, diagnostic tools, subtle signs of injury, and optimal treatment with the focus on the freestyle stroke. (Level V evidence).

Sein ML, Walton J, Linklater J, et al: Shoulder pain in elite swimmers: primarily due to swim-volume-induced supraspinatus tendinopathy. *Br J Sports Med* 44:105–113, 2010.

This article reviews causes of shoulder pain in elite swimmers. Data indicate supraspinatus tendinopathy induced by large amounts of swimming training is major cause. (Level IV evidence)

Swaine IL: Time course of changes in bilateral arm power of swimmers during recovery from injury using a swim bench. *Br J Sports Med* 31:213–216, 1997.

Thirteen competitive swimmers were tested using a swim bench power test at 4, 8, and 12 weeks after return to training after an average 3.7-week absence because of injury. Peak power output, mean power output, and power decay for each arm during 30 seconds of exercise were measured. Differences in bilateral arm power output after injury persist for at least 8 weeks after return to swimming training. (Level IV evidence).

Swanik KA, Lephart SM, Swanik CB, et al: The effects of shoulder plyometric training on proprioception and selected muscle performance characteristics. *J Shoulder Elbow Surg* 11:579–586, 2002.

Twenty-four female D1 swimmers were evaluated before and after a 6-week plyometric training program. Proprioception and kinesthesia were assessed for IR and ER at 0°, 75°, and 90% of subjects maximum ER. Biodex II was used to assess strength at 60°, 240°, and 450°/seconds. Two-way analysis of variance showed significant improvement ($p < 0.05$) in proprioception, kinesthesia, and selected muscle performance characteristics. (Level IV evidence).

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3. Creighton DW, Shrier I, Schultz R, et al: Return-to-play in sport: a decision-based model. *Clin J Sport Med* 20:379–385, 2010.
4. Swaine IL: Time course of changes in bilateral arm power of swimmers during recovery from injury using a swim bench. *Br J Sports Med* 31:213–216, 1997.

Multiple-Choice Questions

QUESTION 1. What is an appropriate level of intensity for an athlete beginning the hypertrophy phase of a strength and conditioning program?

A. 85% to 95% of one-repetition maximum (1RM)
B. Body weight
C. 60% to 85% of 1RM
D. 50% of 1RM

QUESTION 2. What is a benefit of upper-body plyometric exercises following shoulder injury?

A. Increase in strength
B. Improvement in proprioception
C. Muscle hypertrophy
D. Decrease in pain

QUESTION 3. What is the nature of the strength and conditioning program during the competition phase?

A. Low volume, high intensity
B. Low volume, low intensity
C. High volume, low intensity
D. High volume, high intensity

QUESTION 4. Which is an example of a strength:power superset?

A. Deadlift: barbell squat
B. Biceps curl: triceps kickback
C. Bench press: medicine ball chest pass
D. Power lunges: jumping rope

QUESTION 5. Which of the following would NOT be an appropriate criterion for allowing a swimmer to return to training without supervision?

A. Strength symmetrical to unaffected side
B. Ability to complete training sessions
C. Absence of pain
D. ROM symmetrical to unaffected side

Answer Key

QUESTION 1. Correct answer: **C** (see Phase I)

QUESTION 2. Correct answer: **B** (see Phase II)

QUESTION 3. Correct answer: **A** (see Phase I, Chronic Variables)

QUESTION 4. Correct answer: **C** (See Phase II—Performance Enhancement Techniques)

QUESTION 5. Correct answer: **B** (see Sports Performance Testing)

Chapter 4



Superior Labral Pathology (SLAP/Long Head Biceps)

INTRODUCTION

Thomas J. Gill IV, MD, Kaitlin M. Carroll, BS, and Amee L. Seitz, PT, PhD, DPT, OCS

Background

- Superior labral tears were originally described by Andrews et al. in 1985 as lesions that involve the labrum from the anterior portion of the superior glenoid notch to the posterior glenoid, including the anchor of long head of the biceps tendon.
- Superior Labrum Anterior to Posterior (SLAP) tears. SLAP tears are frequently associated with concurrent shoulder pathology, including anterior and posterior Bankart tears, full and partial thickness rotator cuff tears, and acromioclavicular joint arthrosis.

Epidemiology

Age
- 20 to 50 years

Sex
- Male

Sport
- Baseball
- Football
- Tennis
- Javelin
- Wrestling

Position
- Pitchers
- Linebackers
- Offensive linemen

Pathophysiology

Intrinsic Factors

- Composed of fibrocartilaginous tissue, the labrum serves as an anchor point for the capsuloligamentous structures of the shoulder. The labrum deepens the concavity of the glenoid cavity to provide added stability to the glenohumeral joint.
- The pathology includes the attachment point of the long head of the biceps tendon (Figure 4-1).
- The anterior superior labrum frequently extends into the MGHL or IGHL rather than inserting onto glenoid margin (Figure 4-2).
- Functional importance:
  - Possible humeral head depressor
  - Restraint to external rotation in abduction
  - Helps maintain anterior stability of the shoulder joint
- Eccentric contraction of biceps muscle can tear the superior labrum at the biceps anchor.
- Deceleration phase of throwing places high eccentric stresses on the superior labrum, while the late cocking phase of throwing place high "peel-back" forces on the posterosuperior labrum.
- SLAP tears are often implicated as a cause of shoulder pain, weakness, and worsening athletic performance, especially in overhead athletes.
- Understanding the anatomy of the labrum is essential in the diagnosis and treatment of SLAP tears,

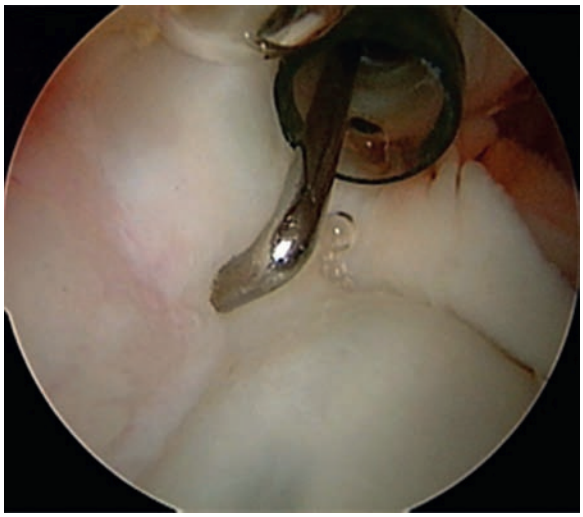

FIGURE 4-1. The pathology of the labrum includes the attachment of the long head of the biceps tendon.

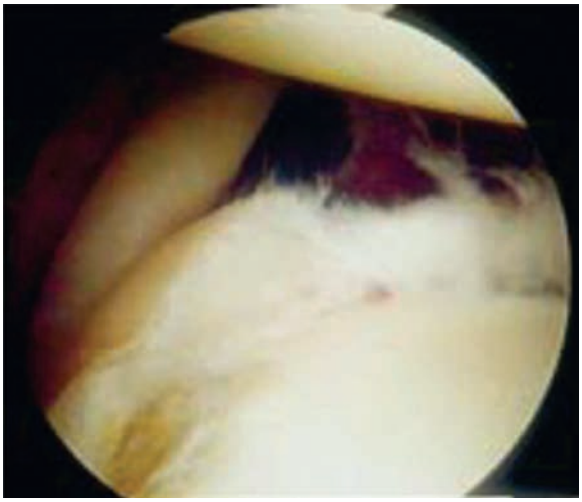

FIGURE 4-3. Type I SLAP tear.

particularly with respect to differentiating normal from abnormal labral morphologies. In addition, extensive SLAP tears may occur anteriorly and posteriorly, leading to associated instability symptoms as well.

- The labrum serves as an anchor point for the capsuloligamentous structures of the shoulder while increasing the radius of curvature of the glenoid cavity. By doing so, it provides added glenohumeral stability, as well as the attachment point for the long head of biceps tendon at the superior glenoid tubercle.

Traumatic Factors

- Falling on an outstretched arm
- Direct blow to the shoulder
- Sudden pull or lifting a heavy object
- Forceful overhead motions
- Compression injuries

Classic Pathological Findings

SLAP lesions are typically classified into four basic types:

- Type I SLAP tears consist of superior labral fraying, without instability of the biceps anchor (Figure 4-3). These lesions are seldom symptomatic, and have unclear clinical significance
  - Fraying and degeneration of the edge
  - Firmly attached labrum and biceps anchor
- Type II SLAP lesions are the most commonly symptomatic and repairable type of SLAP tear (Figure 4-4). They can occur by the "peel-back" phenomenon, repetitive eccentric biceps contractions, or from a fall on an outstretched arm. Type II tears involve detachment of the

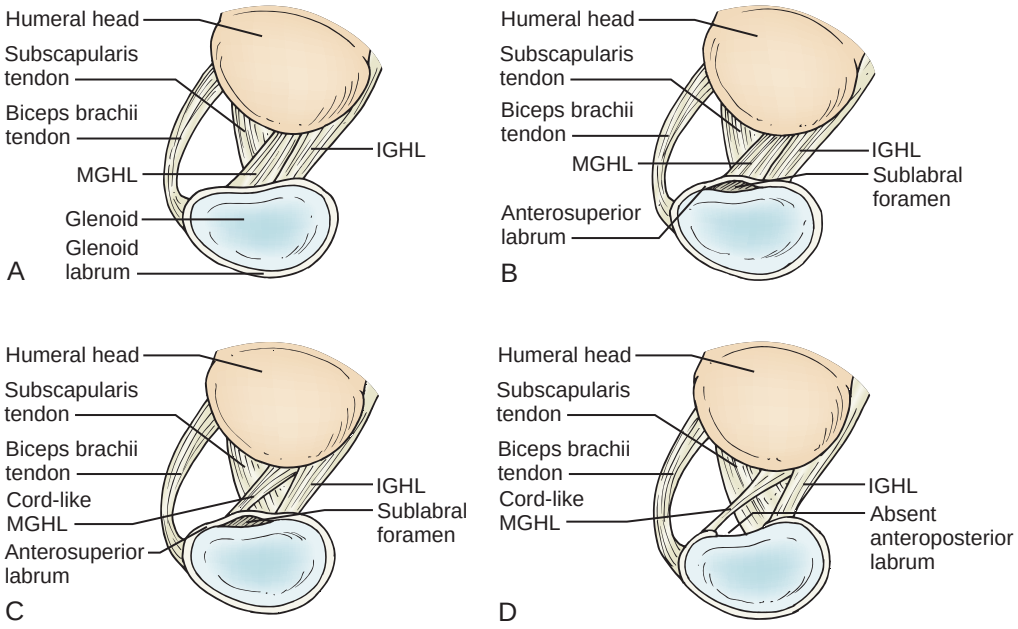

FIGURE 4-2. The anatomic position of the anterior superior labrum and its extension into the MGHL and IGHL.

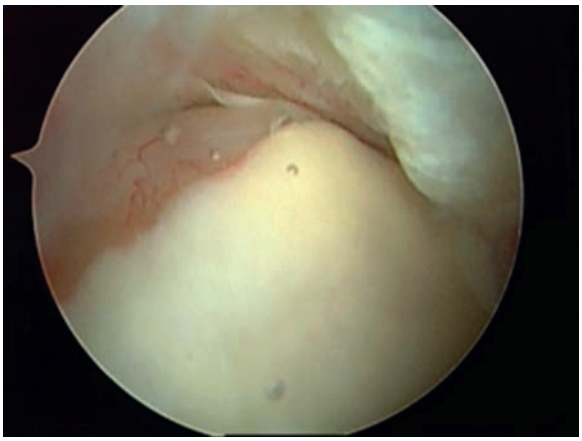

FIGURE 4-4. Type II SLAP tear.

superior labrum from the supraglenoid tubercle, and result in an unstable biceps anchor/attachment
  - Labrum and biceps anchor are detached
  - Complex arches away from glenoid neck
- Type III tears involve a bucket-handle detachment of the labrum in which the actual biceps origin remains stable (Figure 4-5). Complaints of shoulder "catching," "locking," or "stabbing pain" are common.
  - Bucket handle tear
  - Remaining portion of biceps and labrum are still well attached at their insertion
- Type IV SLAP lesions include a bucket handle tear of the labrum where the tear extends into the substance of the biceps tendon (Figure 4-6)
  - Portions of the labrum displaceable into glenohumeral joint

Clinical Presentation

History

- Diagnosing a clinically relevant SLAP tear can be difficult.

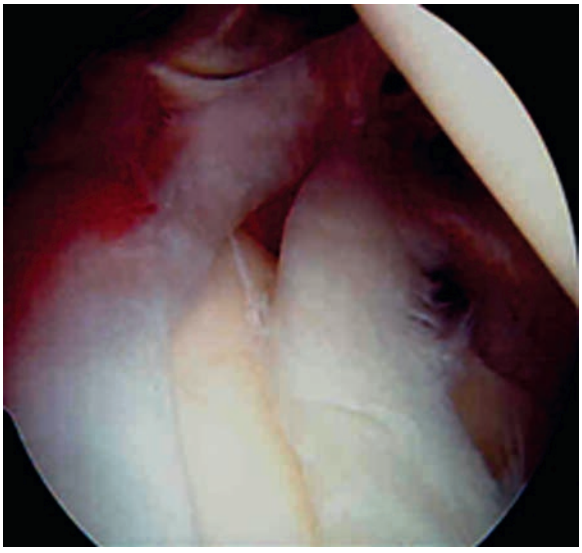

FIGURE 4-5. Type III SLAP tear.

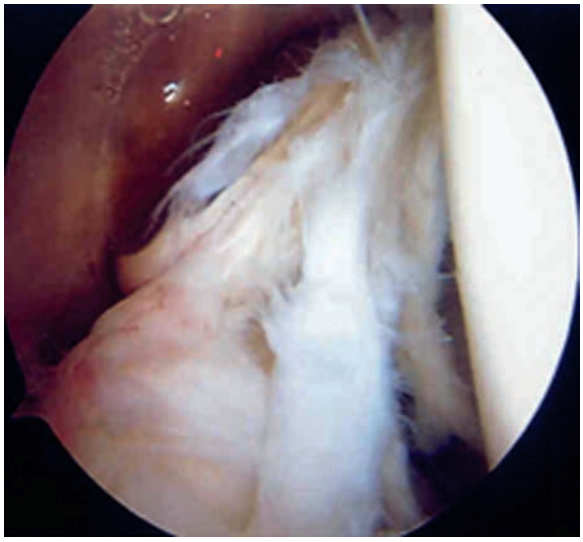

FIGURE 4-6. Type IV SLAP tear.

- Complaints of shoulder pain and weakness, especially with throwing, are typical.
- A history of a traction or repetitive throwing or overhead activity may help in the diagnosis.
- Athletes will frequently present with symptoms of pain, clicking, weakness or even instability.
- Pain, usually with overhead, lifting, or traction type of activities.
- Pain reaching out to the side.
- Occasional night pain or pain with daily activities.
- A sense of instability or the shoulder "feeling out of place."
- Decreased range of motion and strength.
- The symptoms are usually worse with the arm in the abducted and externally rotated position ("peel-back" position) as seen in the late cocking phase of throwing, or during an overhead serve in tennis.
- Although a fall on an outstretched arm can also cause a SLAP tear, a history of trauma is typically not present in overhead athletes.
- Athletes with type III SLAP tears often present with catching, locking or "dead-arm" type symptoms that can be confused with instability, due to the bucket handle tear catching between the humerus and glenoid.
- There are multiple physical examination tests that have been described to diagnose SLAP tears. These tests include: Speed's test, Yergason's test, O'Brien's test, Jobe's relocation test, active compression test, pain provocation test, crank test, anterior slide, apprehension test with the arm abducted to 90° in maximum external rotation, and tenderness in the rotator interval.
- The active compression test (O'Brien's test) has been shown to be a predictable and clinically useful sign in the diagnosis of SLAP tears.
- Throwing athletes complain of loss of velocity, control, and decreased confidence.
- SLAP tears often mimic the same symptoms as rotator cuff tears.

Physical Examination

Abnormal Findings

- Positive O'Brien's test ("active compression test")
- Pain with apprehension test
- Clicking
  - Compression and internal and external rotation

Pertinent Normal Findings

- Negative load and shift test
- No true "apprehension" with apprehension testing
- Rotator cuff strength testing is typically normal, although some false-positive weakness on empty can testing can occur

Imaging

- Plain radiographs
- Magnetic resonance imaging
  - Technological advancements in MRI have improved our ability to confirm the diagnosis of a superior labral tear. However, MRI findings must always be interpreted in the context of the athlete's history and physical examination. Incidental findings of labral tears on MRI are common in overhead athletes.
  - MRI arthrography (MRA): an injection of contrast (usually gadolinium) into the joint before the MRI scan has been shown to facilitate diagnosis.

Differential Diagnosis

- Pathologies such as rotator cuff tears and AC joint sprains/arthritis can cause false positive physical examination tests.
  - Patients typically complain of pain when reaching out to the side or behind them, as opposed to the classic overhead pain found with rotator cuff tears.
- An isolated sublabral foramen, a sublabral foramen with a cord-like middle glenohumeral ligament, and a cord-like middle glenohumeral ligament with the absence of tissue at the anterosuperior labrum (also termed the "Buford complex").
  - These variations can be seen in 10% to 15% of all shoulders and should not be mistaken for a SLAP tear.
  - As a general rule of thumb, labral variations are generally not thought to be "pathologic" if it occurs between 12 and 3 o'clock in a right shoulder, or between 9 and 12 o'clock in a left shoulder.

Treatment

Nonoperative Management

- Stretching
- Formal physical therapy
- Strengthening
- Cortisone injections
- Activity modification

Guidelines for Choosing Among Nonoperative Treatments

- Injections used for patients with associated pain on impingement testing
- Selective AC joint injection used to help differentiate AC joint pathology from true SLAP tear
- Stretching used in patients with associated glenohumeral internal rotation deficit (GIRD)

Surgical Indications

- Treatment options include superior labral repair, biceps tenodesis, or biceps tenotomy
- Absolute—failure to respond to rehabilitation after 6 months and symptoms deemed relative to the SLAP region
- Relative—inability to return to premorbid level of play

Aspects of History, Demographics, or Exam Findings that Affect Choice of Treatment

- Surgical treatment more commonly used for patients with an acute injury (e.g., fall on an outstretched arm), or with significant pain/weakness on examination that is not responsive to rehabilitation
- Nonoperative treatment preferred for pitchers and overhead athletes unless they cannot return to play due to their symptoms

Aspects of Clinical Decision Making When Surgery is Indicated

- Marked pain/weakness on O'Brien's testing
- Inability to throw
- Loss of velocity/accuracy when throwing

Evidence

Andrews JR, Carson WG, Jr, McLeod WD: Glenoid labrum tear related to the long head of the biceps. *Am J Sports Med* 13:337–341, 1985.

A retrospective review of 73 baseball pitchers who underwent shoulder arthroscopies of their dominant shoulder for tears of the glenoid labrum. At the time of the arthroscopy, the tendon of the long head of the biceps originated from the superior portion of the glenoid labrum and the tear was visible where anterosuperior portion of the labrum tore off the glenoid. (Level IV evidence)

Bencardino JT, Beltran J, Rosenberg ZS, et al: Superior labrum anterior-posterior lesions: Diagnosis with MR arthrography of the shoulder. *Radiology* 214:267–271, 2000.

Study of 52 patients who underwent arthroscopy and open surgery 12 days to 5 months after MR arthrography. The MR arthrography showed correlation between surgical classifications of SLAP tears and SLAP lesions diagnosed at the time of MR arthrography. (Level IV evidence)

Ilahi OA, Labbe MR, Cosculluela P: Variants of the anterosuperior glenoid labrum and associated pathology. *Arthroscopy* 18:882–886, 2002.

This prospective, case series of 20 shoulders that compared the incidence of Buford complex and sublabral foramen with

superior labral pathology. The incidence of the Buford complex and sublabral foramen is higher than previous described and they are correlated with superior labral pathology. (Level IV evidence)

Kim TK, Queale WS, Cosgarea AJ, et al: Clinical features of the different types of SLAP lesions: An analysis of one hundred and thirty-nine cases. *J Bone Joint Surg Am* 85A:66–71, 2003.

A prospective case series of 544 arthroscopic procedures, of which 139 procedures demonstrated a SLAP lesion. At the conclusion of this study, the pathology of SLAP lesions and clinical findings vary depending on the patient population and tears are both isolated and associated with concomitant pathologies. (Level IV evidence)

Nam EK, Snyder SJ: The diagnosis and treatment of superior labrum anterior and posterior (SLAP) lesions. *Am J Sports Med* 31:798–810, 2003.

In this review, the authors discuss the definitive treatment and examination for SLAP lesions based on previous literature. In conclusion, the SLAP tear is hard to diagnose and treat and the treatment of SLAP tears is dependent on the type of SLAP lesion. (Level V evidence)

Parentis MA, Glousman RE, Mohr KS, et al: An evaluation of the provocative test for superior labral anterior posterior lesions. *Am J Sports Med* 34:265–268, 2006.

A series of 132 consecutive shoulder arthroscopy patients were preoperatively examined using a variety of shoulder tests to determine the most accurate test to diagnose a SLAP tear. Although some tests were more specific to type I tears and others more specific to type II tears, the study concluded that there is no single test that can accurately determine a SLAP lesion. (Level IV evidence)

Snyder SJ, Karzel RP, Del Pizzo W, et al: SLAP lesions of the shoulder. *Arthroscopy* 6:274–279, 1990.

A retrospective review of 700 shoulder arthroscopies was performed and identified 27 patients with a SLAP tear. The preoperative imaging tests did not accurately diagnose the SLAP lesions. In conclusion, this study suggest that the treatment for SLAP lesions is arthroscopic surgery. (Level IV evidence)

Williams MM, Snyder SJ, Buford D, Jr: The Buford complex–the "cord-like" middle glenohumeral ligament and absent anterosuperior labrum complex: A normal anatomic capsulolabral variant. *Arthroscopy* 10:241–247, 1994.

A retrospective review of 200 shoulder arthroscopy videos were reviewed to study the anterosuperior glenoid quadrant. In 3 of the 200 patients, it was noted that that patients had a "cord-like" middle glenohumeral ligament. This unusual variant in the anatomy was noted to cause confusion between a labral tear and an anatomic abnormality. (Level IV evidence)

Multiple-Choice Questions

QUESTION 1. What concomitant pathologies are NOT associated with SLAP tears?

A. Rotator cuff tear
B. Bankart tear
C. Clavicle fracture
D. Acromioclavicular arthritis

QUESTION 2. List the traumatic factors that contribute to a SLAP tear.

A. Falling on an outstretched arm
B. Sudden pull or lifting a heavy object
C. Forceful overhead motions
D. All of the above

QUESTION 3. Which test is the most widely used to diagnose SLAP tears?

A. O'Brien's test
B. Speed's test
C. Yergason's test
D. Jobe's test

QUESTION 4. In what sport is a SLAP tear most commonly found?

A. Soccer
B. Baseball
C. High Jump
D. Lacrosse

QUESTION 5. What type of SLAP tear is often associated with catching, locking, or "dead-arm" type symptoms?

A. Type I
B. Type II
C. Type III
D. Type IV

Answer Key

QUESTION 1. Correct answer **C** (see Epidemiology)

QUESTION 2. Correct answer: **D** (see Pathophysiology)

QUESTION 3. Correct answer: **A** (see Clinical Presentations)

QUESTION 4. Correct answer: **B** (see Epidemiology)

QUESTION 5. Correct answer: **C** (see Clinical Presentation)

NONOPERATIVE REHABILITATION OF SLAP TEARS

Amee L. Seitz, PT, PhD, DPT, OCS, Alex J. Petruska, Jr., PT, SCS, and Thomas J. Gill IV, MD

GUIDING PRINCIPLES OF NONOPERATIVE REHABILITATION

- A proportion of overhead athletes with SLAP tears, regardless of type, will be able to return to full function and sport with rehabilitation. The patho-anatomical diagnosis is not predictive of outcome.
- A comprehensive examination to identify and address all potential contributing factors and impairments is necessary to optimize the outcome of nonoperative rehabilitation of superior labrum anterior to posterior (SLAP) SLAP tears.
- Rehabilitation of SLAP tears should be individualized to the specific underlying impairments that contribute to movement disorder that vary among athletes.
- Where an athlete begins along the phases of rehabilitation and time frames for progression outlined in this chapter is dependent upon the pain, reactivity of shoulder structures, extent of movement impairments, and individualized patient response.
- Although it is not necessary to follow the specific time frames outlined for each phase, it is essential to meet the milestones/criteria to advance to the next phase of rehabilitation.

Phase I (weeks 0 to 4)

Protection

- Athlete should be instructed in joint protection strategies including positioning the shoulder with pillows in the "loose pack" position to sleep and during application of cryotherapy.
- Athlete should be instructed to avoid activities that provoke symptoms and limit use of upper extremity below shoulder height and in front of scapular plane.

Management of Pain and Swelling

- Ice intermittently, as needed up to 4 to 5 times per day 15 to 20 minutes at a time
- Nonsteroidal antiinflammatory medications as prescribed by the surgeon
- A TENS unit or electrical stimulation may be used to reduce pain. Using TENS for 20 minutes at a time has been shown to reduce nociceptive responses and pain perception.[1] Electrical stimulation has also been shown to suppress inflammatory responses at the cellular level in vitro.[2]
- An evaluation by the sports medicine physician for a subacromial steroid injection may be helpful to reduce pain or address any plateaus in progression to meet Phase I rehabilitation goals in a 4-week period.

Techniques for Progressive Increase in Range of Motion

- Phase I rehabilitation is designed to restore normal and pain-free AA/AROM of the shoulder. Athletes that do not present with AROM limitations and minimal to no pain with ROM may progress immediately to Phase II.
- ROM progressions are not limited by time frames and should be guided by the athlete's tolerance.
- For athletes with A/PROM limitations, ROM progression should begin with restoring internal and external rotation with the arm at the side and elevation in the scapular plane.

TIMELINE 4-1: **Nonoperative Rehabilitation of SLAP Tears**

PHASE I (weeks 1 to 4)	PHASE II (weeks 4 to 8)
• Activity modifications and positioning for comfort • PT modalities • AAROM exercises all plans as tolerated • Mobilizations grade I-II GH joint and soft tissue mobilization as needed • Thoracic spine mobilizations/manipulations as needed • Submaximal isometrics for GH joint muscles per pain tolerance • TBS/TAS/TLS activities as tolerated	• PT modalities as needed • PROM-full all planes including horizontal adduction and IR • Posterior-inferior GH and scapulothoracic mobilizations II-IV as needed • TBS/TAS/TLS activities as recommended and tolerated • Scapular exercises—PREs • TAS—biceps/triceps PREs • Glenohumeral exercises—PREs • Rotator cuff exercises—PREs • PNF exercises proximal resistance • OKC Rhythmic stabilization exercises • CKC exercises • CKC manual perturbation exercises

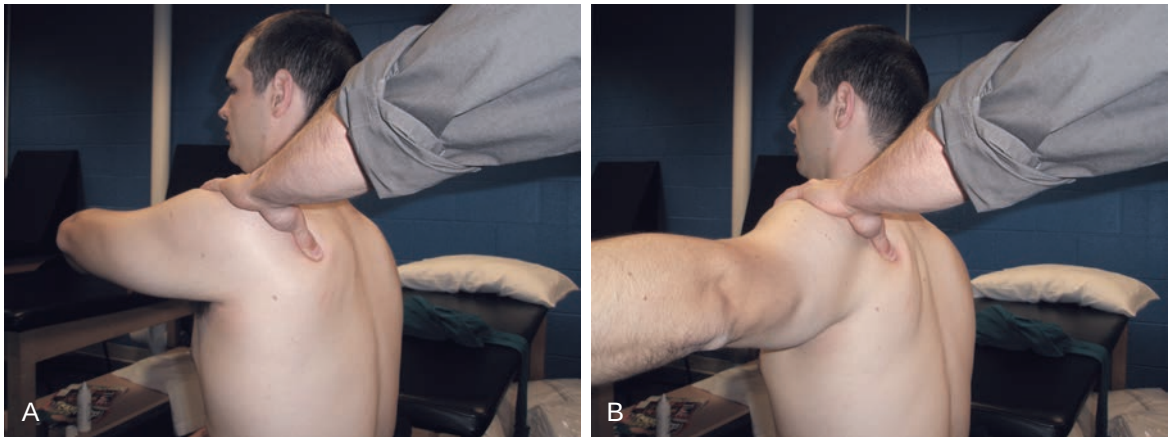

FIGURE 4-7. Manual therapy technique to address soft tissue impairments in the infraspinatus with application of pressure to infraspinatus (**A**) in flexion and move into (**B**) horizontal abduction of the shoulder.

- Once full A/PROM in elevation, and full IR and ER at the side is achieved, athletes can be progressed with internal and external rotation gradually to 90° of abduction.

Manual Therapy Techniques

- Grade I to II glenohumeral mobilizations inferior and posterior for pain in midrange to assist with ROM progression.
- Thoracic spine manipulation or grade III to IV mobilization for extension and rotation mobility and to reduce pain.[3-5]

Soft Tissue Techniques

- Pectoralis minor active release or preferred soft tissue technique as needed to normalize muscle length to restore adequate scapular posterior tilt.[6] Minimum length can be determined by supine assessment of acromion distance from bed should be equal bilaterally.
- Rotator cuff, specifically infraspinatus (Figure 4-7) and/or subscapularis, soft tissue release techniques as needed.
- Biceps soft tissue release techniques as needed.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Normalize full passive glenohumeral ROM within pain tolerance in all planes starting external/internal rotation in neutral progressing to 45° and 90° of abduction
- T-Bar/stick exercises for AAROM in ER with the arm at side in standing (Figure 4-8) progressing to 90° abduction in supine (Figure 4-9)
- Elbow and wrist ROM stretching
- IR behind the back internal rotation stretching (Figure 4-10)
- Horizontal adduction[7] stretching AAROM (Figure 4-11)
- Thoracic spine extension AROM over 4-inch foam roll
- Initiate hip stretching ABD/IR/ER/flexion as needed. Adequate hip motion will permit normal mechanics with throwing/pitching reducing unwarranted strain at the shoulder.

Other Therapeutic Exercises

- Nonimpact light aerobic activity (bike, elliptical, StairMaster) within pain tolerance
- Lower extremity resistance training is indicated

TIMELINE 4-1 Nonoperative Rehabilitation of SLAP Tears (Continued)

PHASE III (weeks 8 to 12)	PHASE IV (weeks 12 +)
• PROM-maintain full motion • Mobilizations as needed • TBS/TAS/TLS activities as recommended and tolerated • Scapular exercises—PREs • TAS—biceps/triceps PREs • Glenohumeral exercises—PREs • Rotator cuff exercises—PREs • Complete Thrower's 10 plus program • PNF exercises distal resistance • OKC rhythmic stabilization exercises • CKC exercises • CKC manual perturbation exercises • Overhead strengthening exercises • Selected (below shoulder height) sport-specific exercises initiated	• PROM-maintain full motion • Mobilizations as needed • TBS/TAS/TLS activities as recommended & tolerated • Scapular exercises—PREs • TAS—biceps/triceps PREs • Glenohumeral exercises—PREs • Rotator cuff exercises—PREs • IR/ER exercises at 90° • Thrower's 10 plus program -progress intensity • PNF exercises • OKC rhythmic stabilization exercises • CKC exercises • CKC manual perturbation exercises • Plyometrics—progressing to 90°/90° 1 arm plyos • Overhead strengthening exercises • Unrestricted sport-specific exercises • Overhead athletes initiate an return to sport interval program • Initiate sports enhancement and optimization program

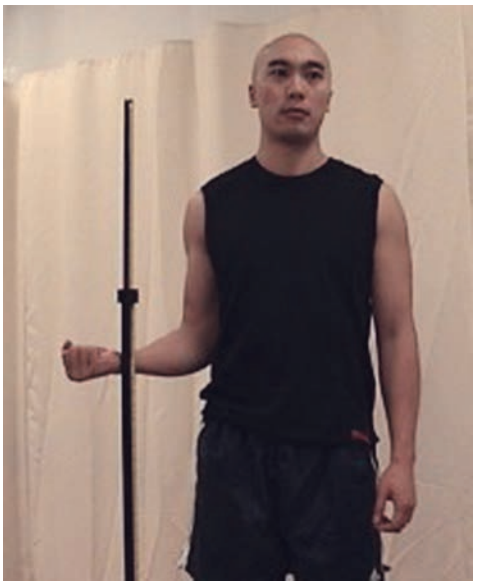

FIGURE 4-8. External rotation active assistive range of motion with the shoulder in neutral.

- Core stability is initiated as able with seated ball exercises and unilateral stance lower extremity reaches and lateral slides on stable surface progressed as technique allows

Activation of Primary Muscles Involved

- Although the focus of this phase of rehabilitation is restoration of normal range of motion, activation of the rotator cuff muscles (IR/ER) with submaximal isometrics is indicated within pain tolerance with the arm at the side progressing to 45° of scapular plane elevation.

Sensorimotor Exercises

- Scapular control exercises with side-lying scapular clock exercises
- Active elevation in scapular plane with mirror and verbal feedback to normalize dynamic scapulohumeral motor control

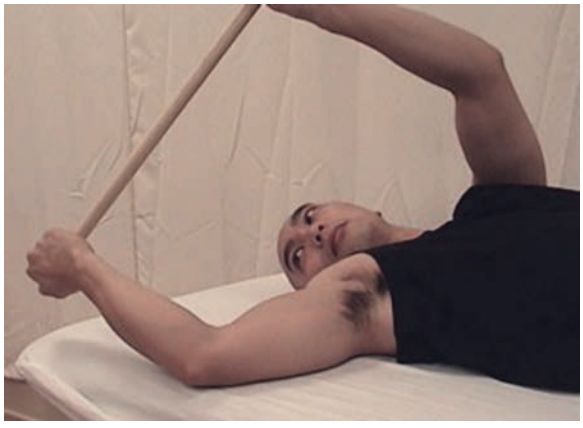

FIGURE 4-9. External rotation active assistive range of motion in 90° abduction.

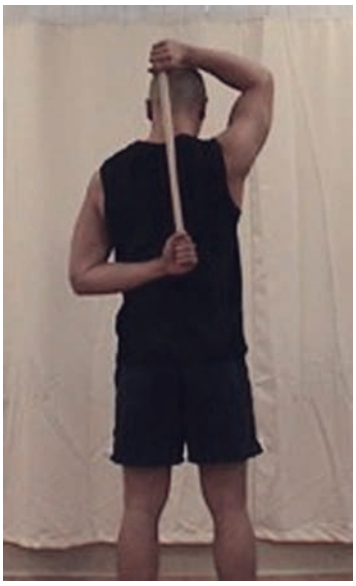

FIGURE 4-10. Internal rotation/behind AAROM with a stick.

Techniques to Increase Muscle Strength, Power, and Endurance

- LE strength training exercises to target hip extensors and rotators
- Elliptical and stair stepper for cardiovascular conditioning

Neuromuscular Dynamic Stability Exercises

- Manual rhythmic stabilization with the arm in pain-free mid-range of motion positions with light resistance

Sport-Specific Exercises

- Overhead athletes should initiate core and lower extremity stability drills progressing to unstable surfaces and in unilateral stance (standing balance, excursions anterior lateral and diagonals) as able with

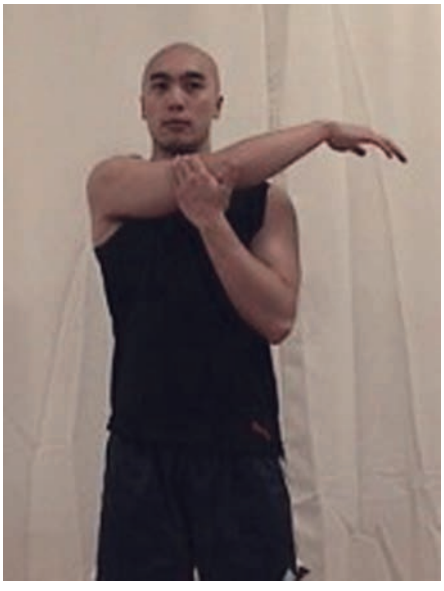

FIGURE 4-11. Horizontal adduction posterior shoulder self-stretching.

good core control. Unstable surfaces require additional core muscle activity and greater challenge to the athlete.

Milestones for Progression to the Next Phase

- Full AROM in all planes of motion, with only mild discomfort at end ranges
- Normal scapulohumeral dynamic control during elevation without resistance as determined by the scapular dyskinesis Test.[8] With this test, the athlete should demonstrate no dysrhythmia or scapular winging during five repetitions of full flexion and abduction.
- Pain minimal to none at rest; minimal increase in pain following exercise

Phase II (weeks 6 to 12)

Protection

- Athletes will be encouraged to minimize painful resisted shoulder motions above shoulder height and behind the plane of the body during daily activities.

Management of Pain and Swelling

- Ice after exercise and as needed 15 to 20 minutes at a time
- Nonsteroidal antiinflammatory medications as prescribed by the surgeon
- TENS unit or electrical stimulation only as needed after exercise

Techniques for Progressive Increase in Range of Motion

- Athletes should have normal AROM but may present with end range restrictions and abnormal arthrokinematics that should be addressed in this phase of rehabilitation.
- Normal inferior glide should be observed in terminal elevation. This can be visually observed with symmetrical skin creases at terminal elevation. Additionally inferior glides can be assessed and compared bilaterally at end range of glenohumeral elevation. Posterior shoulder length should be normalized with at least 20° of horizontal adduction from the vertical while lying supine with the scapula stabilized.
- Glenohumeral total arc of motion should be normalized with the sum of internal and external rotation at 90° of abduction approximating 180°.
- The dominant shoulder in overhead, particularly throwing athletes may demonstrate loss of IR compared to contralateral due to osseous changes of the humerus,[9] but the total arc of internal and external rotation motion should be comparable to the opposite shoulder.

Manual Therapy Techniques

- Common restrictions in posterior and inferior accessory joint motion of the glenohumeral joint should be normalized with grade III mobilizations, mobilizations with movement, and/or terminal ROM stretching. Arthrokinematics with manual accessory motion testing should be assessed in the posterior and inferior direction. Posterior shoulder range of motion can be evaluated with passive horizontal adduction[10] with the scapula stabilized should be greater than 90° or beyond vertical position towards the chest. Internal rotation should be sufficient to allow for the total arc of motion (internal + external rotation ROM) to approximate total arc of motion values for the uninvolved shoulder.[11]
- Manual assisted horizontal adduction stretching while stabilizing the scapula at varying angles of elevation 70° to 100° and IR stretching to appropriately address posterior shoulder soft tissue restrictions.

Soft Tissue Techniques

- Pectoralis minor active release or preferred soft tissue technique as needed to normalize muscle length to restore adequate scapular posterior tilt.[6] Minimum length can be determined by supine assessment of acromion distance from bed should be equal bilaterally
- Continue rotator cuff and/or biceps soft tissue techniques as needed

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Sleeper stretch starting at 45° of flexion progressing to 90° as tolerated (Figure 4-12)
- Bar hang stretch for latissimus and shoulder flexion (Figure 4-13)
- Full pain-free shoulder ROM IR/ER at 90° of abduction
- Continue hip ER/IR/flexion stretching as needed
- Continue thoracic spine extension and rotation stretching as needed

Other Therapeutic Exercises

- Return to all aerobic activity
- Lower extremity resistance training is progressed
- Core stability exercises are progressed to sport-specific positions and conditions

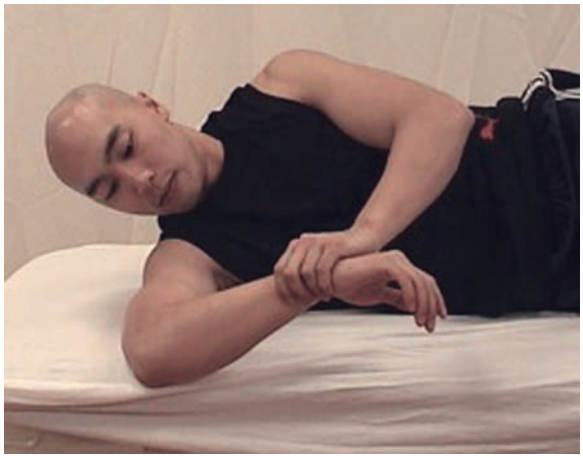

FIGURE 4-12. Sleeper stretch at 90° flexion for posterior shoulder.



FIGURE 4-13. Overhead bar assisted shoulder flexion and latissimus dorsi stretch.

- Total arm strengthening (TAS) is initiated with exercises at or below shoulder height and anterior to scapular plane

Activation of Primary Muscles Involved

Initiate rotator cuff and scapular prone exercises to light isotonic and/or elastic resistance as ROM is normalized without scapular substitution patterns. The scapula should not wing or excessively shrug with any exercise as determined by visual observation.

- Resisted ER in neutral (Figure 4-14)
- Resisted IR in neutral (Figure 4-15)
- Sideling ER (Figure 4-16)
- Shoulder retractions (Figure 4-17)
- Standing "W"s (Figure 4-18)
- Dynamic hug (Figure 4-19)
- Prone rowing (Figure 4-20)
- Prone extension (Figure 4-21)

Sensorimotor Exercises

- Rhythmic stabilization and manual strengthening of the UE with short moment arms/proximal resistance
- The Bodyblade at 0° abduction as well as 90° scapular elevation
- Core stability exercises with manual resistance on stable progressing to unstable surfaces

Open and Closed Kinetic Chain Exercises

- PNF in D1–2 with manual resistance to scapula and humerus with slow reversals
- Closed chain upper extremity PNF in quadruped
- Closed chain rhythmic stabilization in quadruped with hand on ball to provide an unstable surface to challenge the athlete

Techniques to Increase Muscle Strength, Power, and Endurance

- Progression of lower extremity strength training exercises
- Progress to elliptical and stair stepper for cardiovascular conditioning; initiate jogging/running

Plyometrics

- Lower extremity plyometrics can be initiated

Milestones for Progression to the Next Phase

- Normal posterior shoulder flexibility (internal rotation and horizontal adduction). Posterior shoulder range of motion can be evaluated with passive horizontal adduction[10] with the scapula stabilized should be greater than 90° or beyond vertical position towards the chest. Internal rotation should be sufficient to allow for the

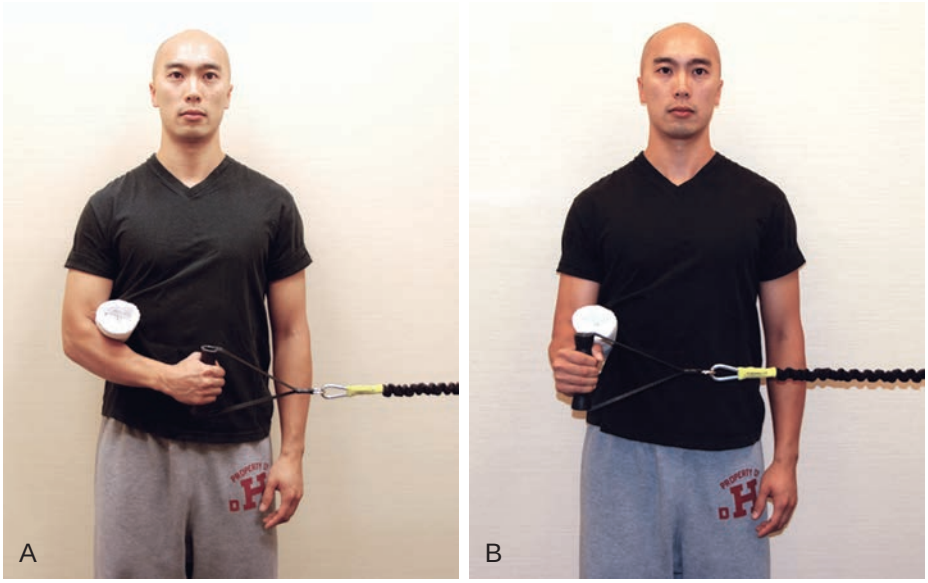

FIGURE 4-14. Resisted external rotation in neutral humeral abduction (**A**) start position and (**B**) end position.

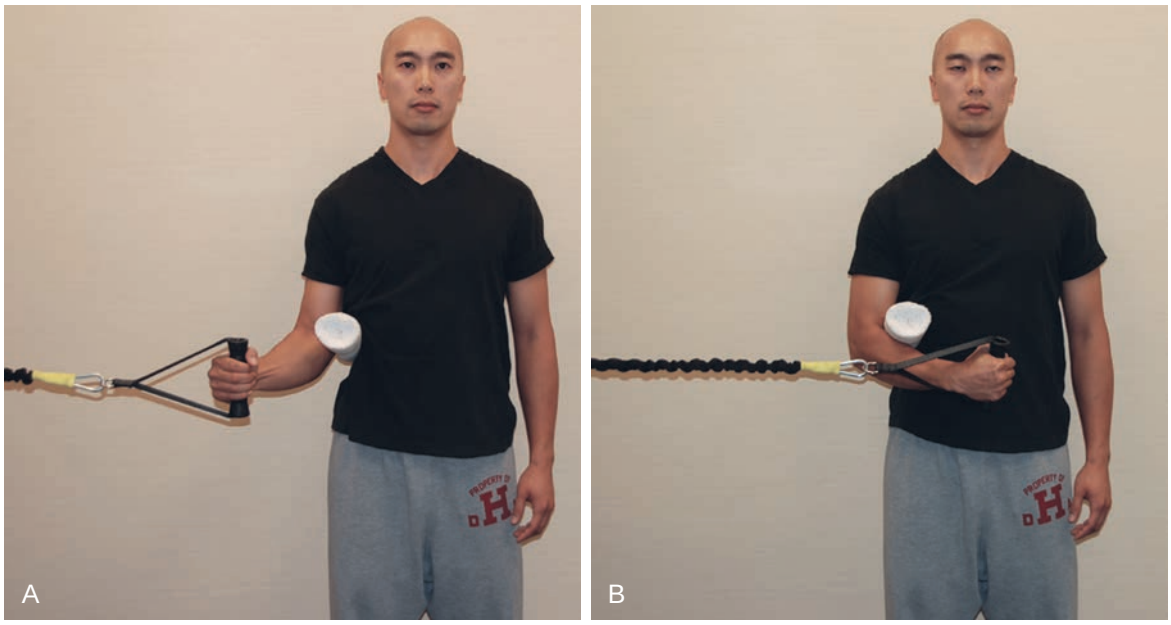

FIGURE 4-15. Resisted internal rotation in neutral humeral abduction (**A**) start position and (**B**) end position.

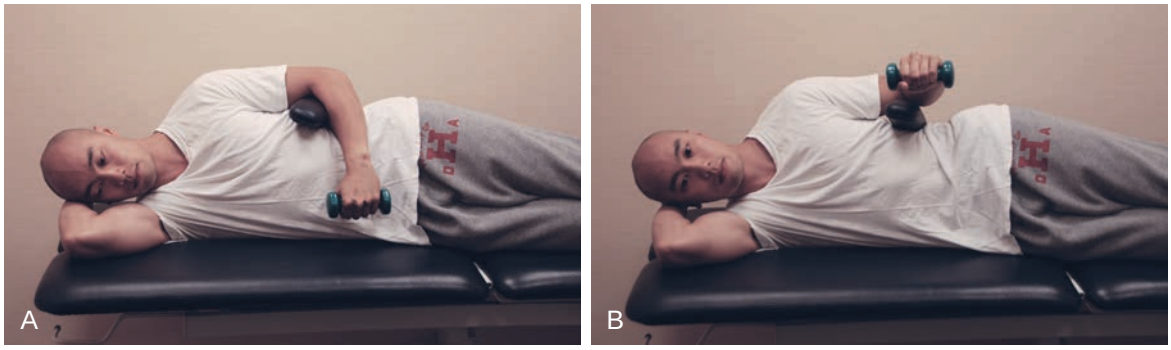

FIGURE 4-16. Side-lying isotonic external rotation (**A**) start position and (**B**) end position.

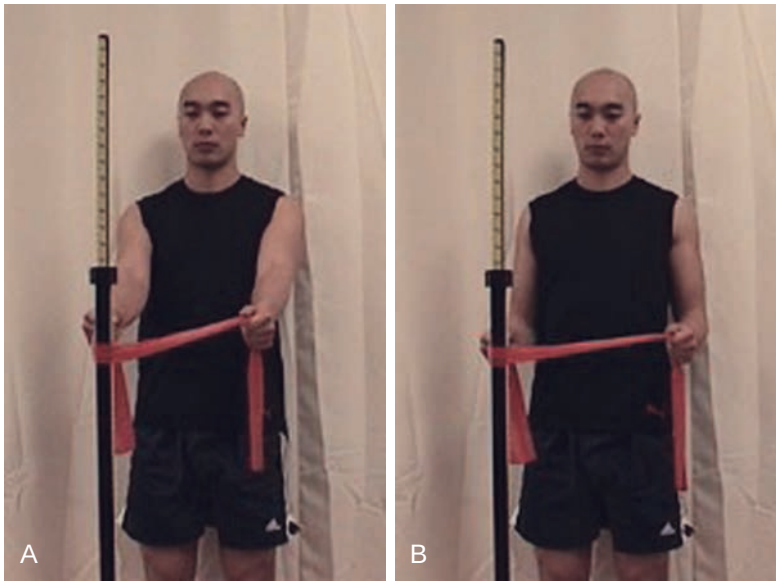

FIGURE 4-17. Resisted shoulder retractions (**A**) start position and (**B**) end position.

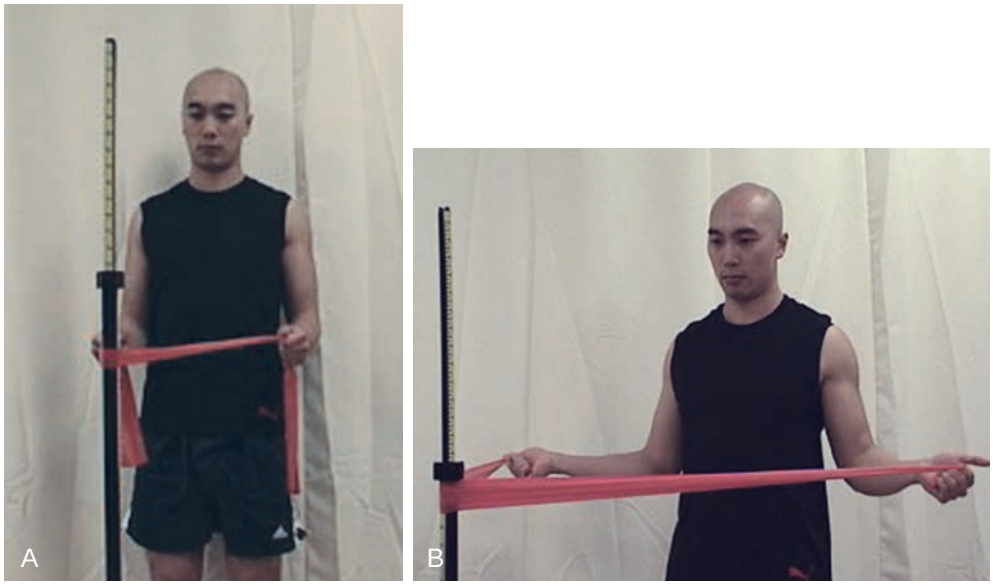

FIGURE 4-18. Standing "W"s (**A**) start position and (**B**) end position.

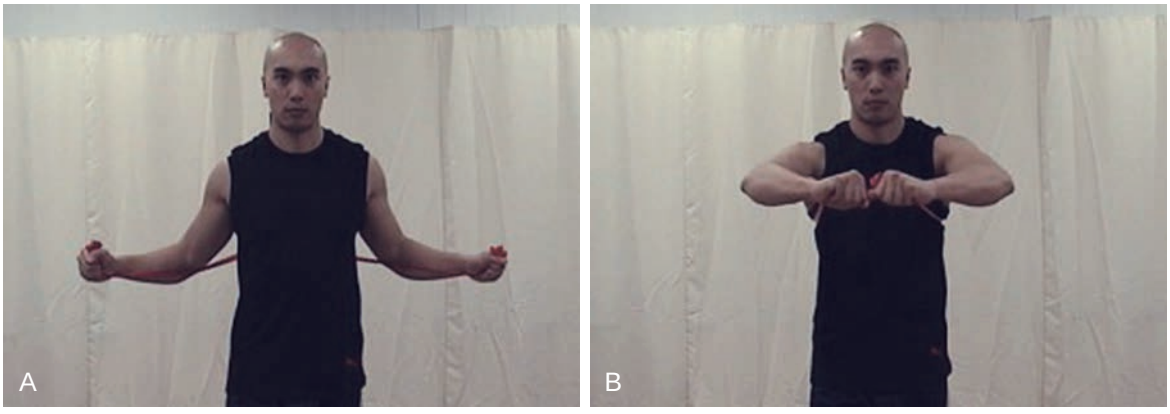

FIGURE 4-19. Dynamic hug strengthening exercise (**A**) start position and (**B**) end position.

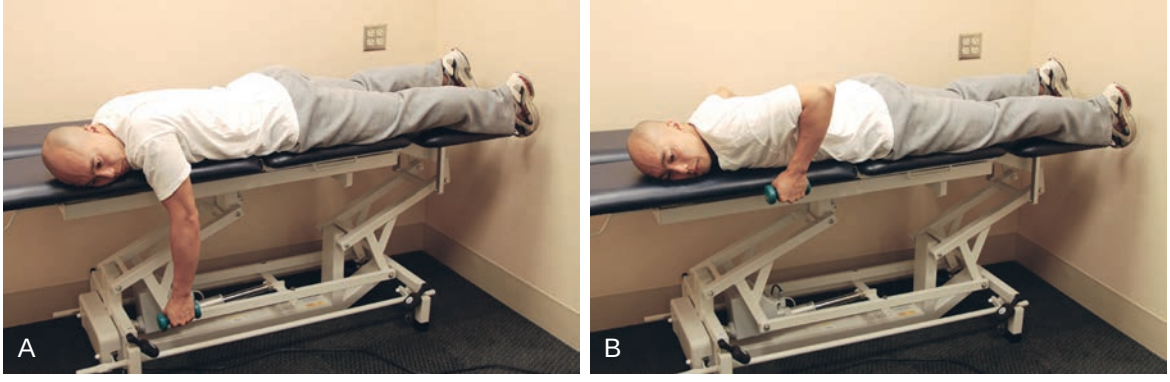

FIGURE 4-20. Prone rowing (**A**) start position and (**B**) end position.

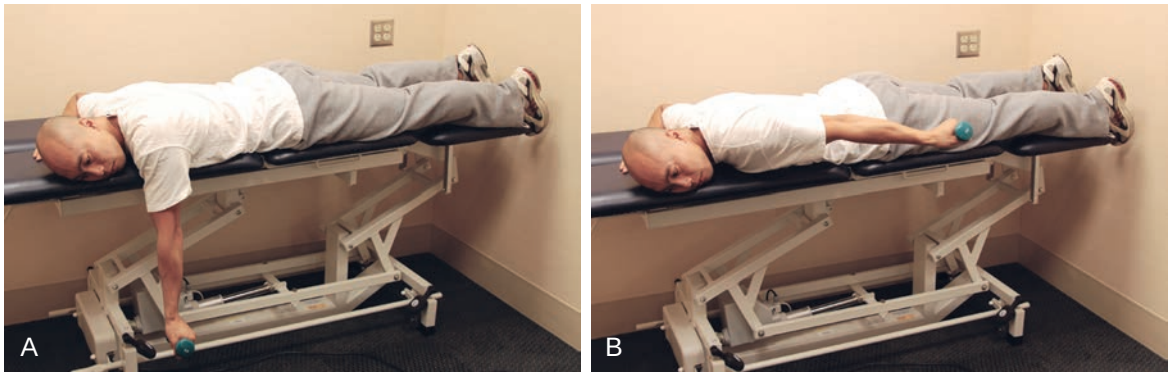

FIGURE 4-21. Prone extension (**A**) start position and (**B**) end position.

total arc of motion (internal + external rotation ROM) to approximate total arc of motion values for the uninvolved shoulder.[11]

- Normal arthrokinematics glenohumeral joint. Arthrokinematics with manual accessory motion testing should be assessed in the posterior and inferior direction with the arm at 90° of abduction and external rotation.
- Normal scapulohumeral motion during active ROM in all planes as determined by the scapular dyskinesis test.[8] With this test, the athlete should demonstrate no dysrhythmia or winging during five repetitions of full flexion and abduction holding 5-lb hand weights.
- Shoulder strength 75% to 80% uninvolved below shoulder height can be assessed with the arm at 0° and 45° of abduction through range of motion with manual resistance of the examiner, but isometrically in multiple ranges with an hand-held dynamometer because an objective measure is more sensitive to detect apparent weakness up to 20% when manual resistance is deemed normal.[12] Isokinetic testing could be used as a more objective measure.
- Normal dynamic trunk and kinetic chain strength and motor control with functional tests including single leg squat or step down with demonstration of neutral varus or valgus alignment of the knee avoidance of pelvic drop and good balance/control, unilateral balance and hold with pitching stance, plank trunk stability with neutral spine for at least 1 minute.

Phase III (weeks 12 to 16)

Management of Pain and Swelling

- Cryotherapy after exercise as needed

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Continue grade III glenohumeral joint mobilizations and terminal ROM stretching for posterior shoulder as needed to maintain ROM
- Thoracic spine mobilization/manipulation as needed

Soft Tissue Techniques

- Continue soft tissue techniques to maintain posterior shoulder (infraspinatus and teres minor) muscle extensibility as needed

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Specific stretching following exercise should be continued to maintain shoulder, thoracic spine and hip flexibility
- Continue sleeper stretches
- Shoulder horizontal adduction stretching
- Hip ABD/IR/ER/flexion stretching
- Thoracic spine extension and rotation
- Pectoralis major stretching in doorway or corner[2] (Figure 4-22) with emphasis on scapular retraction and sensation of the stretch in chest not shoulder
- Continue bar hang stretch for latissimus dorsi stretching

Other Therapeutic Exercises

- Progress aerobic activity
- Lower extremity resistance training is progressed
- Core stability exercises are progressed to sport-specific positions and conditions



FIGURE 4-22. Pectoralis major stretch in doorway.

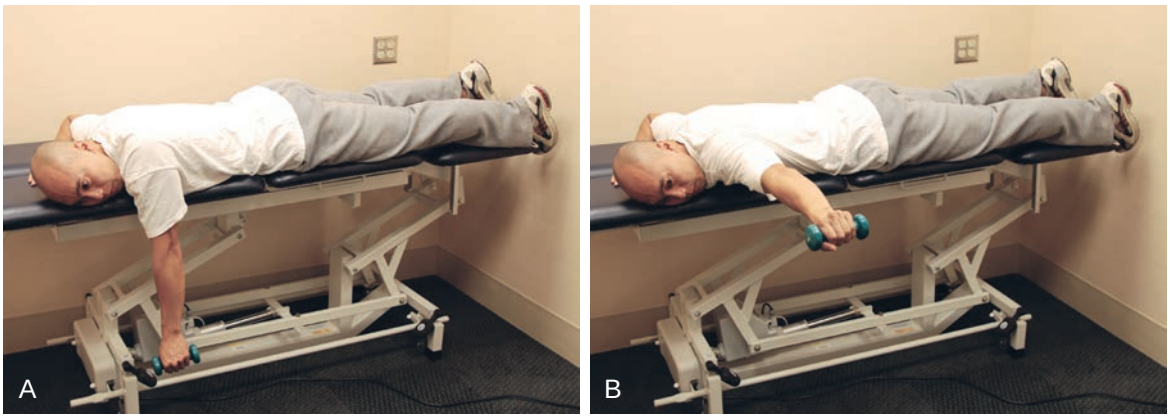

FIGURE 4-23. Prone horizontal abduction "T"s in neutral rotation (**A**) start position and (**B**) end position.

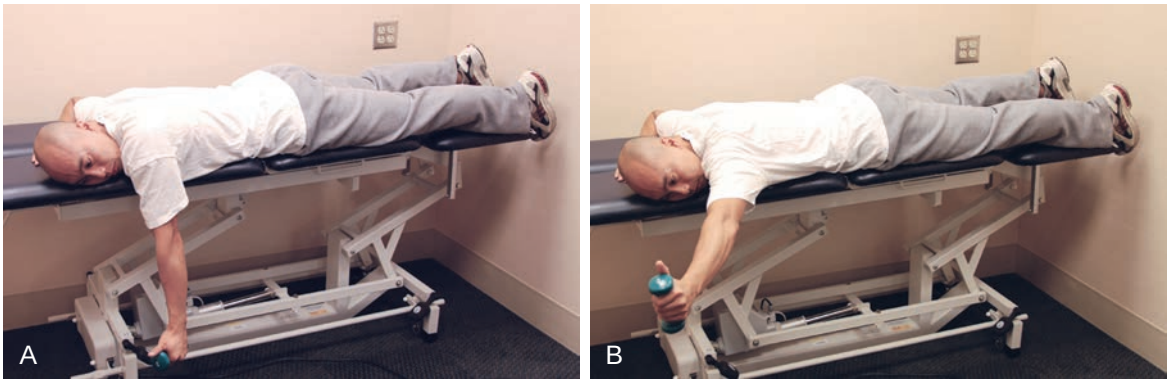

FIGURE 4-24. Prone scaption "Y"s in external rotation at 110° (**A**) start position and (**B**) end position.

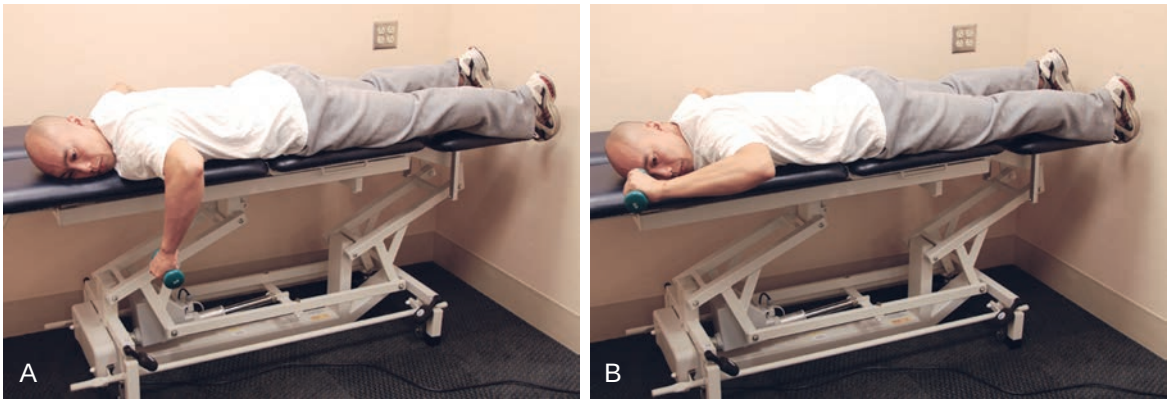

FIGURE 4-25. Prone external rotation at 90° abduction (**A**) start position and (**B**) end position.

- Total arm strengthening initiated with biceps curl, triceps extension, wrist supination, and pronation

Activation of Primary Muscles Involved

Progress shoulder and rotator cuff strengthening to complete a modified Thrower's Ten program[13] with the addition of:

- Prone horizontal abduction "T"s (Figure 4-23)
- Prone scaption "Y"s (Figure 4-24)
- Prone external rotation at 90° abduction (Figure 4-25)
- Shoulder scaption to 90° elevation full can position (Figure 4-26)
- Supine inclined pull ups with scapular retraction[5]



FIGURE 4-26. Scapular plane "full can" elevation to 90°.

Sensorimotor Exercises

- Rhythmic stabilization and manual strengthening of the UE with long moment arms/distal resistance
- The Bodyblade at 0° abduction as well as 90° scapular elevation
- Core stability exercises with manual resistance on stable progressing to unstable surfaces. Progressing to unstable surface requires additional core stability and provides an additional challenge to the athlete.

Open and Closed Kinetic Chain Exercises

- PNF in D1–2 with manual resistance to scapula and humerus with slow reversals and midrange holds.
- Closed chain stability holds in quadruped, plank prone, and side-on stable and unstable surfaces with manual perturbations.

Techniques to Increase Muscle Strength, Power, and Endurance

- Progression of lower extremity strength training exercises.
- Progress to elliptical, stair stepper, jogging/running for cardiovascular conditioning.

Plyometrics

- Light plyometrics with throw at the side (Figures 4-27*A-D*)
- Wall dribbles light resistance overhead and various arm angles (Figure 4-28)
- Decelerations/eccentric control of follow-through in half-kneeling (Figure 4-29)
- Two-hand medicine ball chest pass and side toss
- Continue lower extremity plyometrics with emphasis on frontal plane/lateral movements[14]

Sport-Specific Exercises

- Initiate exercises and sport-specific drills with arm below shoulder height such as fielding drills and base work

Milestones for Progression to the Next Phase

- No complaints of symptoms/pain with exercise, and minimal discomfort after exercise resolves with cryotherapy
- Full pain-free uncompensated AROM of shoulder complex. AROM should be assessed in all planes and considered normal when equal bilaterally
- Excellent core and proximal stability of hips and lower extremity with functional tests such as single leg squat or step down with demonstration of neutral varus or valgus alignment of the knee avoidance of pelvic drop and good balance/control
- Strength of rotator cuff, shoulder and scapular stabilizers at least 80% to 90% uninvolved with isokinetic

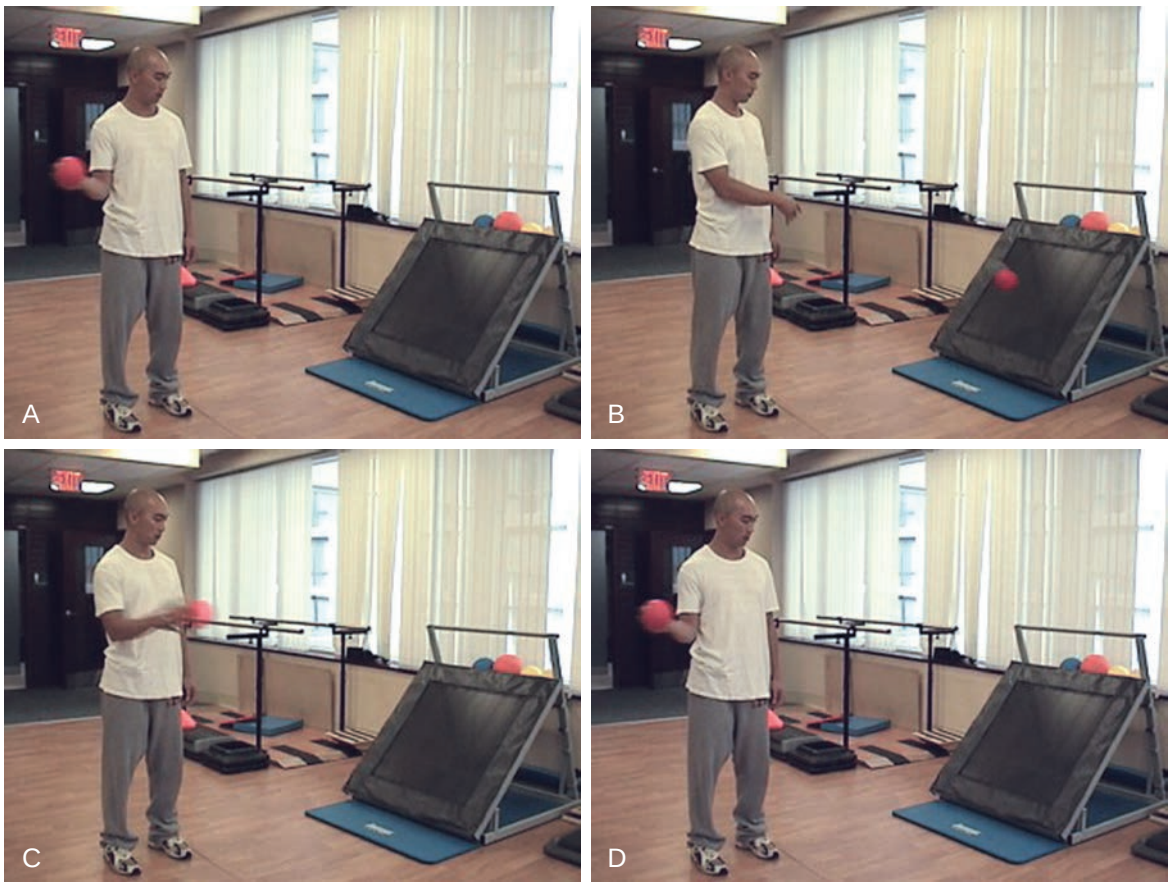

FIGURE 4-27. Plyometrics one arm throw at the side (**A**) wind up, (**B**) release, (**C**) catch, and (**D**) eccentric follow-through.



FIGURE 4-28. Wall dribbles light resistance in various positions (**A**) overhead, (**B**) above 90°, and (**C**) just below 90° abduction.



FIGURE 4-29. Decelerations with eccentric control with (**A**) a catch from a toss behind, and (**B**) eccentric control during follow-through followed by concentric toss behind.

testing, or if unavailable, hand-held dynamometry at multiple arm angles in external rotation, internal rotation and abduction to 90°. Isokinetic testing is preferred.
- Self-report outcome scores >80% such as the Kerlan-Jobe Orthopaedic Clinic[15,16] shoulder and elbow score are more sensitive than regional outcome tools such as the Disability of the Shoulder Arm and Hand.[17]

Phase IV (weeks 16 to 24)

Management of Pain and Swelling

- Cryotherapy with/without electrical stimulation after exercise as needed

Techniques for Progressive Increase in Range of Motion

- Athlete must maintain ROM and flexibility achieved in prior phases
- Strengthening and dynamic plyometric activities progress to more challenging positions of sport in abduction and external rotation

Manual Therapy Techniques

- Continue grade III mobilizations and terminal ROM stretching for posterior shoulder as needed to maintain ROM
- Thoracic spine mobilization/manipulation as needed

Soft Tissue Techniques

- Continue soft tissue techniques to maintain posterior shoulder (infraspinatus and teres minor) muscle extensibility

Stretching and Flexibility Techniques for the Musculotendinous Unit

Specific stretching following exercise should be continued to maintain shoulder, thoracic spine and hip flexibility:
- Sleeper stretches
- Horizontal adduction
- IR/ER/flexion hip stretching

- Thoracic spine extension and rotation. Extension can be facilitated by lying supine over physioball. Rotation can be achieved with side-lying thoracic rotation with hips and lumbar spine flexed to isolate stretch to thoracic region.

Other Therapeutic Exercises

- Progress aerobic activity
- Lower extremity resistance training is progressed
- Core stability exercises are progressed to target deficits noted in sport-specific positions such as unilateral stance in cocking position for pitchers and throwing for fielders
- Total arm strengthening continue; progress with biceps curl, triceps extension, wrist supination and pronation

Activation of Primary Muscles Involved

- Begin sport-specific return to sport progressions (i.e., interval throwing, swimming, tennis programs) and/or collaboration with sports performance specialists once strength, self-report outcome and full uncompensated active and passive ROM goals of this phase are achieved

Sensorimotor Exercises

- Progress rhythmic stabilization and manual strengthening of the UE progressed to long moment arms and distal points of resistance.
- Progress the Bodyblade to 90° abduction and external rotation in bilateral and unilateral stance.
- Progress core stability exercises with manual resistance to unstable surfaces.

Open and Closed Kinetic Chain Exercises

- PNF in D1–2 with manual resistance with fast reversals and terminal holds with perturbations.
- Closed chain PNF in plank and long arc positions progressing to unstable surfaces with emphasis on good scapular control without evidence of winging or shrugging with visual observation.
- Upper extremity closed chain functional training used later for testing. The upper extremity closed chain function test requires the athlete to move their hands alternately back and forth from a pushup position, touching one of two lines at a time placed 3 feet apart on the ground.[18]

Techniques to Increase Muscle Strength, Power, and Endurance

- Progression of LE strength training exercises
- Sport-specific exercises and drills

Plyometrics

Progress plyometrics to unilateral and overhead positions:

- One arm rebounder throwing in abduction (Figure 4-30)
- Progress endurance with wall dribbles at various angles approximating 90° abduction
- Heavy full kinetic chain plyometrics (such as medicine ball floor slams, wall throws, chest pass/side trunk rotation scoop toss/squat throws)
- Continued lower extremity plyometrics with emphasis on frontal plane/lateral movements for throwers

Sport-Specific Exercises

- Initiate return to sport specific interval progressions (throwing/catch, swimming, tennis groundstrokes, etc.) performed on an every-other-day basis
- Athletes should work closely with coaches and trainers to insure proper technique with sport activity, particularly when the athlete is fatiguing
- Pitchers should work with a coach to insure proper mechanics with various types of pitches
- Swimmers should work with a coach to insure proper mechanics with freestyle progressing to other types of swimming strokes
- Tennis players should work with a coach to insure proper mechanics with ground strokes progressing to all types of overhead hits and serves

Milestones for Progression to Advanced Sport-Specific Training and Conditioning

- No symptoms of pain or discomfort during or following exercise
- Functional closed kinetic chain tests (upper extremity, core, lower extremity) are >90% uninvolved or considered normal with good control and accuracy
  - Davies closed kinetic chain upper extremity stability test[19]
  - At least an average of 7 in 3 trials of timed modified pullup for 15 seconds
  - At least an average of 15 in 3 trials of timed pushup for 15 seconds
  - Single arm seated shot put test performed with lower extremities elevated on a chair with a distance of at least 2 m using a 2.72 kg (small softball size) medicine ball
- Strength >90% uninvolved with isokinetic testing or at minimum hand-held dynamometry specific to internal, external, and abduction in multiple arm angles.
- Normal flexibility ROM of posterior shoulder, thoracic spine and hips. Posterior shoulder range of motion can be evaluated with passive horizontal adduction[10] with the scapula stabilized should be greater than 90° or beyond vertical position towards the chest. Internal rotation should be sufficient to allow for the total arc of motion (internal + external rotation ROM) to approximate total arc of motion values for the uninvolved shoulder.[11] Hip flexion ROM should be at least 110° of flexion, and 40° internal rotation.

Criteria for Abandoning Nonoperative Treatment and Proceeding to Surgery or More Intensive Intervention

- Inability to meet milestones/criteria for progression to next phase of rehabilitation in upper limit of time frames specified

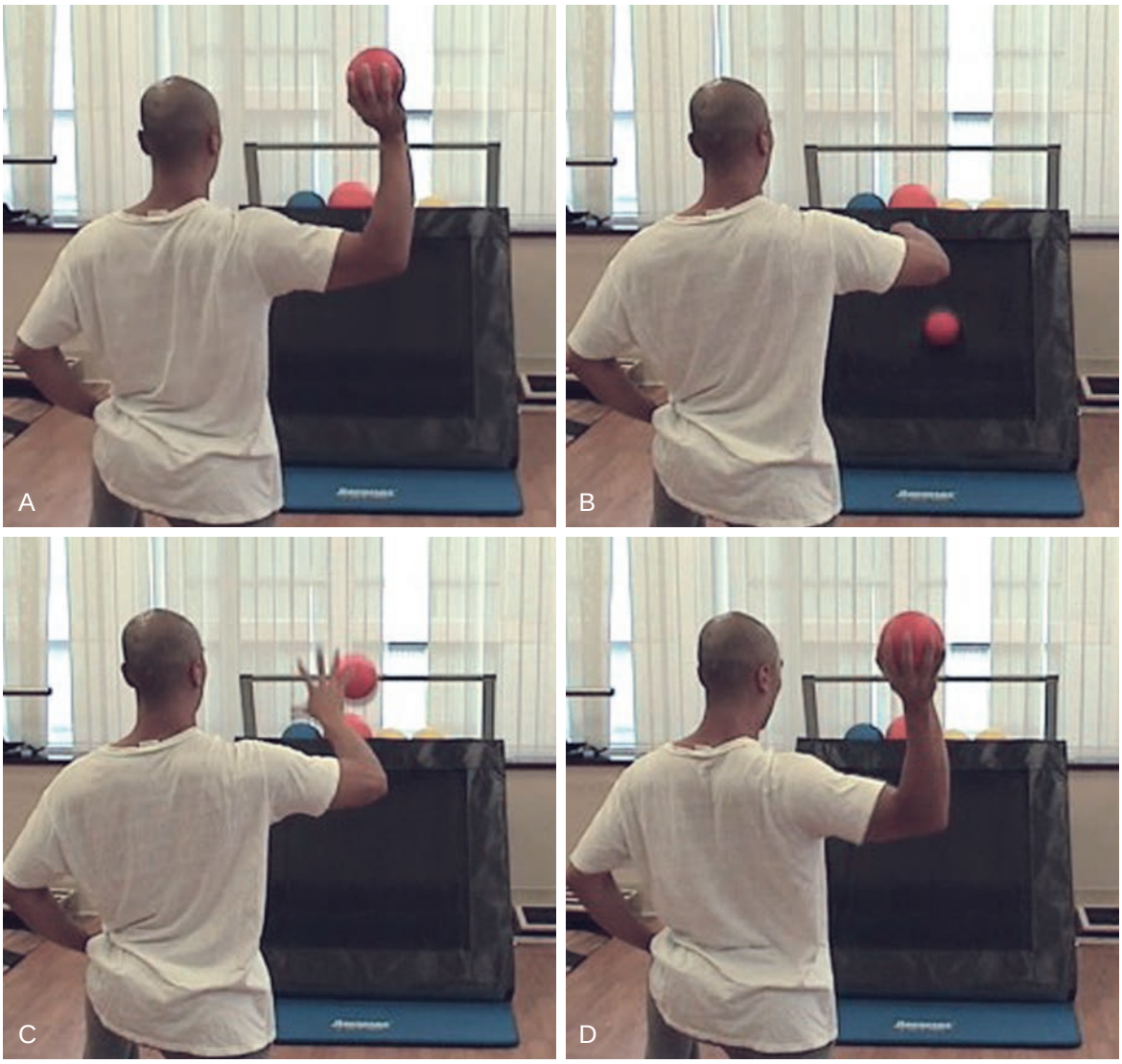

FIGURE 4-30. Plyometrics one arm throw in abducted position (**A**) wind up, (**B**) release, (**C**) catch, and (**D**) eccentric follow-through.

- Pain increases with appropriately phased exercises and does not respond to rest, modalities, ANSAIDS or corticosteroid injection(s)
- Recurrence of injury during any phase of rehabilitation
- Unable to achieve level of performance necessary to successfully return and compete in sport

Tips and Guidelines for Transitioning to Performance Enhancement

- Although skilled rehabilitation of the shoulder and kinetic chain is achieved during Phase I to IV interventions, skill and optimal performance in the specific-sport activities is a necessary component to successful recovery and is frequently overlooked at the end of rehabilitation.
- Performance enhancement further develops the specific skills to optimize performance with the demands required of the athlete's particular specialty within each sport.
- Specialists trained in functional movement screens and evaluation techniques to identify remaining movement dysfunctions and maximize performance are essential to return to sport success. Rehabilitation specialists should work closely with strength and performance enhancement specialists during this final stage of rehabilitation to then transition to a comprehensive performance enhancement program.
- This team approach is optimal for full recovery of the athlete at participating at competitive levels.

Performance Enhancement and Beyond Rehabilitation: Training/ Trainer and Optimization of Athletic Performance

- Performance enhancement and optimization will include a comprehensive program to address performance aspects of the sport including power, strength, accuracy, velocity.

- Performance enhancement should be initiated near the end of rehabilitation in combination or before return to sport progressions are initiated.
- Detailed information regarding sports performance enhancement can be found in the Beyond the basics section.

Specific Criteria for Return to Sports Participation: Tests and Measurements

- Normal uncompensated scapulothoracic and glenohumeral motion under fast and resisted conditions with sport-specific activities. Can observe scapular motion during the functional closed chain upper extremity functional test, and can consult pitching coach to insure adequate mechanics with pitching or throwing. Should assess scapular stability for winging or shrugging with all strengthening exercises and sport-specific drills.
- No symptoms of pain or discomfort during or following exercise
- Maintenance of normal strength and flexibility shoulder, core, lower extremity
  - Shoulder strength >90% uninvolved with isokinetic testing or at minimum hand-held dynamometry specific to internal, external, and abduction in multiple arm angles.
  - Normal posterior shoulder ROM can be maintained with diligent stretching with sleeper stretching and assistance with IR glenohumeral stretching on a daily basis. Passive horizontal adduction[10] with the scapula stabilized should be greater than 90° or beyond vertical position towards the chest. Internal rotation should be sufficient to allow for the total arc of motion (internal + external rotation ROM) to approximate total arc of motion values for the uninvolved shoulder.[11]
  - Lower extremity star excursions or step-downs should be equal bilaterally with good pelvic control.
- Successful completion of return to sport interval progression
- Normal mechanics with sport (throwing, swimming, tennis) and confirmation from coach, trainer, and/or sports performance specialist that performance is optimized for return to competitive play

Evidence

Alberta FG, ElAttrache NS, Bissell S, et al: The development and validation of a functional assessment tool for the upper extremity in the overhead athlete. *Am J Sports Med* 38:903–911, 2010.

Study validating standardized self report upper extremity outcome tool in overhead athletes. (Level III evidence)

Beaton DE, Katz JN, Fossel AH, et al: Measuring the whole or the parts? Validity, reliability and responsiveness of the DASH Outcome Measure in different regions of the upper extremity. *J Hand Ther* 14:128–146, 2001.

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Bergman GJ, Winters JC, Groenier KH, et al: Manipulative therapy in addition to usual medical care for patients with shoulder dysfunction and pain: a randomized, controlled trial. *Ann Intern Med* 141:432–439, 2004.

RCT on effects of manipulation in patients with shoulder pain. (Level III evidence)

Borstad JD, Ludewig PM: The effect of long versus short pectoralis minor resting length on scapular kinematics in healthy individuals. *J Orthop Sports Phys Ther* 35:227–238, 2005.

Laboratory study examining positions for exercises that increase the length of pectoralis minor. (Level IV evidence)

Goldbeck T, Davies GJ: Test-retest reliability of a closed kinetic chain upper extremity stability test: A clinical field test. *J Sport Rehabil* 9:35–945, 2000.

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Jeong D, Lee J, Yi YS, et al: p38/AP-1 pathway in lipopolysaccharide-induced inflammatory responses is negatively modulated by electrical stimulation. *Mediators Inflamm* 2013:183042, 2013.

Laboratory in vitro study on mechanisms of electrical stimulation on inflammation. (Level IV evidence)

Kebaetse M, McClure P, Pratt NA: Thoracic position effect on shoulder range of motion, strength, and three-dimensional scapular kinematics. *Arch Phys Med Rehabil* 80:945–950, 2000.

Laboratory study examining thoracic position on kinematics. (Level IV evidence)

Kraeutler MJ, Ciccotti MG, Dodson CC, et al: Kerlan-Jobe Orthopaedic Clinic overhead athlete scores in asymptomatic professional baseball pitchers. *J Shoulder Elbow Surg* 22:329–332, 2013.

Study standardized self report upper extremity outcome tool in overhead athletes. (Level III evidence)

Lehman G, Drinkwater EJ, Behm DG: Correlation of throwing velocity to the results of lower-body field tests in male college baseball players. *J Strength Cond Res* 27:902–908, 2013.

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McClure P, Balaicuis J, Heiland D, et al: A randomized controlled comparison of stretching procedures for posterior shoulder tightness. *J Orthop Sports Phys Ther* 37:108–114, 2007.

Study comparing changes in shoulder internal rotation range of motion (ROM), for two stretching exercises, the sleeper and horizontal adduction stretches, in individuals with posterior shoulder tightness. (Level II evidence)

McClure P, Tate AR, Kareha S, et al: A clinical method for identifying scapular dyskinesis, Part 1: reliability. *J Athl Train* 44:160–164, 2009.

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Muth S, Barbe MF, Lauer R, et al: The effects of thoracic spine manipulation in subjects with signs of rotator cuff tendinopathy. *J Orthop Sports Phys Ther* 42:1005–1016, 2012.

Laboratory study examining mechanisms of thoracic spine manipulation in individuals with rotator cuff disorders. (Level IV evidence)

Myers JB, Oyama S, Wassinger CA, et al: Reliability, precision, accuracy, and validity of posterior shoulder tightness assessment in overhead athletes. *Am J Sports Med* 35:1922–1930, 2007.

Study examining relability and concurrent validity of internal rotation and horizontal adduction measurements of posterior shoulder tightness. (Level III evidence)

Negrete RJ, Hanney WJ, Kolber MJ, et al: Reliability, minimal detectable change, and normative values for tests of upper extremity function and power. *J Strength Cond Res* 24:3318–3325, 2010.

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Reagan KM, Meister K, Horodyski MB, et al: Humeral retroversion and its relationship to glenohumeral rotation in the shoulder of college baseball players. *Am J Sports Med* 30:354–360, 2010.

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Vassal F, Creac'h C, Convers P, et al: Modulation of laser-evoked potentials and pain perception by transcutaneous electrical nerve stimulation (TENS): A placebo-controlled study in healthy volunteers. *Clin Neurophysiol* 124:1861–1867, 2013.

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Wilk KE, Meister K, Andrews JR: Current concepts in the rehabilitation of the overhead throwing athlete. *Am J Sports Med* 30:136–151, 2002.

Review of an exercise and rehabilitation program for overhead athletes. (Level V evidence)

Wilk K, Andrews JR, Arrigo C, editors: *Preventative and rehabilitative exercises for the shoulder and elbow*, ed 6, Birmingham, American Sports Medicine Institute, 2001.

Contains the original Thrower's Ten exercise program. (Level V evidence)

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Multiple-Choice Questions

QUESTION 1. The rehabilitation for nonoperative management of SLAP tears is focused on:

A. Rotator cuff strengthening
B. Core stability
C. Posterior shoulder flexibility
D. Impairments identified from a comprehensive examination

QUESTION 2. The following is true of Phase I rehabilitation of SLAP tears **EXCEPT:**

A. Include normalizing glenohumeral AROM in all planes
B. Is necessary to complete for at least 4 weeks in all athletes
C. Includes modalities and cryotherapy as needed to improve pain
D. Includes strengthening at terminal ranges of motion

QUESTION 3. Common to most overhead athletes with SLAP tears, posterior shoulder flexibility should be addressed with:

A. Sleeper stretch
B. Horizontal adduction self-stretching
C. Glenohumeral joint mobilizations and soft tissue techniques
D. All of the above

QUESTION 4. Plyometrics for the involved shoulder and upper extremity should be initiated:

A. In positions of stability with the arm in neutral and below shoulder height
B. In simulated positions of throwing/serving/swimming
C. In closed chain behind the plane of the body
D. Rarely

QUESTION 5. The final decision for return to play following rehabilitation of a SLAP tear should be based on testing from:

A. Successful completion of interval return to sport program
B. Clearance from the rehabilitation specialist and physician that milestones have been met
C. Approval from the coach, trainer/strength and conditioning specialist
D. All the above

Answer Key

QUESTION 1. Correct answer: **D** (see key points)

QUESTION 2. Correct answer: **B** (see key points)

QUESTION 3. Correct answer: **A** (see Phase II)

QUESTION 4. Correct answer: **A** (see Phase III)

QUESTION 5. Correct answer: **D** (see Phase IV)

POSTOPERATIVE REHABILITATION AFTER TREATMENT OF SLAP TEARS

Amee L. Seitz, PT, PhD, DPT, OCS, and Thomas J. Gill IV, MD

Indications for Surgical Treatment

Indications for surgical treatment of a superior labrum anterior to posterior (SLAP) tear are persistent symptoms with loss of function and sports performance despite conservative treatment. Symptoms can include:

- Pain, usually with overhead activities
- Loss of strength
- Catching, locking, popping, or grinding
- Occasional night pain or pain with daily activities
- A sense of instability in the shoulder
- Decreased range of motion

Brief Summary of Surgical Treatment

Major Surgical Steps

- General anesthesia and shoulder arthroscopy
- Beach chair position
- Arthroscopic portals
  - A posterior viewing portal placed 2 cm inferior to the posterolateral corner of the acromion
  - A standard anterior portal placed under direct visualization anterior and 1 cm lateral to the coracoid, with the cannula inserted just inferior to the biceps in the rotator interval
- Arthroscopic evaluation to determine type of SLAP, evaluation of the entire glenoid labrum, biceps tendon, articular surface of the glenoid and humeral head, glenohumeral ligaments, subscapularis tendon, and rotator cuff
- A lateral portal is made under direct visualization just posterior to the biceps tendon at the anterior margin of the supraspinatus in the rotator interval
- The superior glenoid was abraded down to a gently bleeding bony bed posterior to the biceps anchor footprint with a 4.2 mm bone cutting shaver
- Single loaded 3.5 mm suture anchors are placed posterior to the biceps footprint.
- The sutures are passed using a suture passing device. The sutures are tied using an arthroscopic sliding knot (Duncan loop) followed by half hitches.
- A probe is used to evaluate the repair integrity

Factors That May Affect Rehabilitation

Surgical

- The type of SLAP repair strongly dictates rehabilitation progression. A type II and IV involving the biceps anchor have precautions regarding early biceps use and graded return of ROM
- Type I and III SLAP repairs typically require arthroscopic debridement of the labrum and not an anatomic repair. Thus rehabilitation progression may be more aggressive to restore range of motion in early phase

Other Surgical Techniques and Options

- If the patient has involvement that necessitates surgical repair of other structures (rotator cuff tendons) the postoperative rehabilitation course will deviate from SLAP to rotator cuff repair guidelines.

Before Surgery: Overview of Goals, Milestones, and Guidelines[1]

GUIDING PRINCIPLES OF POSTOPERATIVE REHABILITATION

- A thorough understanding regarding the type of SLAP repair and other procedures is essential to rehabilitation success (concomitant rotator cuff repair should follow rotator cuff rehabilitation guidelines)
- Adequate protection of repair including biceps when applicable while minimizing postoperative morbidities
- Understanding of positions and activities that stress repair and time frames for healing
- Restoration of normal arthrokinematics and dynamic neuromuscular control of the shoulder complex is critical to successful recovery

Phase I: Immediate Postoperative Period (days 0 to 14)

Clinical Pearls

- In the week or so immediately following surgery, comfort and pain control is important.
- The patient should be educated in positions to maximize comfort including the use of pillows to prop the shoulder in a "loose pack" position (slight abduction, flexion and neutral rotation) and may be encouraged to sleep in a recliner for the first few days following surgery to achieve this. When the patient lies supine without support behind the elbow, there is tension on the repair and/or superior shoulder joint soft tissues.
- Additionally, the patient would benefit from instruction in strategies to put on a shirt and wash under the arm of the involved shoulder by bending at the waist, similar to a Codman's pendulum exercise.

Goals

- Control pain and swelling
- Protect the repair and promote healing
- Minimize side effects of immobilization including stiffness and muscular atrophy

[1]*Prehabilitation, if appropriate, is described in the Nonoperative Rehabilitation section of this chapter.*

Protection

- The use of a sling at all times is necessary except during ROM exercises and bathing. Patients instructed to avoid active biceps contraction, but use of hand and wrist in front of body while in the sling is permitted within pain tolerance.
- No lifting or carrying objects with the involved hand is instructed.

Management of Pain and Swelling

- Patient education regarding proper positioning to reduce tensile loads on repair and surrounding soft tissue using pillows and/or recliner when resting.
- Ice intermittently, 4 to 5 times per day 15 to 20 minutes at a time
- Oral pain medications as instructed by the surgeon
- TENS unit may be used
- Use of Cryo Cuff or ice packs to minimize pain and inflammation
- Modalities including electrical stimulation

Techniques for Progressive Increase in Range of Motion

Guidelines for progressive increase in ROM (Table 4-1) are based on tissue healing and have been adapted from published literature.[1-3]

- Initial ROM HEP before postoperative surgeon's visit consists of Codman's pendulum exercises for the shoulder or modified version of table forward bow (Figure 4-31) which does not differ in the amount of electrical muscle activity of the shoulder from the pendulum exercise.[1]
- Wrist and hand active ROM exercises are encouraged 4 to 5 times per day
- Postural scapular squeezes with arm supported in the sling 4 to 5 times per day

Manual Therapy Techniques

- Type II, IV SLAP Repair ROM Precautions: ER <15° with the arm in scapular plane, humeral elevation in scapular plane 60° to 75° (precautions adjusted for other concurrent surgical repairs such as rotator cuff involvement)
- PROM: Manual range of glenohumeral joint (per precautions) as well as affected elbow, wrist, and scapula. Muscular guarding should be considered and manual therapy adjusted as necessary to facilitate relaxation of the biceps.
- Type I, III SLAP Repair ROM Precautions: ROM to progress within pain tolerance with elevation in scapular plane to 110°, ER at the side, and AAROM behind the back

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Type II, IV SLAP Repair: Stretching not performed during this stage with the exception of the wrist and hand (elbow bent) as needed

Table 4-1 Postoperative ROM Guidelines

Postop Timeframe	Type SLAP Repair	Range of Motion	Scaption (degrees)	Flexion (degrees)	External Rotation (degrees)	Internal Rotation (degrees)	Abduction (degrees)	Adduction (degrees)	Extension (degrees)	Elbow AROM
0–14 d	Type II, IV	PROM	60	60	15 (in 30 scaption)	45 (in 30 scaption)	N/a	0	0	No active flexion
	Type I, III	P/AAROM/ AROM	120	120	60 (in 30 &45 abduction)	60 (in 45 Abduction)	90	0	20	No active flexion
2–4 wk	Type II, IV	P/AAROM	90	90	30 (in 30 scaption)	60 (in 30 scaption)	80	0	0	No active flexion
	Type I, III	P/AAROM→ AROM	Full	Full	Full (in 90 abduction)	Full in 90 Abduction	Full	Full	Full	Active/ resisted
4–6 wk	Type II, IV	P/AAROM→ AROM	145	145	60 (in 45 abduction)	60 (in 45 Abduction)	90	0	20	AROM flexion
6–10 wk	Type II, IV	AAROM/ AROM	Full	Full	90 (in 90 abduction)	75 (in 90 Abduction)	Full	H Add to 90	Full	Full
10–14 wk	Type II, IV	AROM	Full	Full		Full (in 90 Abduction)	Full	Full H Add	Full	Resisted

- Type I, III SLAP Repair: Gentle stretching of the glenohumeral joint within pain tolerance to normalize PROM in all planes

Other Therapeutic Exercises

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Active contraction of the biceps, elbow flexion and resisted supination, is contraindicated during this phase in patients with type IV SLAP repairs.

Neuromuscular Dynamic Stability Exercises

- Scapular active ROM including elevation and retraction while in the sling is encouraged every 2 to 3 hours to minimize alterations in scapular position and initiate dynamic scapular control. (Figure 4-32)

Milestones for Progression to the Next Phase

- Successful postoperative follow-up visit with surgeon's office
- No signs of infection and adequate wound healing
- Successful pain control
- Understanding of surgical type of SLAP repair and appropriate rehabilitation plan



FIGURE 4-31. Table forward bows for passive range of motion. (**A**) Start position and (**B**) end position.

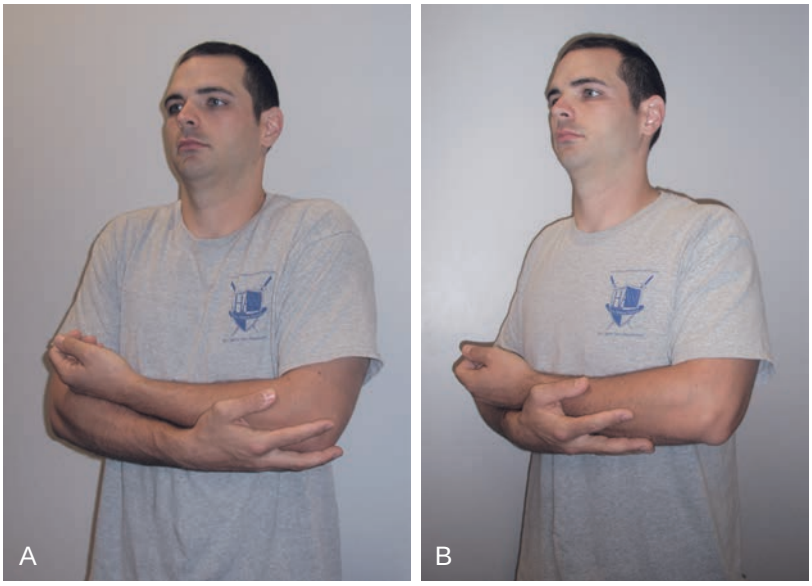

FIGURE 4-32. Scapular ROM in elevation (**A**) and retraction (**B**) which can be performed in the sling.

Phase II (weeks 2 to 6) : Early post-operative phase

Clinical Pearls

- The type of SLAP repair dictates the activities and goals for this phase of rehabilitation.
- The ROM gains should be gradual and well within pain tolerance following ROM Guidelines (Table 4-1).
- Rehabilitation of type II and IV SLAP repairs should focus on protected ROM progressions (Table 4-1) and submaximal rotator cuff and scapular stability exercises.
- Rehabilitation of type I, and III SLAP repairs should wean from sling immediately and focus on normalizing ROM, strength, and dynamic glenohumeral and scapulothoracic control, and core stability.

Goals

- Protection of surgical repair (particularly type II, IV with biceps involvement)
- Gradual restoration of normal glenohumeral range of motion within guidelines
- Decrease pain
- Improve dynamic neuromuscular control rotator cuff, scapular stabilizers, core

TIMELINE 4-2: **Postoperative Rehabilitation after SLAP II and IV Repair**

PHASE I (weeks 1 to 2)	PHASE II (weeks 3 to 6)	PHASE III (weeks 6 to 10)
• Sling • PT modalities • P/AAROM-scapular plane elevation to 60°, ER to 15° and IR to 45° in scapular plane • Active-assistive Codman's exercises and forward bow • Elbow ROM-no active biceps • Wrist and hand ROM exercises	• DC sling between 4 and 6 wk • PT modalities • P/AAROM—wk 3–4 flexion & scapular plane elevation to 90°, ABD to 80°, ER to 30° and IR to 60° in scapular plane; wk 5–6 flexion & scapular plane elevation to 145°, ABD to 90°, ER and IR to 60° in scapular plane & abduction 45° • No active elevation, extension, abduction and biceps up to 4 wk • Elbow stretching at 4 wk • Mobilizations GH joint grade II as needed • TBS/TLS activities as recommended & tolerated • OKC submaximal rhythmic stabilization with short moment arms and proximal perturbation • Rotator cuff exercises—submaximal pain free isometrics at 4 wk • Scapular clock and standing trunk/thoracic spine PNF AROM	• PT modalities as needed • P/AAROM—full ROM in flexion, abduction & scapular plane elevation, ER to 90° and IR to 75° at 90° ABD • End range GH and posterior shoulder stretching in horizontal adduction to 90° • Mobilizations GH joint grade III, IV emphasis on posterior and inferior as needed • TBS/TLS activities as recommended and tolerated • Scapular exercises—PREs • Rotator cuff exercises—PREs • PNF exercises • OKC rhythmic stabilization short moment arms and proximal perturbation • CKC exercises in quadruple progressing to knee plank positions

Protection

Type II, IV SLAP Repair ROM Precautions
- Continued use of sling until postop week 4 to 6 depending on surgeon preference and patient compliance with ROM restrictions
- No active elevation, extension, or abduction until 4 weeks
- No resisted biceps activities (shoulder and elbow flexion, supination)

Type I, III SLAP Repair ROM Precautions
- Gradually wean from sling based on pain tolerance

Management of Pain and Swelling

- Use of Cryo Cuff or ice packs as necessary
- Oral pain medications as needed
- Modalities including interferential electrical stimulation or TENS

Techniques for Progressive Increase in Range of Motion

Increase ROM guidelines for progressive increase in ROM in this phase are outlined in Table 4-1.

Manual Therapy Techniques

Type II, IV SLAP Repair
- Incremental increase in passive glenohumeral ROM per guidelines (Table 4-1): ER to 30° (weeks 3 to 4) and 60° (weeks 5 to 6) with the arm in scapular plane (Figure 4-33), flexion and scapular plane elevation to 90° (weeks 3 to 4) then 145° (weeks 5 to 6), extension to tolerance and IR in scapular plane to 45° initiated in week 4
- Initiate glenohumeral posterior inferior mobilizations grade II for pain progressing to grade III at 6 weeks postop to restore abnormal arthrokinematics as indicated within ROM limitations



FIGURE 4-33. Scapular plane IR and ER passive GH ROM.

- Initiate scapular mobilizations elevation, retraction, depression and posterior tilt

Type I, III SLAP Repair
- Normalize to full passive glenohumeral ROM within pain tolerance in all planes starting ER in neutral progressing to 45° and 90° of abduction
- Grade II, III mobilizations inferior and posterior as needed to reduce anterior superior stress to the capsule in flexion and abduction with external rotation

Soft Tissue Techniques

- Pectoralis minor active release or preferred soft tissue technique as needed to normalize muscle length to restore adequate scapular posterior tilt.[4] Minimum length can be determined by supine assessment of acromion distance from bed should be equal bilaterally.
- Scar mobilization as needed

Additionally type I, III SLAP repair can initiate:
- Normalize posterior shoulder ROM within pain tolerance with horizontal adduction to 90° and internal rotation at 90° of abduction

TIMELINE 4-2 Postoperative Rehabilitation after SLAP II and IV Repair (Continued)

PHASE IV (weeks 10 to 14)	PHASE V (weeks 14 to 24)	PHASE VI (weeks 24+)
• PROM—maintain full motion • Mobilizations as needed • TBS/TAS initiating bicep specific/TLS activities as recommended & tolerated • Scapular exercises—PREs progressed • Rotator cuff exercises—PREs • Thrower's Ten full program • PNF exercises • OKC rhythmic stabilization and manual perturbation exercises • CKC exercises—long moment arm positions stable to unstable surfaces • CKC manual perturbation exercises • Plyometrics—2 arm below shoulder height progressing to 1 arm • Sport-specific exercises begin • Overhead athletes can initiate an interval program (throwing, swimming, tennis) once ROM, strength, and pain goals are met	• PROM—maintain full motion • Mobilizations as needed • TBS/TAS/TLS activities as recommended & tolerated • Scapular exercises—PREs • TAS—biceps/triceps PREs • Rotator cuff exercises—PREs • Thrower's Ten progress intensity • PNF exercises • OKC rhythmic stabilization exercises • CKC exercises • CKC manual perturbation exercises • Plyometrics—overhead acceleration/deceleration progressing to 90/90 1 arm • Overhead strengthening exercises • Sport-specific exercises progressed • Overhead athletes complete an interval program (throwing, swimming, tennis) • Various types of pitches from mound/hits/serves/strokes without restrictions are initiated	• PROM—maintain full motion as needed • Mobilizations as needed • TBS/TAS/TLS activities as recommended & tolerated • Scapular exercises—PREs • TAS—biceps/triceps PREs • Rotator cuff exercises—PREs • Thrower's Ten progress intensity • PNF exercises • OKC rhythmic stabilization exercises • CKC exercises • CKC manual perturbation exercises • Plyometrics—overhead acceleration/deceleration progressing to 90/90 1 arm • Overhead strengthening exercises • Sport-specific exercises progressed • Overhead athletes complete an interval program (throwing, swimming, tennis) • Various types of pitches from mound/hits/serves/strokes without restrictions

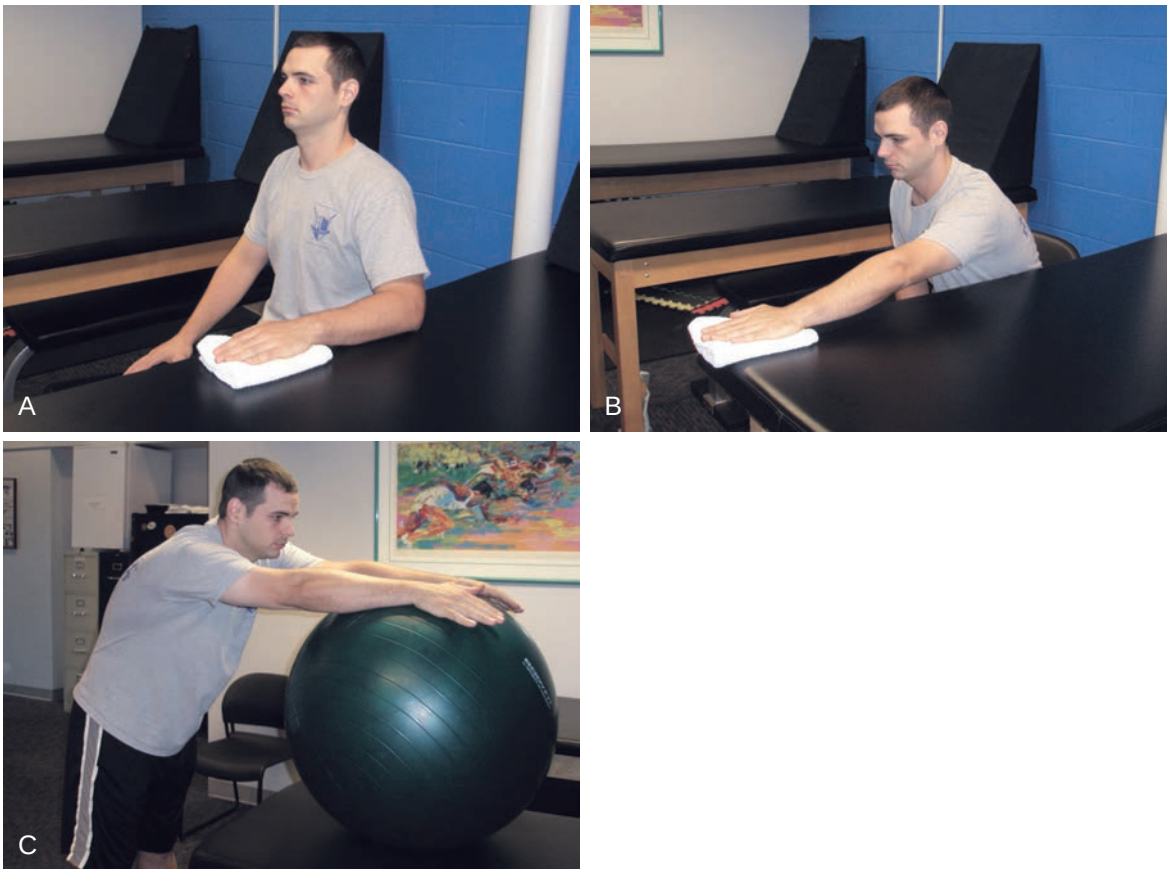

FIGURE 4-34. Stretching elevation with table slides (**A, B**) and ball walks (**C**).

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Closed chain upper extremity table slides progressing to flexed trunk position, ball walks (Figure 4-34) and wall slides within ROM precautions
- T-bar/cane exercises for AAROM within ROM precautions performed supine
- Elbow and wrist ROM stretching until normalized
- Behind the back internal rotation stretching using a towel to gently assist

Additionally type I, III SLAP repair can initiate:

- End range terminal stretching in all planes within pain tolerance until full ROM is achieved
- Posterior shoulder stretching with horizontal adduction to normal progressing to sleeper stretch[4]

TIMELINE 4-3: **Postoperative Rehabilitation after SLAP I and III Repair**

PHASE I (weeks 1 to 2)	PHASE II (weeks 3 to 6)	PHASE III (weeks 6 to 10)
• Sling • PT modalities • A/AAROM-scapular plane elevation to 120°, ER/IR to 60° in 45° ABD • Active-assistive Codman's exercises and forward bow • Submaximal isometrics • Elbow ROM—no active biceps • Wrist and hand ROM exercises	• DC sling • PT modalities • ROM full active and passive • End range GH and posterior shoulder stretching • Mobilizations II, III, IV as needed • TBS/TAS/TLS activities as recommended and tolerated • Scapular exercises—PREs • TAS—biceps/triceps PREs • Rotator cuff exercises—TheraBand and PREs • CKC exercises—Standing and quadruped	• PT modalities as needed • End range GH and posterior shoulder stretching • Mobilizations III, IV emphasis posterior and inferior as needed • TBS/TAS/TLS activities as recommended and tolerated • Thrower's Ten • PNF exercises • OKC rhythmic stabilization and short arc manual perturbation exercises • CKC exercises in plank positions from knees to toes • Plyometrics—2 arm below 45° abduction • Overhead strengthening exercises



FIGURE 4-35. Unilateral lower extremity lateral slides (**A**) and anterior reaches (**B**).

Other Therapeutic Exercises

- Return to nonimpact light aerobic activity (bike, elliptical, StairMaster) within pain tolerance once sling is discharged
- Lower extremity resistance training is initiated
- Core stability is initiated as able with seated ball exercises and unilateral stance lower extremity reaches and lateral slides (Figure 4-35) on stable surface progressed as technique allows

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

Type II, IV SLAP repair:

- Initiate rotator cuff internal/external rotation isometrics within pain tolerance at 4 weeks
- Rhythmic stabilization drills open chain within pain tolerance and ROM guidelines (Table 4-1)

Additionally type I, III SLAP repair can initiate:

- Isometrics for rotator cuff and shoulder in abduction, flexion, extension and adduction initiated immediately
- Active ROM in elevation scapular plane with emphasis on normal scapulohumeral rhythm
- Progress rotator cuff and scapular prone exercises to light isotonic and/or elastic resistance as ROM is normalized without scapular substitution patterns
  - Resisted IR/ER in neutral with elastic resistance
  - Sideling ER and forward punches
  - Side-lying scaption
  - Prone horizontal abduction, rowing

Sensorimotor Exercises

- Scapular clock
- Active elevation in scapular plane with mirror and verbal feedback to normalize dynamic motor control

TIMELINE 4-3 **Postoperative Rehabilitation after SLAP I and III Repair** (Continued)

PHASE IV (weeks 10 to 14)	PHASE V (weeks 14 to 24)
• PROM—maintain full motion • Mobilizations as needed • TBS/TAS/TLS activities as recommended and tolerated • Scapular exercises—PREs • Rotator cuff exercises—PREs • Thrower's Ten progress intensity • PNF exercises • OKC rhythmic stabilization and long arc manual perturbation exercises • CKC exercises plank and long arc positions • CKC manual perturbation exercises • Plyometrics—2 arm progressing to 1 arm overhead • Sport-specific exercises begin • Overhead throwing athletes can begin an interval program (throwing, swimming, tennis)	• PROM—maintain full motion • Mobilizations as needed • TBS/TAS/TLS activities as recommended & tolerated • Scapular exercises—PREs • TAS—biceps/triceps PREs • Rotator cuff exercises—PREs • IR/ER exercises at 90° • Thrower's Ten progress intensity • PNF exercises • OKC rhythmic stabilization exercises • CKC exercises • CKC manual perturbation exercises • Plyometrics—2 arm chest passes progressing to 90/90 1 arm plyos • Overhead strengthening exercises • Sport-specific exercises progressed • Overhead athletes complete an interval program (throwing, swimming, tennis) • Initiate various types of pitches/hits/serves/strokes without restrictions



FIGURE 4-36. Thoracic spine rotations in quadruped heel sitting.

Open and Closed Kinetic Chain Exercises

- Kneeling thoracic spine rotation once sling is discharged to improve scapular and thoracic mobility (Figure 4-36)

Additionally type I, III SLAP repair:

- Closed chain quadruped bent elbow progressing to elbow straight closed chain proximal stability exercises (plank on knees to toes prone and side)

Techniques to Increase Muscle Strength, Power, and Endurance

- Progression of LE strength training exercises
- Progress to elliptical and stair stepper for cardiovascular conditioning

Additionally type I, III SLAP repair:

- Progress biceps and triceps exercises in standing
- Progression of rotator cuff and scapular strength training exercises as tolerates without substitution

Neuromuscular Dynamic Stability Exercises

Type II, IV SLAP repair:

- Initiate submaximal isometrics for rotator cuff (IR/ER), shoulder (ABD, flex, ext) and scapular musculature (shrugs, retraction)
- Manual rhythmic stabilization within ROM guidelines

Additionally type I, III SLAP repair:

- PNF glenohumeral diagonals with manual proximal and distal resistance
- Manual rhythmic stabilization

Sport-Specific Exercises

- Overhead athletes should initiate core and lower extremity stability drills in unilateral stance (standing balance, excursions anterior lateral and diagonals)

Milestones for Progression to the Next Phase

Type II, IV SLAP repair:

- Active ROM without scapular compensations to 150° elevation, ER 50°, IR behind back to L5
- PROM per ROM guidelines

Type I, III SLAP repair:

- Full pain-free active ROM with elevation, abduction and IR/ER at 90° of abduction (overhead athletes may demonstrate loss of IR compared to contralateral but total arc of motion internal and external rotation should be normalized)
- Normal arthrokinematics glenohumeral joint and posterior shoulder ROM. Arthrokinematics with manual accessory motion testing should be assessed in the posterior and inferior direction. Posterior shoulder range of motion can be evaluated with passive horizontal adduction[5] with the scapula stabilized at an angle greater than 90° or beyond the vertical position towards the chest. Internal rotation should be sufficient to allow for the total arc of motion (internal + external rotation ROM) to approximate total arc of motion values for the uninvolved shoulder.[6]
- Normalized scapulohumeral motion during elevation as determined by the scapular dyskinesis test.[7] With this test, the athlete should demonstrate no dysrhythmia or winging during five repetitions of full flexion and abduction holding 5-lb hand weights.

Phase III (weeks 6 to 10)

Clinical Pearls

It is critical that ROM gains are made gradually in positions of stability (scapular plane at side) progressing to positions that challenge stability or integrity of SLAP repair (combined abduction and ER to 90°). Patients with type II and IV SLAP repairs should understand ROM progression and limitations for this phase of rehabilitation. Strengthening and dynamic control exercises should be progressed in the same progressive ROM manner with emphasis on proper form, free of scapular substitution patterns and pain. Proper technique and endurance is favored over increasing resistance.

Goals

- Gradually restore normal A/PROM in all planes
- Improve rotator cuff, scapular muscle strength and neuromuscular control
- Normalize dynamic trunk and kinetic chain strength and motor control

Protection

- Use of sling is no longer indicated

Management of Pain and Swelling

- Oral analgesic use is continued as needed
- NSAID therapy may be prescribed for persistent pain
- Modalities ice and electrical stimulation for pain control PRN
- Cryotherapy is used posttherapy to mitigate postexercise inflammation and soreness

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Continue glenohumeral mobilizations grade III with emphasis on posterior and inferior portion of the capsule to restore abnormal arthrokinematics as indicated

Type II, IV SLAP repair:

- Incremental increase in glenohumeral ROM motion to FULL: ER to 90° and IR to 75° with the arm in 90° progressing to full abduction, flexion and scapular plane elevation (Table 4-1).

Soft Tissue Techniques

- Pectoralis doorway stretching as needed to normalize scapular ROM. Doorway stretch should be performed unilateral with emphasis of movement on scapular retraction not glenohumeral horizontal abduction. Caution should be taken to avoid hyperabduction of the humerus as the humerus should remain in the plane of the scapula during this exercise with longer duration holds up to 30 seconds.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- End range stretching in all planes including hands behind the head and reaching up behind back as indicated to achieve normal motion
- Posterior shoulder ROM in cross chest stretch and internal rotation at 90° of abduction (sleeper stretch)

Other Therapeutic Exercises

- Return to all aerobic activity
- Lower extremity resistance training is progressed
- Core stability exercises are progressed to sport-specific positions and conditions

Additionally type I, III SLAP repair:

- Total arm strengthening initiated

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

Type II, IV SLAP repair:

- Initiate rotator cuff and scapular prone exercises to light isotonic and/or elastic resistance as ROM is normalized without scapular substitution patterns
- Resisted IR/ER in neutral
- Side-lying ER and forward punches
- Shoulder retractions
- Standing "W"s (Figure 4-37)
- Prone horizontal abduction "T"s, rowing, extension
- No resistance isolated to biceps

Type I, III SLAP repair:

- Progress shoulder and rotator cuff strengthening to a Thrower's Ten program[8]
  1. Diagonal pattern (D2) flexion
  2. Diagonal pattern (D2) extension
  3. Humeral ER at 0° abduction
  4. Humeral IR at 0° abduction
  5. Humeral ER at 90° abduction
  6. Humeral IR at 90° abduction
  7. Shoulder flexion to 90°
  8. Shoulder scaption
  9. Prone horizontal abduction at neutral
  10. Prone horizontal abduction with full ER at 100°
  11. Prone row
  12. Press-ups
  13. Pushups
  14. Bicep curls/elbow flexion
  15. Triceps extension/elbow extension
  16. Wrist extension/wrist flexion
  17. Wrist supination/wrist pronation



FIGURE 4-37. Standing "W"s with elastic resistance.

Sensorimotor Exercises

- Rhythmic stabilization and manual strengthening of the UE with short moment arms/proximal resistance
- The Bodyblade at 0° abduction as well as 90° scapular elevation
- Core stability exercises with manual resistance on stable progressing to unstable surfaces

Open and Closed Kinetic Chain Exercises

- PNF in D1–2 with manual resistance to scapula and humerus with slow reversals
- Closed chain PNF in quadruped (Figure 4-38)

Additionally type I, III SLAP repair:

- Closed chain quadruped to plank, bent elbow progressing to elbow straight closed chain proximal stability exercises (plank on knees to toes prone and side) Figure 4-39

Techniques to Increase Muscle Strength, Power, and Endurance

- Progression of LE strength training exercises
- Progress to elliptical and stair stepper for cardiovascular conditioning

Plyometrics

ONLY type I, III SLAP repair:

- Light plyometrics with side-lying ball drops (Figure 4-40)
- Two arm rebounder shoulder internal and external rotation with arms at the side (Figure 4-41), chest passes with shoulder ROM below 45° elevation
- Wall dribbles light resistance overhead

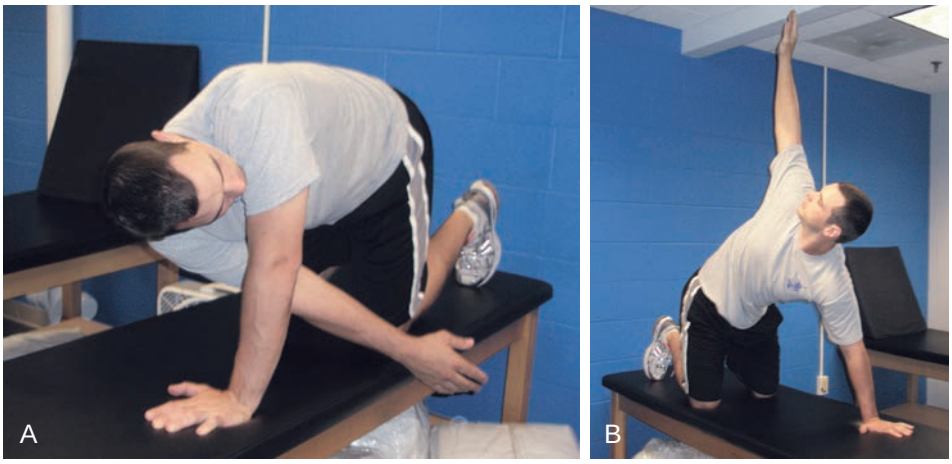

FIGURE 4-38. Closed chain PNF in quadruped.

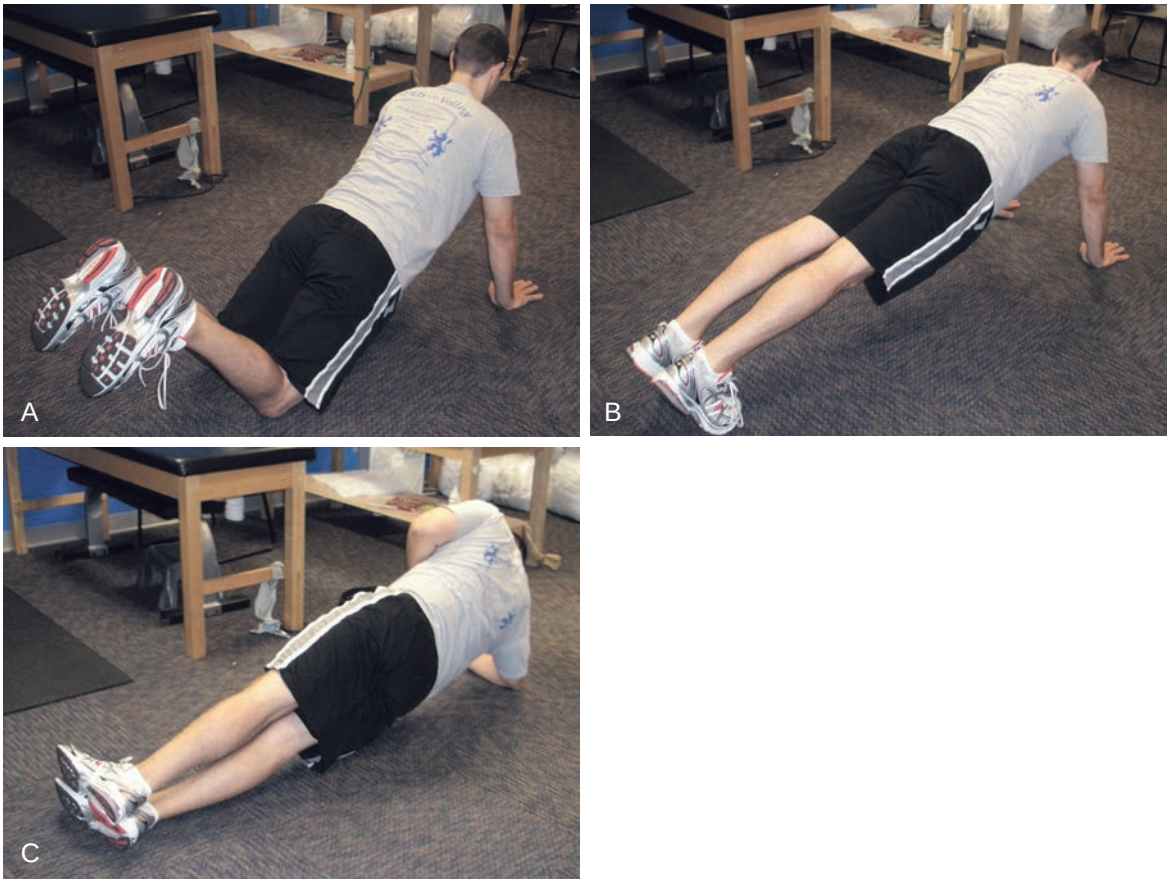

FIGURE 4-39. Plank position prone from knees (**A**), toes (**B**) and side-lying (**C**).

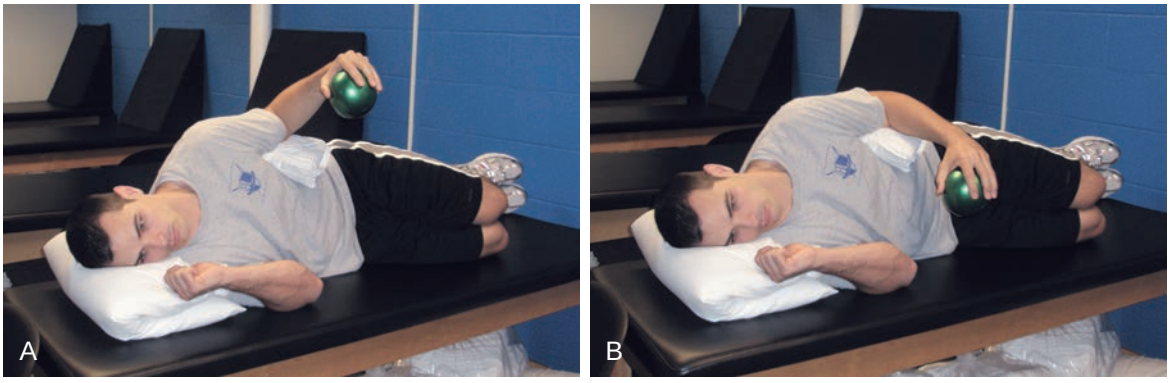

FIGURE 4-40. Eccentric ball drops (A) and catch B



FIGURE 4-41. Plyometrics using rebounder below chest height in IR/ER.

Sport-Specific Exercises

- Initiate exercises and sport-specific drills with arm at the side such as fielding, glove work, and lower extremity footwork drills.

Milestones for Progression to the Next Phase

Type II, IV SLAP repair:
- Full pain-free active ROM with elevation, abduction and IR/ER at 90° of abduction (the dominant shoulder in overhead, particularly throwing athletes may demonstrate loss of IR compared to contralateral due to osseous changes[9] but total arc of internal and external rotation motion should be normalized)

Type I, III SLAP repair:
- Normal arthrokinematics of the glenohumeral joint and posterior shoulder ROM. Arthrokinematics with manual accessory motion testing should be assessed in the posterior and inferior direction. Posterior shoulder range of motion can be evaluated with passive horizontal adduction[5] with the scapula stabilized at an angle greater than 90° or beyond the vertical position towards the chest. Internal rotation should be sufficient to allow for the total arc of motion (internal + external rotation ROM) to approximate total arc of motion values for the uninvolved shoulder.[6]
- Normalized scapulohumeral motion during active ROM in all planes with the scapular dyskinesis test[7] previously described in this chapter.
- Strength 75% to 80% of uninvolved side below shoulder height can be performed with the arm at 0° and 45° of abduction through range of motion with manual resistance of the examiner, but isometrically in multiple ranges using an hand-held dynamometer because an objective measure is more sensitive to detect apparent weakness up to 20% when manual resistance is deemed normal.[10] Isokinetic testing should be deferred until the end of the next phase.

Phase IV (weeks 10 to 14)

Clinical Pearls

- Posterior shoulder flexibility is paramount for successful outcome of all SLAP repairs due to the undue stress a tight posterior capsule can have on the superior-anterior glenohumeral joint structures.
- Horizontal adduction ROM should be achieved with assistance of the therapist manually stabilizing the scapula and at varying angles of elevation 70° to 100° and IR stretching (Figure 4-42) to appropriately address varying shoulder soft tissue restrictions that may be posterior–superior or posterior–inferior.[11]
- Sleeper stretches are an additional cornerstone to restoring normal posterior shoulder tissue length.[4] Rehabilitation in this stage of patients with type II and IV repairs focuses on restoring terminal ROM and progressing strengthening in protected planes of motion.
- Patients with type I and III SLAP repairs rehabilitation progress more quickly with the focus in this phase of rehabilitation to include restoring full strength, and endurance to prepare for return to sport progressions.

Goals

- Full shoulder range of motion in all planes without substitution or pain
- Restore shoulder strength to 80% contralateral side
- Improve muscular strength, power, and endurance
- Improve neuromuscular control and dynamic stability
- Enhance proprioception and kinesthesia

Management of Pain and Swelling

- Ice after exercise

Techniques for Progressive Increase in Range of Motion

Progressive increase in ROM to full per ROM guidelines Table 4-1.

Manual Therapy Techniques

- Glenohumeral mobilizations grade III with emphasis on posterior and inferior portion of the capsule to restore abnormal arthrokinematics in full GH ROM as needed

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Posterior shoulder stretching in horizontal adduction and sleeper stretch

Other Therapeutic Exercises

- Progress aerobic activity
- Lower extremity resistance training is progressed

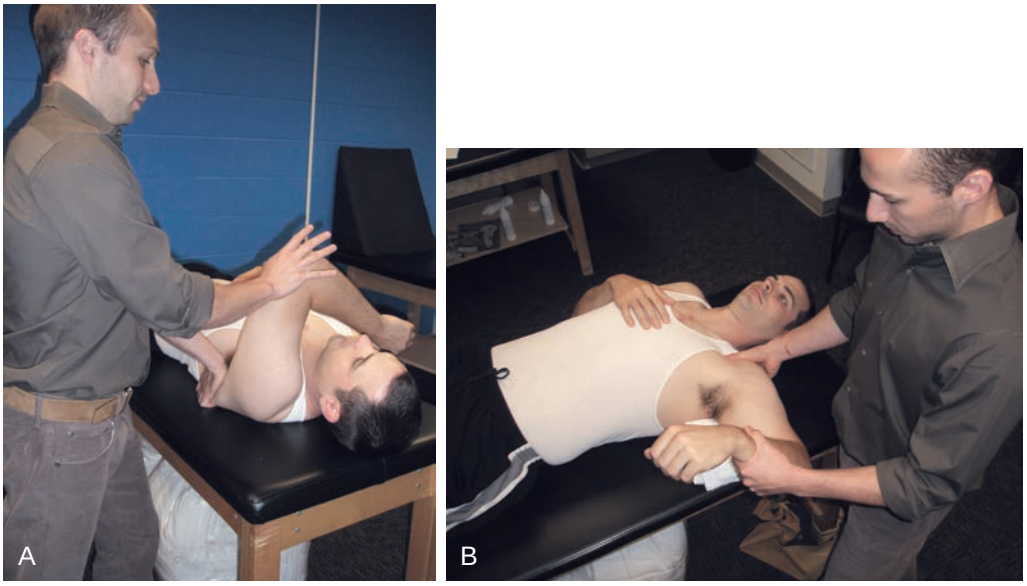

FIGURE 4-42. Manually assisted horizontal adduction (**A**), and IR (**B**) posterior shoulder stretching.

- Core stability exercises are progressed to sport-specific positions and conditions

Additionally type II, IV SLAP repair:

- Total arm strengthening initiated

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

Type II, IV SLAP repair:

- Dynamic hug added to target subscapularis muscle strength.[12] Exercise is performed with the technique of supine dumbbell flys but with TheraBand in standing.
- Prone "Y"s added
- Initiate bicep strengthening
- Thrower's Ten program initiated

Type I, III SLAP repair:

- No restrictions/limitations
- Begin sport-specific return to sport progressions (i.e., interval throwing program)

Sensorimotor Exercises

Type I, III SLAP repair:

- Rhythmic stabilization and manual strengthening of the UE progressed to long moment arms in scapular plane elevation and flexion (Figure 4-43)
- The Bodyblade progressed to 90° abduction and external rotation
- Core stability exercises with manual resistance on stable progressing to unstable surfaces

Open and Closed Kinetic Chain Exercises

Type I, III SLAP repair:

- PNF in D1–2 with manual resistance to scapula and humerus with fast reversals
- Closed chain PNF in plank and long arc positions progressing to unstable surfaces

Techniques to Increase Muscle Strength, Power, and Endurance

- Progression of LE strength training exercises.
- Sport-specific exercises and drills

Plyometrics

Type II, IV SLAP repair:

- Light plyometrics with side-lying and prone ball drops below 45° elevation
- Two-arm rebounder shoulder internal external rotation with arms at the side, chest passes with ROM below 45° elevation



FIGURE 4-43. Rhythmic stabilization in scapular plane (**A**) and flexion (**B**).

- Wall dribbles light resistance overhead

Additionally type I, III SLAP repair:

- Progress plyometrics to unilateral and overhead positions
- Heavy full kinetic chain plyometrics
- One arm rebounder shoulder internal external rotation in abducted position

Sport-Specific Exercises

Additionally type I, III SLAP repair:

- Return to sport-specific interval progressions (throwing, swimming, tennis, etc.) performed on an every other day basis

Milestones for Progression to the Next Phase

Type II, IV SLAP repair:

- Normal arthrokinematics glenohumeral joint and posterior shoulder ROM
- Normalized scapulohumeral motion during active ROM in all planes
- Strength 75% to 80% uninvolved below shoulder height

Type I, III SLAP repair:

- No pain with unrestricted activity
- Successful completion/progress with return to sport interval progressions
- Return to sport testing (goals below)

Phase V (weeks 14 to 24)

Clinical Pearls

- Caution should be taken to avoid progressing the patient too quickly while core stability, proximal scapulothoracic dynamic control and/or adequate rotator cuff strength has yet to be achieved.
- Use of dynamic tests such as the closed kinetic chain upper extremity stability test[13], timed modified pull-up, timed pushup, or single arm shot put tests are helpful to train athletes while monitoring for normal scapular motion with absence of winging or hiking is important.[14]
- Skilled rehabilitation focuses on technique, proper neuromuscular control, and the entire kinetic chain to maximize success in this phase of rehabilitation.
- Rehabilitation professionals who are not familiar working with athletic populations should collaborate with those who have experience and/or consult a strength and conditioning specialist.

Goals

- Progressive increase in functional activities to prepare for unrestricted activity
- No complaints of symptoms/pain with exercise
- Full pain-free uncompensated AROM
- Excellent core and proximal stability of hips and lower extremity with functional tests such as single leg squat or step-down with demonstration of neutral varus or valgus alignment of the knee avoidance of pelvic drop and good balance/control
- Strength of rotator cuff, shoulder and scapular stabilizers at least 80% to 90% uninvolved with isokinetic testing, or if unavailable, hand held dynamometry at multiple arm angles in external rotation, internal rotation and abduction to 90°. Isokinetic testing is preferred.
- Self-report outcome scores >80% such as the Kerlan-Jobe Orthopaedic Clinic[15,16] shoulder and elbow score are more sensitive than regional outcome tools such as the Disability of the Shoulder Arm and Hand.[17]

Management of Pain and Swelling

- Ice after exercise

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Glenohumeral mobilizations grade III with emphasis on posterior & inferior portion of the capsule to restore abnormal arthrokinematics in full GH ROM as needed

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Posterior shoulder stretching in horizontal adduction and sleeper stretch to attain and maintain normal flexibility

Other Therapeutic Exercises

- Progress aerobic activity
- Lower extremity resistance training is progressed
- Core stability exercises are progressed to sport-specific positions and conditions
- Total arm strengthening

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- No restrictions/limitations
- Begin sport-specific return to sport progressions (i.e., interval throwing, swimming, tennis programs) once strength, self-report outcome and full uncompensated active and passive ROM goals of this phase are achieved

Sensorimotor Exercises

- Initiate or progress rhythmic stabilization and manual strengthening of the UE progressed to long moment arms and distal points of resistance
- Initiate or progress The Bodyblade at 90° abduction and external rotation
- Initiate or progress core stability exercises with manual resistance on stable progressing to unstable surfaces

Open and Closed Kinetic Chain Exercises

- PNF in D1–2 with manual resistance with fast reversals and terminal holds with perturbations. (Figure 4-44)
- Closed chain PNF in plank and long arc positions progressing to unstable surfaces

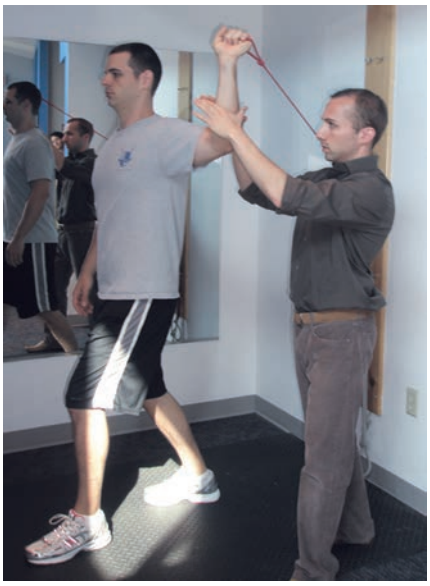

FIGURE 4-44. PNF D2 with terminal holds and manual perturbations.

Techniques to Increase Muscle Strength, Power, and Endurance

- Progression of LE strength training exercises
- Sport-specific exercises and drills

Plyometrics

- Progress plyometrics to unilateral and overhead positions
- Supine IR/ER ball catch and toss with the therapist
- Heavy full kinetic chain plyometrics such as ball slams, medicine ball overhead and sidebody throws
- One arm rebounder shoulder internal external rotation in abducted position

Sport-Specific Exercises

- Initiate or continue return to sport-specific interval progressions (throwing, swimming, tennis, etc.) performed on an every other day basis once strength, ROM and self-report outcome goals are met
- Athletes should work closely with coaches and trainers to insure proper technique with sport activity, particularly when the athlete is fatiguing
- Pitchers should work with coaches to insure proper mechanics with fastball progressing slowly to other types of pitches
- Swimmers should work with coaches to insure proper mechanics with freestyle progressing to other types of swimming strokes
- Tennis players work with coaches to insure proper mechanics with ground strokes progressing to all types of overhead hits and serves

Milestones for Progression Advanced Sport-Specific Training and Conditioning

- No pain with unrestricted activity
- Successful completion/progress with return to sport interval progressions with normal mechanics
- Return to sport testing (goals below)

Criteria for Return to Sport

General

- Normal uncompensated scapulothoracic and glenohumeral motion under fast and resisted conditions using the scapular dyskinesis test[7] as previously described in this chapter
- No symptoms of pain or discomfort during or following exercise
- Functional closed kinetic chain tests, such as such as the closed kinetic chain upper extremity stability test,[13] timed modified pull up, timed pushup, or single arm shot put tests, are >90% uninvolved or considered normal with good control and accuracy
- Strength >90% uninvolved with isokinetic testing or at minimum hand-held dynamometry specific to internal, external, and abduction in multiple arm angles.
- Successful completion of return to sport interval progression

Sport-Specific

- Throwing includes normal mechanics and attention to maintaining form for duration of expected outing and ability to independently maintain posterior shoulder length and rotator cuff strength with home program
- Swimming mechanics are normalized for all types of strokes required for training and competition
- Tennis stroke mechanics are normalized for overhead serve and all types of hitting

After Return to Sport

Continuing Fitness or Rehabilitation Exercises

- Core and total body strengthening conditioning is critical to success in athletic play following SLAP repair

Exercises and Other Techniques for Prevention of Recurrent Injury

- Posterior shoulder flexibility exercises with emphasis on horizontal adduction and sleeper stretch should be included in routine postplay maintenance.
- Thrower's Ten program
- Adequate rest, and periodization of sport-specific training following each competitive season is essential to injury prevention

Evidence

Borstad JD, Dashottar A: Quantifying strain on posterior shoulder tissues during 5 simulated clinical tests: a cadaver study. *J Orthop Sports Phys Ther* 41:90–99, 2011.

Cadaveric study examining positions that tension various portions of posterior capsule. (Level IV evidence)

Goldbeck T, Davies GJ: Test-retest reliability of a closed kinetic chain upper extremity stability test: a clinical field test. *J Sport Rehabil* 9:35–45, 2000.

Study examining reliability of newly developed tests for functional stability in healthy subjects. (Level III evidence)

Manske R, Prohaska D: Superior labrum anterior to posterior (SLAP) rehabilitation in the overhead athlete. *Phys Ther Sport* 11:110–121, 2010.

Review of rehabilitation for various types of SLAP repairs. (Level V evidence)

McClure P, Balaicuis J, Heiland D, et al: A randomized controlled comparison of stretching procedures for posterior shoulder tightness. *J Orthop Sports Phys Ther* 37:108–114, 2007.

Study examining the effectiveness of horizontal adduction and IR stretching on shoulder ROM in asymptomatic adults. (Level 1 evidence)

McClure P, Tate AR, Kareha S, et al: A clinical method for identifying scapular dyskinesis, part 1: reliability. *J Athl Train* 44:160–164, 2009.

Study examining reliability of newly developed test to identify abnormal scapular motion. (Level III evidence)

Myers JB, Oyama S, Wassinger CA, et al: Reliability, precision, accuracy, and validity of posterior shoulder tightness assessment in overhead athletes. *Am J Sports Med* 35:1922–1930, 2007.

Study examining reliability and concurrent validity of internal rotation and horizontal adduction measurements of posterior shoulder tightness. (Level 3 evidence)

Negrete RJ, Hanney WJ, Kolber MJ, et al: Reliability, minimal detectable change, and normative values for tests of upper extremity function and power. *J Strength Cond Res* 24:3318–3325, 2010.

Study examining reliability of newly developed test to test functional upper extremity function and power. (Level III evidence)

Reagan KM, Meister K, Horodyski MB, et al: Humeral retroversion and its relationship to glenohumeral rotation in the shoulder of college baseball players. *Am J Sports Med* 30:354–360, 2002.

Study provides evidence regarding osseous changes that may account for a shift in the arc of motion (IR /ER) in collegiate baseball players. (Level V evidence)

Tyler TF, Nahow RC, Nicholas SJ, et al: Quantifying shoulder rotation weakness in patients with shoulder impingement. *J Shoulder Elbow Surg* 14:570–574, 2005.

Study examining the strength of the shoulder using dynamometry in patients with impingement considered to have normal strength with manual muscle testing. (Level III evidence)

Uhl TL, Muir TA, Lawson L: Electromyographical assessment of passive, active assistive, and active shoulder rehabilitation exercises. *Pm R* 2:132–141, 2010.

Study examining EMG activity of the shoulder with various postoperative rehabilitation exercises. (Level III evidence)

Wilk KE, Arrigo C, Andrews JR: Rehabilitation of the elbow in the throwing athlete. *J Orthop Sports Phys Ther* 17:305–317, 1993.

Review exercise and rehabilitation program for overhead athletes. (Level V evidence)

Wilk KE, Meister K, Andrews JR: Current concepts in the rehabilitation of the overhead throwing athlete. *Am J Sports Med* 30:136–151, 2002.

Review exercise and rehabilitation program for overhead athletes. (Level V evidence)

Wilk KE, Reinold MM, Dugas JR, et al: Current concepts in the recognition and treatment of superior labral (SLAP) lesions. *J Orthop Sports Phys Ther* 35:273–291, 2005.

For rehabilitation of various types of SLAP repairs. (Level V evidence)

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14. Negrete RJ, Hanney WJ, Kolber MJ, et al: Reliability, minimal detectable change, and normative values for tests of upper extremity function and power. *J Strength Cond Res* 24:3318–3325, 2010.
15. Alberta FG, ElAttrache NS, Bissell S, et al: The development and validation of a functional assessment tool for the upper extremity in the overhead athlete. *Am J Sports Med* 38:903–911, 2010.
16. Kraeutler MJ, Ciccotti MG, Dodson CC, et al: Kerlan-Jobe Orthopaedic Clinic overhead athlete scores in asymptomatic professional baseball pitchers. *J Shoulder Elbow Surg* 22:329–332, 2013.
17. Beaton DE, Katz JN, Fossel AH, et al: Measuring the whole or the parts? Validity, reliability and responsiveness of the DASH Outcome Measure in different regions of the upper extremity. *J Hand Ther* 14:128–146, 2001.

Multiple-Choice Questions

QUESTION 1. Why is the rehabilitation progression slower with type II, IV SLAP repairs?

A. The labrum has been debrided.
B. The rotator cuff tendons are involved.
C. The labrum and biceps long head tendon anchor has been repaired.
D. The labrum without the biceps tendon has been repaired.

QUESTION 2. What postoperative week is full A/PROM is expected for type I, III SLAP repairs?

A. Week 2
B. Week 6
C. Week 12
D. Week 16

QUESTION 3. Critical to full return of overhead sport activities are normal arthrokinematics at the glenohumeral joint. How do you assess the length of the posterior shoulder tissues?

A. External rotation ROM
B. IR ROM
C. Horizontal adduction
D. All the above

QUESTION 4. To protect the repair, ROM and strengthening progressions start in which plane of motion?

A. Coronal
B. Sagittal
C. Transverse
D. Scapular plane

QUESTION 5. What BEST describes when patients following type II, IV SLAP repair can be progressed from Phase III to Phase IV rehabilitation?

A. At 10 weeks postoperative time frame
B. As long as the goals of Phase III rehabilitation has been achieved
C. Strength >80% uninvolved
D. None of the above

Answer Key

QUESTION 1. Correct answer: **C** (see Phase II)

QUESTION 2. Correct answer: **B** (see Phase II)

QUESTION 3. Correct answer: **D** (see Phase III and Phase IV)

QUESTION 4. Correct answer: **D** (see Phase II and Table 4-1)

QUESTION 5. Correct answer: **B** (see Phase III)

BEYOND BASIC REHABILITATION: RETURN TO PITCHING AND THROWING AFTER SLAP TEAR REPAIR

Thomas J. Gill IV, MD, Joseph J. Van Allen, MSPT, SCS, ATC, CSCS, and Jeremiah Randall, PT, DPT, ATC, CSCS

Introduction

ASPECTS OF PITCHING AND THROWING THAT REQUIRE SPECIAL ATTENTION IN REHABILITATION

- Full glenohumeral range of motion with special emphasis place on shoulder abduction and external rotation
- Adequate glenohumeral strength
- Adequate periscapular strength
- Completion of an upper extremity medicine ball plyometric progression
- Return of proper throwing mechanics
- Completion of an interval throwing program (Boxes 4-1, 4-2) with no pain and minimal muscle soreness

SLAP Labrum Repair in the Pitcher and Thrower: Key Aspects

- Injuries to the superior and posterosuperior labrum are commonly seen in overhead athletes, especially throwers. This is caused by the extreme forces placed on the glenohumeral joint during the late cocking and early acceleration phases of throwing. These forces result in the "peel-back phenomenon," which can lead to unstable biceps anchors (type II SLAP tear).[1]
- In addition, the extreme degree of external rotation in abduction can lead to "internal impingement," as the articular surface of the infraspinatus tendon impacts the posterosuperior labrum.[2]
- The deceleration phase of throwing requires eccentric contraction of the biceps, which has been hypothesized to lead to superior labral tearing.[3]
- Returning to a high level of throwing is challenging after surgical repair of a SLAP tear, especially if full and complete strength and external rotation/abduction is not restored during the rehabilitation process.
- Several studies have reported on returning to previous level of competition following a SLAP repair in the overhead athlete/baseball population:
  - Neri et al.[4] reported that 13 of 23 (57%) overhead athletes who underwent a type II SLAP repair had returned to the preinjury level of competition at a 1-year follow-up.
  - A study conducted by Cohen et al. in 2011[5] reported that 7 of 22 (32%) professional baseball players who underwent a labral repair returned to previous or higher level of competition.

BOX 4-1 Return to Throwing Program Summary

Criteria to Initiate Interval Throwing Program

- Full glenohumeral range of motion
- Adequate glenohumeral strength
- Adequate dynamic stabilization
- Completion of an upper extremity medicine ball plyometric progression
- Physician clearance

Definitions

- Fastball: Two seam or four seam fastball that, in which stress on the joints (glenohumeral, elbow, or wrist) involved, is minimal compared to other pitches.
- Change up: Off-speed pitch with a similar arm action to the fastball and similar stress placed across the joints of the upper extremity
- Breaking pitches: Type of off-speed pitch that places increased stress on the joints (glenohumeral, elbow, or wrist) involved. (e.g., slider, breaking ball)
- Flat ground: Pitching performed on flat ground (not mound) at a distance of 60 feet with a catcher down.
- Slope work: Initiation of throwing off the mound by gradually increasing the angle from the horizontal ground to the height of the mound.
  - Mound is 10 inches above the playing field. Starting 6 inches in front of the pitcher's rubber, the mound slopes downward to playing field at a rate of 1 inches per foot over a span of 6 feet.
  - Bullpen sessions: Throwing session completed off the mound in the bullpen at a distance of 60 feet in a controlled setting with no batter present
  - Live batting practice: Sport-specific setting with the pitcher throwing to a batter with the pitch selection predetermined.
  - Simulated game: Sport-specific setting with the pitcher throwing to a batter with the pitch selection based on a game situation.

Basic Principles

- Max number of throws at each distance per day is 25 throws
- Initiate each new distance with 15 throws
- Maximum distance is 120 feet
- Off-days from throwing are incorporated based on pathology, time off from throwing, position, muscle soreness experienced, and other individual factors
  - Early stages of an interval throwing program incorporate an alternating throwing routine.
    - Day 1: Throw
    - Day 2: Off
    - Day 3: Throw
    - Day 4 : Off
    - Day 5 Throw
  - As the interval throwing program progresses, throwing on consecutive days is incorporated.
    - Day 1: Throw
    - Day 2: Throw
    - Day 3: Off
    - Day 4: Throw
    - Day 5: Throw
    - Day 6: Off
    - Day 7: Throw
    - Day 8: Throw
    - Day 9: Throw
    - Day 10: Off
- Pitch progression (flat ground and sides)
  - Fastball → Change up→ Breaking balls
- Bullpen session progression
  - 25 Fastball → 30 Fastball/Change up → 35 All
- Game progression
  - 1 inning/25 pitches → 2 innings/35 pitches
- Incorporate a crow hop at 90 feet and beyond
- Concentrate on using proper throwing mechanics during all steps of the throwing progression
- Pitching coach should be present at all times during the interval throwing program

Criteria to Progress to Next Step

- Able to complete full throwing program with no pain or exacerbation of symptoms reported
- Able to complete throwing program with minimal muscle fatigue
- Able to complete throwing program with ball on a straight line (no "rainbows")
- No muscle soreness reported the following day.

Continued on following page

BOX 4-1 Return to Throwing Program Summary *(Continued)*

Individual Differences

- Each athlete will progress at their own rate through the interval throwing program
- Individuals may need additional days when throwing is initiated on flat ground and each time a new variable is added to the throwing program—throwing breaking balls, mound work, etc.

Warm-Up Principles Prior to Interval Throwing Program

- Increase core body temperature through any mode of cardiovascular exercise
- Static/dynamic stretching of the glenohumeral joint with emphasis on the posterior rotator cuff
- Glenohumeral joint therapeutic exercise prethrowing routine to increase local muscle temperature of involved upper extremity

BOX 4-2 Return to Throwing Program

Step 1

- 25 at 60′

Step 2

- 25 at 60′
- 15 at 75′

Step 3

- 25 at 60′
- 25 at 75′

Step 4

- 15 at 60′
- 15 at 75′
- 15 at 90′

Step 5

- 15 at 60′
- 25 at 75′
- 25 at 90′

Step 6

- 15 at 60′
- 25 at 90′
- 15 at 105′

Step 7

- 15 at 60′
- 25 at 90′
- 25 at 105′

Step 8

- 15 at 60′
- 15 at 90′
- 15 at 120′

Step 9

- 15 at 60′
- 15 at 90′
- 25 at 120′

Step 10

- 15 at 60′
- 15 at 90′
- 25 at 120′
- Flat Ground—Fastball

Step 11

- 15 at 60′
- 15 at 90′
- 25 at 120′
- Flat ground—Fastball/change up
- Slope work—Fastball

Step 12

- 15 at 60′
- 15 at 90′
- 25 at 120′
- Flat ground—Fastball/change up
- Slope work—Fastball/change up

Step 13

- Side × 25 Pitches—fastball

Step 14

- 15 at 60′
- 15 at 75′
- 25 at 120′
- Flat ground—Fastball/change up/breaking pitches

Step 15

- Side × 30—Fastball/change up

Step 16

- Side × 35—All pitches

Step 17

- Live batting practice (BP): 1 inning/25 pitches

Step 18

- Live BP: 2 innings/40 pitches (20/20)
  - 10′ rest between sets to simulate time between innings

Step 19

- Simulated game 1 inning/25 pitches

Step 20

- Simulated game 2 innings/35 pitches (20/15)
  - 10′ rest between sets to simulate time between innings

Step 21

- Game: 2 innings/35 pitches

Phase I: Advanced Strength and Conditioning Programs

Periodization

- **Linear Model:** A model that typically separates a training program into cycles and primarily manipulates the variables of intensity and training volume. May be separated into specific cycles depending on the athlete's needs and ultimate goals.
- **Microcycles:** A model in which training periods during this phase that would last 2 to 4 weeks depending on the goals of the athlete. The actual time period would be based primarily on the athlete's pathology and time period since last throwing.
  - Within the microcycles a preparatory period would be included to prepare the athlete for an interval throwing program. Within that preparatory period a hypertrophy/strength phase in which intensity and training volume would be manipulated with the intensity at a moderate level and training volume at a high level. As the athlete progresses to the end of this phase, the intensity would increase and the training volume would decrease accordingly.

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- **Flexibility/Joint Mobility for Joint Stability:** It is important to address areas of muscle tightness that can impact muscle performance and ultimately sports performance. Various approaches to improve flexibility can be used including static stretching, dynamic stretching, preparatory warm-ups, and proprioceptive neuromuscular facilitation (PNF) techniques.
- Joint mobility is an important area to address during the rehabilitation process and is essential to maintain an appropriate balance between joint stability and mobility to allow the extremity to function properly.
- Various joint mobilization methods are incorporated through each rehabilitation phase to maintain an appropriate amount of joint mobility.
- Joint stability is defined as the ability to maintain joint congruity while undergoing unconscious perturbations to allow the extremity to perform an optimal movement pattern (throwing). This can be incorporated through the use of proprioception and perturbation drills in both a closed and open kinetic chain environment. As the rehabilitation program is advanced, flexibility continues to be incorporated but is no longer of primary importance.
- **Training with Optimum Posture:** Corrective exercise to address postural faults should be emphasized in the early stages of rehabilitation and continued through the advanced phases as exercises become more complex.
- **Sensorimotor and Balance Training:** Joint mechanoreceptors responsible for sensorimotor integration are often primary impairments following labral surgery. Proprioception training incorporated in the early stages of rehabilitation is hypothesized to reestablish sensitivity of the joint mechanoreceptors and increase dynamic stabilization of the shoulder joint allowing for coordinated muscle activity during functional movements. These exercises are advanced in the remaining phases to be incorporated with functional movements. During this phase, joint repositioning drills are the primary means used to stimulate the joint mechanoreceptors while allowing the appropriate healing to occur. In addition, proprioception training (Bodyblade drills, etc.) for the uninvolved extremity has been indicated to demonstrate gains for the surgical extremity.
- **Core Training:** A training technique incorporated throughout the entire rehabilitation process and advanced as appropriate to include open or closed kinetic chain exercises. In this phase, basic core training is continued with respect to the healing structures of the glenohumeral joint. The core training movements would include glute bridge progression, bird dog progression, and static plank series.
- **Cardiorespiratory Training:** In addition to specific rehabilitation techniques to the glenohumeral joint, there are benefits to training the cardiorespiratory system.[6] Certain hormones are released by endocrine glands during this type of training that aid in the recovery process and assist in maintaining a level of fitness for the entire body. Examples of these hormones include epinephrine, released by the adrenal gland, and growth hormone, released by the pituitary gland. In this phase, basic cardiorespiratory training is included to build a base level of fitness for the athlete.
- **Multi-planar Training Exercises:** During this phase, exercises are primarily uniplanar movements to maximize strength gains for specific muscles. As the athlete progresses to the end of Phase I and into Phase II the exercises progress to multiplanar movements (see Figure 4-52).
- **Training for Optimum Muscle Balance:** Muscle balance, specific to the strength and flexibility of the agonist and antagonist muscles should be addressed in the earlier phases of rehabilitation and continue to be emphasized as the athlete is progressed to functional movements. In this phase, basic strengthening of the rotator cuff and parascapular muscles is indicated based on the strength impairments of the individual (Figure 4-45).[7] The strengthening movements indicated for each postsurgical case will vary and depend on the impairments identified by the rehab specialist. Examples of exercises that may be indicated during this phase balance include full can (Figure 4-46)[8] and SL ER (Figure 4-47).[9]
- **Training for Optimum Muscle Functional Strength:** Targeting muscles and movement patterns that closely resemble the desired movement to improve maximal force at a specific velocity. The strengthening movements during this phase are nonfunctional and designed to build basic strength based on previously identified strength impairments. Examples of exercises that may be indicated during this phase balance include full can (Figure 4-46) and SL ER (Figure 4-47).
- **Neuromuscular Dynamic Stability Exercises:** A concept that is a key component of any shoulder rehabilitation



FIGURE 4-45. Prone scapular retraction with 90° shoulder abduction with external rotation.

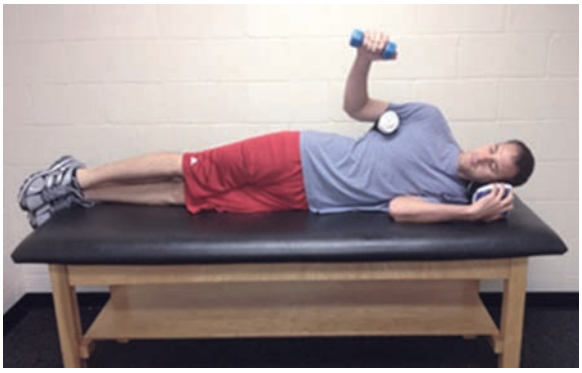

FIGURE 4-47. Side-lying external rotation exercise.



FIGURE 4-46. Standing full can exercise.

caused by the inherent instability of the glenohumeral joint. Trained by using proprioception techniques in an open or closed kinetic chain environment that challenge the joint mechanoreceptors in response to planned or unplanned perturbations of the extremity. Important to establish this type of stability in a controlled fashion during the early stages of rehab and progress as appropriate. During this phase, stability is accomplished through joint repositioning drills and incorporating manual proprioception drills as appropriate with respect to the healing tissues.

Olympic Lifts Used in the Training Program

- **Snatch:** This technique is not commonly used in the rehabilitation or training of the overheard throwing athlete caused by the stress applied to the shoulder and elbow joints. This specific lift offers little benefit and not does resemble functional movements of the overhead athlete.

TIMELINE 4-4: **Postoperative Rehabilitation After Shoulder SLAP Labral Repair**

PHASE I (weeks 1 to 4)

week 0–2

- Sling
- PT modalities
- PROM/gentle AAROM
  - Flexion to 60° (wk 2: flexion to 75°)
  - Elevation in scapular plane to 60°
  - ER/IR with arm in scapular plane
    - ER to 10°–15°
    - IR to 45°
- No active ER, extension, abduction, or elevation
- Submaximal isometrics for shoulder musculature
- Elbow/hand ROM
- Hand gripping movements
- No isolated biceps contractions

weeks 3–4

- Sling
- PT modalities
- PROM/AAROM
  - Flexion to 90°
  - Abduction to 75°–85°
  - ER in scapular plane and 35° abduction to 25°–30°
  - IR in scapular plane and 35° abduction to 55°–60°
- No active extension, abduction, or elevation
- Initiate rhythmic stabilization drills
- ER/IR tubing at 0° abduction
- Continue submaximal isometrics
- Discontinue use of sling at 4 wk

PHASE II (weeks 5 to 9)

weeks 5–6

- Continue to progress ROM
  - Flexion to 145°
  - ER at 45° abduction: 45°–50°
  - IR at 45° abduction: 55°–60°
  - At 6 wk begin light and gradual ER at 90° abduction—progress to 30°–40° ER
  - Initiate stretching exercises
  - Initiate light (easy) ROM at 90° abduction
  - ER/IR tubing at 0° abduction
  - Initiate PNF manual resistance
  - Initiate active shoulder abduction (without resistance)
  - Initiate "full can" exercise (weight of arm)
  - Initiate prone rowing, prone horizontal abduction
  - No isolated biceps contractions

weeks 7–9

- Continue to progress ROM
  - Flexion to 180°
  - ER at 90° abduction: 90°–95°
  - IR at 90° abduction: 70°–75°
- Continue all stretching exercises
- Progress rotator cuff/parascapular strengthening exercises

- **Clean and Jerk:** This technique is not commonly used with the overheard throwing athlete caused by the stress applied to the shoulder and elbow joints. This specific lift offers little benefit and not does resemble functional movements of the overhead athlete.
- **Power Clean:** This technique is not commonly used with the overheard throwing athlete caused by the stress applied to the shoulder and elbow joints. This specific lift offers little benefit and does not resemble functional movements of the overhead athlete.

Training Principles Used in the Design of the Program

- **Principle of Progression**: The ability to advance an athlete from basic movements (single joint, uniplanar, primary muscle group activation) to complex movements (multijoint, multiplane, multimuscle group involvement).
- Natural progression during the rehabilitation process is moving from simple movements to complex functional movements that mirror the throwing motion and incorporate the same muscle groups. In this phase, basic rotator cuff and scapular strengthening exercises should be used to provide a base level of strength for the athlete.
  - Example: Prone scapular retraction with shoulder abduction at 90° with an external load (cuff weight) with emphasis on controlled eccentric movement of the posterior rotator musculature (Figure 4-45). This is a single plane exercise involving multiple joints that target the primary muscles used during the throwing motion. However, this is not considered a functional movement caused by the body position and nonfunctional movement of the upper extremity.
- **Principle of Overload**: The progression of an athlete to a higher volume or intensity training session than accustomed to advance their functional status. To apply this principle appropriately, the total volume (sets, reps, resistance) must be progressed in a timely manner to maximize strength gains while avoiding the negative effects of overtraining.
- **Principle of Variation**: Each rehabilitation program should include options of exercises that target the same muscle groups to avoid stagnation or a plateau in gains. Exercises that target the primary external rotators of the rotator cuff (infraspinatus and teres minor) are of primary importance in a postsurgical overheard thrower. There are several different variations of this exercise that can be included to maximize strength gains.
  - Examples of movements that target the external rotators:
    - Prone scapular retraction with 90° shoulder abduction with external rotation (Figure 4-45).
    - Side-lying external rotation (Figure 4-47).
    - Wall slides (Figure 4-48)
  - The rehab specialist must keep in mind that each one of these movements provides differing levels of infraspintus/teres minor muscle activity and must take that into account when determining when each movement is appropriate.
- **Principle of Individualization**: Each rehabilitation program should be tailored to fit each athlete according to their specific needs. Multiple factors should be taken into account; body composition, age, position, injury history.

TIMELINE 4-4 **Postoperative Rehabilitation After Shoulder SLAP Labral Repair** (Continued)

PHASE III (weeks 10 to 14)	PHASE VI (weeks 14 to 16+)
weeks 10–12	**weeks 14–16**

• Continue to progress ROM
  • ER at 90° abduction: 110°–115°
  • IR at 90° abduction: 70°–75°
• Continue all stretching exercises
• Progress rotator cuff/parascapular strengthening exercises
• Initiate modified upper body program in weight room
	• Continue to progress ROM to functional demands of throwing
	• Progress isolated biceps strengthening
	• Progress bilateral medicine ball drills
	• Initiate unilateral medicine ball drills
	• Continue all stretching exercises
	• Progress rotator cuff/parascapular strengthening exercises

weeks 12–14	**weeks 16+**
• Continue to progress ROM to functional demands of throwing • Initiate isolated biceps strengthening • Initiate bilateral medicine ball drills • Continue all stretching exercises • Progress rotator cuff/parascapular strengthening exercises	• Initiate return to throwing program • progress through throwing program as appropriate • Mound/slope work • Live BPs/simulated games • Game competition • Continue all stretching exercises • Progress rotator cuff/parascapular strengthening exercises

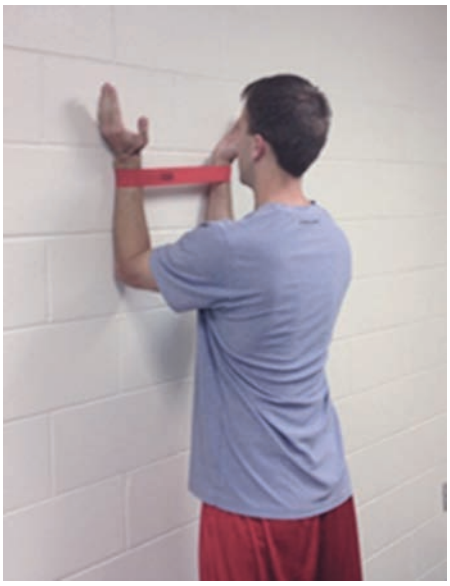

FIGURE 4-48. Wall slides exercise.

- **Principles of Specificity**: The principle of specific adaptation to imposed demands (SAID) is often used in the design of rehabilitation programs. The type of rehabilitation principles that are implemented is the driving force behind the types of adaptations that the body will undergo during the rehabilitation process.
- In this case, the movements should closely resemble the motion of throwing to retrain the primary muscles involved. This concept is primarily applied during the second phase to prepare the athlete for the interval throwing program to follow.

Application of Acute Training Variables

- **Repetitions:** Each set of a specific exercise should be 15 to 25 repetitions during this phase
- **Sets:** Each exercise should be performed for three sets during this phase
- **Rest Interval:** Primarily the fast glycolysis and oxidative energy system is used during the rehabilitation training sessions. A work to rest ratio of 1:3 is used to maximize training effects [6]
- **Intensity:** During this phase, the intensity of the rehabilitation is moderate to high
- **Training Frequency:** Strength training during this phase would be performed 3 to 4 times per week, and every other day for the principle of rest and recovery of the muscles
- **Training Duration:** An appropriate training program during this phase would be 45 to 60 minutes in duration.
- **Training Volume**: The training volume during this phase would be high to prepare the athlete for the stresses applied during throwing. At the end of this phase, the training volume would begin to decrease.
- **Exercises Specificity:** Figures 4-46 through 4-49 are examples of specific exercises that should incorporated during Phase I; however, the entire program should not be limited to these four exercises.

Phase II: Performance Enhancement Training Techniques

Periodization

- During this phase, a linear periodization model is continued to maximize the rehabilitation process. During this microcycle, the preparatory period is used to continue to prepare the athlete for an interval throwing program.
- The power phase of the microcycle is introduced to prepare the appropriate tissues for the stresses during throwing. As in the previous phase, the variables of intensity and training volume would be manipulated and an inversely proportional concept would be applied. The intensity would increase as the phase progresses with the training volume decreasing at a subsequent rate. At the end of this phase, the intensity would be at a high level with the training volume low.

Program Design/Performance Training Program

- **Core Training:** In the advanced stages of rehabilitation, integrated core training with upper extremity movements is essential to maximize the optimum rehabilitation outcome. Open or closed kinetic chain upper extremity exercises may be incorporated with basic core stability training to maximize the rehabilitation outcome.
  - Example: Performing a full can exercise on an unstable surface with an altered base of support. This incorporates a basic shoulder movement with a core stability exercise (Figure 4-50).
- **Cardiorespiratory Training:** The same basic principles apply as in the previous phase. The cardiorespiratory training will begin to become more sport-specific at this point to prepare the athlete for returning to a game-like setting.



FIGURE 4-49. Standing internal rotation exercise.



FIGURE 4-50. Physioball full can exercise.

- **Multi-Planar Training Activities:** Exercises involving multiple planes of movement are continued in this phase in preparation for throwing.
- **Training for Optimum Muscle Functional Power:** Movement patterns that closely resemble the desired movement to improve maximal force and completed in the shortest amount of time possible are introduced in this phase.
  - An upper extremity medicine ball plyometric progression is introduced during this phase to improve the power of the upper extremity. This progression is explained in more detail later in this chapter.
- **Plyometric Training:** Underused training technique in the upper extremity is an excellent progression to bridge the gap between basic rotator cuff and scapular strengthening movements to an interval throwing program. This type of training uses the stretch shortening cycle to increase the power of specific movement patterns similar to throwing.
  - Example: Bilateral medicine ball chest pass (Figure 4-51)

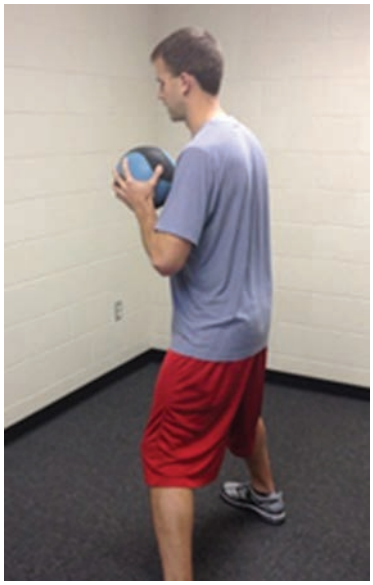

FIGURE 4-51. Bilateral medicine ball chest pass.

- **Functional Training:** Movement patterns that closely resemble the throwing motion.

Olympic Lifts Used in the Training Program

- **Snatch:** This technique is not commonly used in the rehab or training of the overheard throwing athlete caused by the stress applied to the shoulder and elbow joints. This specific lift offers little benefit and not does resemble functional movements of the overhead athlete.
- **Clean and Jerk:** This technique is not commonly used with the overheard throwing athlete caused by the stress applied to the shoulder and elbow joints. This specific lift offers little benefit and not does resemble functional movements of the overhead athlete.
- **Power Clean:** This technique is not commonly used with the overheard throwing athlete caused by the stress applied to the shoulder and elbow joints. This specific lift offers little benefit and not does resemble functional movements of the overhead athlete.

Training Principles Used in the Design of the Program

- **Principle of Progression:** The basic exercise presented in Phase I (see Figure 4-45) is progressed to a proprioceptive neuromuscular facilitation (PNF) D2 movement involving an eccentric contraction of the posterior rotator cuff using the throwing motion in a functional base of support (left half kneeling). (Figure 4-52).

Application of Acute Training Variables

- Repetitions: The repetitions of each exercise decreases to 12 to 15 for each exercise.
- Sets: Each exercise should be performed for two sets during this phase.
- Intensity: During this phase the intensity level is high
- Training frequency: Training would be performed 3 times a week during this phase.

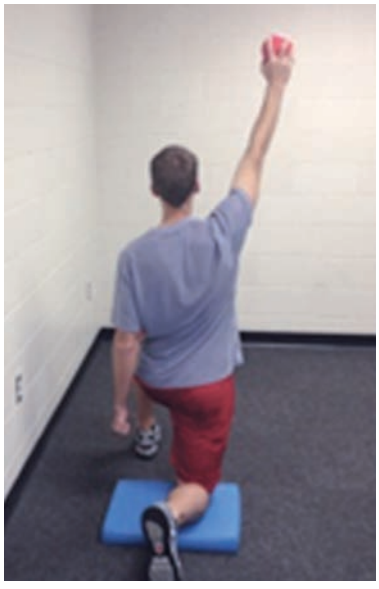

FIGURE 4-52. Left half kneeling PNF D2 eccentric medicine ball catches.

- Training duration: An appropriate training program during this phase would be 30 to 45 minutes in duration.
- Training volume: The training volume decreases compared to the previous phase.
- Specific exercises used in the training: Examples of exercises to be implanted during this phase have been presented prior to this section. These examples are intended to be examples and progressed accordingly.

Phase III: Sport-Specific Training

Program Design/Performance Training Program

- **Core Training:** In this phase, the core training continues to be integrated with shoulder exercises.
- **Cardiorespiratory Training:** This aspect of the training becomes position-specific during this phase of training.
- **Multi-planar Training Activities:** The multi-planar exercises performed in the previous two phases are now progressed to a sport-specific movement (throwing).

Sport-Specific Concepts of Integrated Training

- Training that involves a specific sport movement within a controlled environment. Examples of this training would include live batting practice and simulated games.

Olympic Lifts Used in the Training Program

- **Snatch:** This technique is not commonly used in the rehab or training of the overheard throwing athlete caused by the stress applied to the shoulder and elbow joints. This specific lift offers little benefit and not does resemble functional movements of the overhead athlete.
- **Clean and Jerk:** This technique is not commonly used with the overheard throwing athlete caused by the stress applied to the shoulder and elbow joints. This specific lift offers little benefit and not does resemble functional movements of the overhead athlete.
- **Power Clean:** This technique is not commonly used with the overheard throwing athlete caused by the stress applied to the shoulder and elbow joints. This specific lift offers little benefit and not does resemble functional movements of the overhead athlete.

Sports Performance Testing

General Information

- **General History:**
  - A through medical examination by a medical doctor should be obtained prior to the initiation of any training program.
  - A past medical history questionnaire should be filled out and reviewed with the athlete to identify family history of pathology, genetic disorders, and nutritional tendencies.
- **Subjective Questionnaires:** A variety of questionnaires are used to identify potential areas of concerns.
- **Medical History:** A previous medical history should be obtained.
- **Sports Injury History:** A previous sports injury history should be obtained.
- **Surgical History:** Surgical history of the athlete should be obtained and taken into consideration when designing a rehabilitation program.
- **Chronic Conditions/Medication:** Chronic conditions and past/current medications should be obtained.

Specific Criteria for Progression to the Next Stage to Determine Readiness for Pitching and Throwing

Objective Tests

- **Body Composition Tests:** Tests to measure body fat percentage are commonly used to assess the training effects of the entire body. Techniques used are skinfold measurements, underwater and hydrostatic weighing.
- **Movement Performance Testing:** Numerous performance-testing methods can be used to measure specific movements and functional movements. The functional movement screen (FMS) is often used as a part of the preparticipation physical assessment. Additional functional tests specific to the upper extremity are presented below.

Range of Motion (Phase I)

- The primary impairment in the early stages of rehabilitation must be normalized before addressing additional impairments. Preinjury ranges of motion measurements are obtained prior to the injury to have a baseline specific to the individual.
- The minimum goal is to obtain the preinjury range of motion and progress to normalize impairments when compared to the uninvolved extremity. Clinical research has examined glenohumeral range of motion. Specific research has focused on range of motion changes in pitchers and the effect that throwing has on it.[10,11] Additionally, range of motion and its correlation to pathology has also been studied.[12-14]

Strength (Phase II)

- The impairment that becomes the primary focus once the range of motion goals have been achieved.
- Traditionally, strength is measured using subjective manual muscle testing but this method has poor reliability and is not the preferred method from a research standpoint.[15]
- A hand-held dynamometer is a measuring device that can be used to objectively measure strength gains during the rehab progression.[16]
- Isokinetic testing can also be used as an objective measurement. This type of testing is explained in detail in the following section.

Upper Extremity Plyometric Progression (Phase II)

- To prepare the athlete for the stresses placed on the involved extremity during throwing, an upper extremity plyometric medicine ball progression is implemented. The progression for this activity would follow the model below:
  - Bilateral medicine ball concentric movements
  - Bilateral medicine ball eccentric movements
  - Bilateral medicine ball functional movements
  - Unilateral medicine ball concentric movements
  - Unilateral medicine ball eccentric movements
  - Unilateral medicine ball functional movements
- This progression should be completed over the course of several weeks taking into account the athlete's pathology, etc. The ability to complete the progression pain-free and with minimal muscle soreness following would indicate the athlete is ready to initiate an interval throwing program.

Functional Testing

- Limited clinical research exists involving upper extremity functional testing. Specific tests and outcomes are presented in the following section.
- The objective tests that are currently used are specific to the stability of the shoulder complex rather than the functional movement of throwing. Ideally, the overhead athlete would pass certain functional tests before initiating a throwing program but the lack of researched methods in this area makes it difficult. Although not specific to the overhead thrower, the following are upper extremity objective tests that can be used.
  - Isokinetic strength testing
    - Several prominent research studies have used isokinetic testing of the external and internal rotators of the shoulder to quantify muscle strength. Using this data, a ratio of 66% has been developed between the two muscle groups to indicate a minimum strength level for a healthy population. This has been studied in both baseball and non-baseball populations.[16-19]
  - Davies closed kinetic chain stability tests[20]
    - The athlete's body is placed in a push-up position with tape 36″ apart. The object is to move both hands back and from between tape marks counting each repetition completing within 15 seconds. A test retest study of this test produced a reliability coefficient of 0.927 indicating it to be highly reliable.[21] Additional testing by Rousch[22] determined reference values for this test.
    - Insert table with reference values here.
  - One arm hop test[23]
    - The athlete is placed in a unilateral push-up position with a 10.2 cm step-up box directly lateral to the involved extremity. The subject performs a one arm hop onto the step-up box and returns to the starting position. A total of five repetitions are performed with the time taken to complete recorded.

Outcome Scales used for Patient's Progression and Status

- American shoulder and elbow surgeons shoulder form (ASES). A self-administered questionnaire used to assess pain and ADL function in patients with shoulder pathology. This questionnaire is based on a 100-point scale and can be administered through the rehabilitation process to track a patient's progress.[24]
- Disabilities of the arm, shoulder, and hand (DASH). The DASH is a self-administered questionnaire to assess pain of function of the upper extremity. A 100-point scale is used in which the higher the score, the higher the disability of the patient.

Criteria to Release an Athlete to Complete Participation in Pitching without Further Supervision

- Typically following a SLAP repair, the athlete will return to throwing at approximately 4 months postsurgery. The athlete is not released to return to game competition until successful completion of an interval throwing program. Specific criteria used to progress through a throwing program is outlined in the Return to Throwing Program Summary. In addition to successfully progressing through this throwing program, the athlete must demonstrate preinjury velocity and accuracy to access if he is ready to return to game competition.

Evidence

Burkhart SS, Morgan C: SLAP lesions in the overhead athlete. *Orthop Clin North Am* 32:431–441, viii, 2001.

This study reported on a case series of 54 baseball players and their rate of return to preinjury performance level after the repair of a type II SLAP lesion. Eighty-seven percent of players were able to return to their preinjury level of throwing and 84 were able to return to their prior level of performance. (Case Series, Level IV evidence)

Gorantla K, Gill C, Wright RW: The outcome of type II SLAP repair: a systematic review. *Arthroscopy* 26:537–545, 2010.

A systematic review of the results of type II SLAP lesions in studies with a minimum of 2-year follow-up and level IV evidence or higher published in English peer-reviewed journals. This review found that the arthroscopic repair of type II SLAP tears had excellent results in individuals who did not participate in throwing or overhead sports, and those that participated in these activities had varying results. (Systemic review of Level III and IV studies, Level IV evidence)

Neri BR, ElAttrache NS, Owsley KC, et al: Outcome of type II superior labral anterior posterior repairs in elite overhead athletes: Effect of concomitant partial-thickness rotator cuff tears. *Am J Sports Med* 39:114–120, 2011.

A retrospective case series on 23 elite (college or professional) overhead athletes who had a minimum 1-year follow-up after an arthroscopic repair of type II SLAP lesions compared to a healthy cohort of athletes. Only 57 % of athletes were able

to return to their preinjury level of competition. (Cohort study, Level III evidence)

Neuman BJ, Boisvert CB, Reiter B, et al: Results of arthroscopic repair of type II superior labral anterior posterior lesions in overhead athletes: assessment of return to preinjury playing level and satisfaction. *Am J Sports Med* 39:1883–1888, 2011.

A retrospective review of 30 overhead athletes who underwent arthroscopic surgery for repair of a type II SLAP tear. Arthroscopic results based on the American Shoulder and Elbow Society (ASES) and the Kerlan-Jobe Orthopaedic Clinic shoulder and elbow (KJOC) score had excellent results, however, these scores were not reliable for throwers. (Case series, Level IV evidence)

Sayde WM, Cohen SB, Ciccotti MG, et al: Return to play after Type II superior labral anterior-posterior lesion repairs in athletes: a systematic review. *Clin Orthop Relat Res* 470:1595–1600, 2012.

A literature review of English peer reviewed journals from 1950 to 2010 reporting on 506 patients with type II SLAP repairs and a minimum of a 2-year follow-up from 14 different studies. Most individuals were able to return to their previous level of play, however overhead athletes were less likely to return to their previous level of play. (Level III evidence)

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Multiple-Choice Questions

QUESTION 1. What is the key range of motion that requires special attention when returning an athlete to this sport?

A. Abduction
B. Internal rotation
C. External rotation
D. Both A and C.

QUESTION 2. What Olympic lift is NOT included in this rehabilitation?

A. Dips
B. Clean and jerk
C. Power clean
D. Snatch

QUESTION 3. What exercises should athletes continue indefinitely?

A. Biceps strength
B. Periscapular training
C. Postural exercise
D. Sleeper stretch

QUESTION 4. What are the important considerations for return to throwing?

A. Time from surgery
B. Range of motion
C. Return to full strength
D. All of the above

QUESTION 5. Athletes with SLAP tears are most commonly symptomatic during which phase of throwing?

A. Deceleration
B. Early cocking
C. Late cocking
D. Follow-through

Answer Key

QUESTION 1. Correct answer: **D** (see Introduction)

QUESTION 2. Correct answer: **A** (see Phase I)

QUESTION 3. Correct answer: **B** (see Sports Performance training)

QUESTION 4. Correct answer: **D** (see Sports Performance Testing)

QUESTION 5. Correct answer: **C** (see Introduction)

BEYOND BASIC REHABILITATION: RETURN TO VOLLEYBALL AFTER LABRAL SURGERY (SLAP REPAIR OR DEBRIDEMENT AND DECOMPRESSION OF SPINOGLENOID NOTCH CYST)

Aaron Brock, MS, ATC, CSCS, PES, Alexander K. Meininger, MD, and Sherwin S.W. Ho, MD

Introduction

- Overuse injuries of the glenohumeral joint are common in overhead athletes.
- Volleyball athletes are particularly at risk and up to 60% of intramural competitive volleyball athletes note shoulder dysfunction.[1]
- It has been estimated that a competitive volleyball athlete practices 20 hours and performs over 1000 overhead spikes weekly.
- Infraspinatus loss of strength has been shown to be up to 22% in volleyball players with suprascapular neuropathy.
- Power loss up to 40% by Cybex testing has been documented.[2]
- Thirty percent of professional male volleyball players have evidence of infraspinatus atrophy (Figure 4-53), diminished external rotation strength, or fatty infiltration.[3]
- Subclinical suprascapular neuropathy can be found in an additional 12% of volleyball athletes.[2,4,5]
- Electrophysiologic and clinical evidence of suprascapular denervation has been found in 33% to 45% of competitive volleyball players.[4,6]
- The natural history of suprascapular neuropathy in volleyball players suggests 8% fail to respond to conservative treatments.[7]
- Both conservative and surgical therapies have shown a successful return to sport.[7]
- Surgical repair of type II SLAP tears has been associated with 74% return to sport in overhead athletes.



FIGURE 4-53. A,B: Suprascapular nerve injuries showing atrophy.

- Any athlete recovering from SLAP tears or infraspinatus syndrome must undergo a phased upper extremity return to play program (UERPP).

Seven Goals of Advanced Therapy

- Progress rotator cuff strength and endurance, placing emphasis on external rotation.
- Progress scapular stabilizer strength and endurance.
- Progress dynamic stability and neuromuscular control.
- Manage and modify upper body strength and conditioning.
- Progress the kinetic chain and core training.
- Address hypertonic tissue e.g., manual therapy (myofascial release, active release technique [ART] for tightness typical of volleyball athletes: posterior rotator cuff/capsule, pectoralis minor, latissimus dorsi, upper trapezius, and levator scapulae).
- Initiate return-to-play program with appropriate technique.

Table 4-2 Exercise Ranking

Muscle	Exercise	Notes
Supraspinatus	1. Full can to 120° 2. Prone Y 3. Pushup plus (+) 4. Prone W (ER at 90°)	1. Better than empty can 2. Also good exercise for lower trap 3. Also good for serratus anterior 4. Also good for external rotators
Infraspinatus & teres minor	1. Side-lying ER 2. Standing ER at 0° 3. Prone W (ER at 90°) 4. Prone Y	1. Highest EMG activity and safe (with towel roll) 2. Allows for proper form without compensation 3. Increased capsular strain but high EMG 4. Good activation of ER group
Subscapularis	1. IR at 90° 2. IR at 0° 3. Pushup plus (+) 4. Scapular hug	1. Decreased large muscle activation compared to 0° 2. More large muscle group activation 3. Also good for serratus anterior 4. Also good for serratus anterior

Phase I: Advanced Strength and Conditioning Programs

Periodization

- SLAP rehabilitation is functionally divided into:
  - Microcycles: Progression through each phase (weekly most common)
  - Mesocycles:
    - Strengthening
    - Sport-specific exercise
    - Upper extremity return to play program
- Stepwise and undulating periodizations are both important aspects of SLAP rehabilitation.

Program Design/Performance Training Program: Advanced SLAP Therapy

Despite the many differences between sport-specific demands, goals in the early phase of any SLAP rehabilitation program is to:[8]

- Restore full range of motion
- Control pain and inflammation
- Provide maximum protection to the shoulder complex

Once the acute and intermediate phases of therapy have been successfully completed, it is time to move beyond basic rehabilitation and introduce more dynamic loads to the shoulder complex and prepare the patient's shoulder for volleyball activity. Researchers using indwelling electromyography have identified the exercises included below that maximize muscular activity in the rotator cuff and scapular stabilizers.[9-12]

Rotator Cuff Strength and Endurance[10] (Table 4-2)

- Degrees of abduction/flexion: Advanced rehabilitation begins to include exercises replicating normal patterns of motion, such as proprioceptive neuromuscular facilitation (PNF), trunk muscle activation and core strengthening. Appropriate SLAP rehabilitation focuses on those exercises exceeding 90° of abduction/flexion.
  - Scaption
  - Diagonal pulls: low resistance PNF movements such as a low-to-high cross-body pull
  - 90°/90° external rotation (ER)/internal rotation (IR)
  - Retract and rotate (Figure 4-54)
  - Bodyblade vibration core training: Two-handed Bodyblade controlled oscillations positioned at 160° of shoulder flexion
  - Wall bounces
  - Point of contact (see progress dynamic stability and improve neuromuscular control, below, for explanation)
- Resistance/reps: Undulating periodization of resistance and repetition is employed to focus on strength and endurance.
  - Increasing resistance and lower repetitions can be used to induce muscle hypertrophy and strength goals
  - Lower resistance is combined with higher repetitions to achieve endurance goals. Examples:
    - 4 × 8 to failure each set versus 3 × 30 with intense lactate burn
    - Dumbbell and pulley machines best for strength
    - Bands and body blade good for endurance
- Type of exercises: With a strength-base established, eccentric exercises can be introduced to further strengthen the deceleration (negative) component of the rotator cuff. Common exercises are:
  - 90/90 ball catches
  - Scaption ball catches
  - Wall bounces
  - Plyometric back rebounds



FIGURE 4-54. Retract and rotate/scapular punch.

- Speed: The volleyball spike requires incredibly high torque throughout the shoulder girdle. Safe introduction of fast twitch movements can begin to get the athlete comfortable with quick accelerations. Start with comfortable, short arcs of motion. Caution should be taken when getting into the fully cocked position.
  - Diagonal pulls with Thera-Band
  - Hitting pull backs: Thera-Band or SportCord
  - Exercise in the cocking phase of the volleyball spike is performed by attaching resistance to the wrist allowing the hand to be free

Rokito et al.[13] review the five phases of a volleyball spike:

- Windup: Begins with shoulder extension as the player swings the arms behind the body to create momentum and ends with flexion and abduction as the player initiates external rotation.
- Cocking: Begins with the initiation of external rotation and ends with maximal external rotation and scapular retraction.
- Acceleration: Begins with forceful internal rotation and elbow extension ending with ball impact
- Deceleration: Begins with ball impact at ~1 o'clock position and ends with arm perpendicular to the trunk as it is extended
- Follow-through: Begins with upper arm perpendicular to the trunk and ends when shoulder extension is complete.

A. Suprapsinatus

- During a volleyball spike supraspinatus activity was highest (71%) during the windup phase.[13]
- Therefore, it's important to evaluate which exercises would best activate and strengthen this muscle.

Supraspinatus activity is similar in both the empty and full can exercise; although the full can may be preferred because:

- IR does not allow the greater tuberosity to clear from under the acromion during humeral elevation, which decreases the mechanical advantage of the supraspinatus thus increasing tensile stresses to the tendon.[14] This may also create more pain and therefore a compensatory shoulder shrug.[14]
- IR creates scapular protraction or winging and anterior tilt to the scapula, decreasing the subacromial space and therefore increasing subacromial impingement.[15]

Supraspinatus strengthening exercises include:

- Prone full can (prone horizontal abduction 100° thumbs up)
- Pushup plus
- Overhead press in scapular plane
- Prone ER at 90° abduction
- Standing ER at 90° abduction
- PNF flexion/extension patterns

B. Infraspinatus (IF)/teres minor (TM)

- Infraspinatus activity approaches 60% during windup. Teres minor activity was at 39% upon windup and increased to 51% during cocking and acceleration.
- SLAP lesions are often found associated with weakness of the external rotators in overhead athletes.
- The IF is prone to be atrophied in volleyball attackers caused by suprascapular nerve injury.
- IF/TM exercises include:
  - Prone horizontal abduction at 100° with ER
  - Side-lying abduction, flexion
  - Full can
  - D1/D2 flexion patterns.

C. Subscapularis (SS)

Subscapularis activation is highest in acceleration (65%) and lowest during follow-through (16%). Simultaneous SS and IF activation during humeral elevation resists superior humeral head translation and neutralizes the IR and ER torques they generate to help enhance joint stability.[16]

The SS is highly active in several shoulder exercises:

- Pushup plus
- Scapular dynamic hugs (Figure 4-55)
- Scapular rows
- Side-lying abduction
- D2 flexion and extension patterns
- ER exercises to help stabilize the GH joint

Scapular Stabilizer Strengthening[9] (Table 4-3)

- Serratus anterior (SA)
  - SA is most active in:
    - Pushup plus
    - Dynamic hug
    - Serratus punches
  - Significant SA activity was also demonstrated with:
    - D1 and D2 diagonal pattern flexion
    - D2 diagonal pattern extension

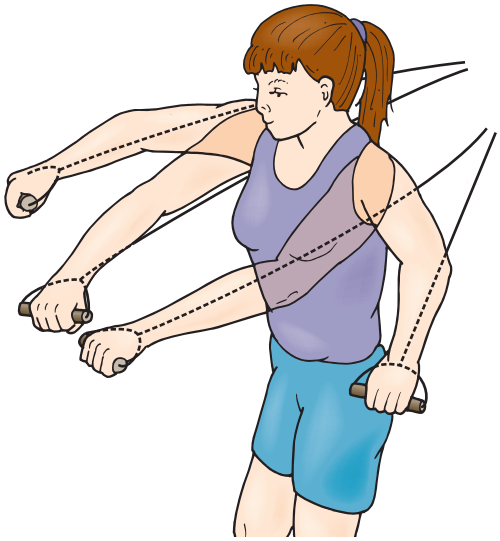

FIGURE 4-55. The dynamic hug exercise horizontally flexes the humerus at a constant 60° of humeral elevation while the hands follow an imaginary arc until maximum protraction is attained. *(Redrawn from Decker MJ, Hintermeister RA, Faber KJ, Hawkins RJ: Serratus anterior muscle activity during selected rehabilitation exercises. Am J Sports Med 27:784-791, 1999.)*

  - Supine upward scapular punch
  - IR and ER at 90° abduction, flexion.
- Trapezius muscle controls scapular upward rotation and elevation through the upper trapezius (UT), retraction by the middle trapezius (MT), and upward rotation and depression for the lower trapezius (LT).

Table 4-3 Scapular Stabilization Exercises

Muscle	Exercise	Notes
Serratus anterior	1. Pushup plus 2. Dynamic hug 3. Serratus punch at 120° 4. Scaption at 120°	1. Also good for IS and TM. 2. Performed below 90° 3. Also adds upward rotation 4. Also good for SS
Lower trapezius	1. Prone Y 2. Prone W (ER at 90°) 3. Prone T thumbup 4. ER Pull aparts	1. High EMG, also good for supraspinatus 2. High EMG, also good for IS and TM 3. Good ratio of upper lower to upper trapezius 4. Good ratio and good for IS and TM
Middle trapezius	1. Prone row 2. Prone Y 3. Prone T thumbup 4. Prone W (ER at 90°)	1. High EMG, good ratio of trapezius activation 2. High EMG 3. High EMG, good for lower trapezius 4. High EMG, also good for IS and TM
Upper trapezius	1. Shrug 2. Prone row 3. Prone T thumbup	1. High EMG 2. Good ratio for upper, middle, and lower trapezius 3. Also good for lower and middle trapezius
Rhomboids	1. Prone row 2. Prone T thumbup 3. Prone I (extension)	1. Also good for trapezius 2. Also good for trapezius 3. High EMG

  - High UT activity occurs with:
    - Shoulder shrug
    - Prone rowing
    - Prone horizontal abduction at 90° and 135°
    - D1 pattern flexion and most other exercises with humeral elevation above 120°.
  - High LT activity occurs in:
    - Prone rowing
    - Prone horizontal abduction at 90° and above
    - D2 PNF flexion and extension
    - High scapular rows, along with abduction and flexion
  - Four exercises to improve balance between typically overactive UT and typically underactive LT:[17]
    - Side-lying ER
    - Side-lying forward flexion
    - Prone horizontal abduction with ER
    - Prone extension
- Rhomboids and levator scapulae function as scapular retractors, downward rotators, and elevators. Exercises used to strengthen the RC and scapular stabilizers are also effective in strengthening the rhomboids and LS.

Progress Dynamic Stability and Improve Neuromuscular Control

- The goal of dynamic coordination of the rotator cuff and scapular stabilizers is accomplished by coactivation and force coupling between the shoulder girdle musculature.
- As the athlete's shoulder strength improves, exercises that replicate sport-specific movement patterns should be incorporated. Many of these terminal exercises may involve multijoint, multiplanar functional movement patterns.[18]

When prescribing exercises to enhance this neuromuscular control and maximize force couple action, we always consider the following:

1. Proprioceptive Neuromuscular Facilitation (PNF)/diagonal patterns. PNF has moderate support for its effectiveness in promoting functional progression.[19-21] We prefer D1 extension, D2 extension, and D2 flexion and typically avoid D1 flexion caused by impingement concerns. I also prefer manual resistance with PNF but diagonal patterns with a band or cable system are adequate alternatives.
2. Rhythmic Stabilization (RS): Reflexive muscular responses are produced via isometric contractions in various ROM. I perform RS in two volleyball specific joint positions, end cocking phase (abduction, ER) and at point of contact (POC) (~10 to 11 o'clock in scapular plane). The POC position is a loose packed position and therefore elicits less proprioceptive feedback.[22,23] Therefore focusing RS in the POC, sport-specific position may create more dynamic stability during the volleyball spike.
3. Closed kinetic chain (CKC) exercise: Upper extremity CKC or weight bearing exercises produce humeral head compression within the glenoid thereby enhancing muscular cocontraction.[24-26] The dynamic stabilizing system is even further stressed when adding RS and unstable surfaces to CKC exercises (i.e., front

planks, side planks, front hand step-ups, lateral hand step-ups, weight shifts, pushup plus (+), etc.).

Manage Upper Body Strength and Conditioning

Upper body modifications include:

Bench Press: The bench press stresses the humeral head stabilizers and long head of biceps brachii.

- Eliminate straight bar bench and use only dumbbells. Dumbbell bench press is more difficult than straight bar bench and therefore less weight is needed to get the desired effect. Dumbbells also allow for easier modification of hand spacing, grip selection, and GH motion.
- Stay narrow and keep abduction at less than 45° (keep elbows in). This minimizes peak shoulder torque and reduces cuff and biceps requirements for humeral head stabilization.[27]
- Recruit serratus anterior by adding a reach or plus (+) to the press whether it is a bench press or pushup.

Pushups: Use the same modification principles as the bench press:

- Narrow hand positioning (less than 1.5 shoulder width).
- Limit abduction by keeping the elbows in next to the trunk.
- Limit ROM (place medicine ball under the sternum).
- Recruit serratus anterior by adding a plus (+) at the end range.
- Volume of chest exercise needs to be monitored since tightness in the pectoralis muscles possibly creates an undesirable postural effect of rounded shoulders.

Shoulder press:

- Avoid barbell and use dumbbell instead.
- Begin the shoulder press with a neutral grip and in the scapular plane.
- Extra attention needs to be placed on the scapular retractors during the press
- Avoid behind the head shoulder press caused by the high five position (GH-abduction in ER) creating anterior shear stress and labral stress.
- Proceed with caution to the full overhead position where dynamic stability is challenged and impingement is likely.
- The explosive push press can be added when the athlete has completed controlled shoulder press exercises with no symptoms.

Biceps:

- The bicep needs to be protected with SLAP injuries. However, as the biceps is an important shoulder stabilizer, it should be included in a comprehensive strength-training program. Scapular retraction should be emphasized while performing biceps exercises and resistance should be mild to moderate.

Triceps:

- With concern for impingement, overhead triceps extension should not be performed. Lying triceps extensions or standing triceps pushdowns are alternatives; or add a triceps kick back to a single arm row.

Pullups:

- Chin-ups create more activate of the biceps and therefore need to be limited with SLAP recovery. Traditional pullups are less taxing to the biceps and therefore are safer.[28] Latissimus pulldowns should not be done behind the head. Instead, recline the body 30° and pull the bar to the chest just above the xiphoid process.

Power/hang cleans:

- Can possibly be stressful to the shoulder complex as the weight is "racked" after being pulled from the floor. The deceleration phase of a power clean creates an eccentric contraction of the biceps and therefore is undesirable for athletes with a SLAP lesion. It's important to use bumper plates so the athlete can drop the bar to the platform without having to decelerate the bar.[27]

Squats:

- Squats require the athlete to support the bar in the high five position which may be undesirable. Therefore, front squats may be an appropriate substitute. Front squats allow for a bar position that is much safer for injured shoulders.[27]

Kinetic Chain Involvement and Core Training

Some examples of kinetic chain exercises include:

1. Rotational squat press: Holding a plate, dumbbell or cable, squat and reach down. Then squat up and rotate while pressing the arms upward.
2. Front lunge punches: Lunge forward and punch forward or upward at the same time.
3. Lawnmowers: Squat down, reach low, and pull diagonally upward.
4. Lateral lunge punches: Squat in the frontal plane and add a diagonal or front punch.
5. Single leg cable reach and pull: begin in a single Romanian dead lift (RDL) stance reaching forward, then mid row while performing a single leg RDL movement.

Examples of core stability exercises ("train from the inside out"):[29]

1. McGill's Big 3: 1. Curl up: Lie on your back with one leg flat and one knee bent (foot flat on the floor). Curl your trunk up without flexing your cervical spine.
2. McGill's Big 3: 2. Side plank: Brace yourself on your elbow and lift your hips off the ground keeping a straight solid posture. Add weight to increase demand.
3. McGill's Big 3: 3. Bird dog: Start on hands and knees. Extend one hip while reaching (flexing) with the opposite arm.
4. Stir the pot: Assume the elbow front plank position on a physioball and rotate the ball clockwise and counterclockwise while maintaining a straight solid position.
5. Dying bugs: Lie on your back with hips and knees flexed and arms straight up to the ceiling, set your core, and extend one knee while reaching back with the opposite arm

Examples of traditional core strength exercises:

1. Hanging knee to elbows: Hang from a pullup bar and flex the hips and touch the knees to elbows with a slow return to the hanging position.
2. Weighted toe touches: Lie on your back with knees extended and hips flexed to ~45°. Set the core and perform an abdominal crunch as you touch a bar to your toes.
3. Windshield wipers: Lie on your back on the floor and hold a bar up in the beginning bench press position, then swing both legs side to side with straight knees.
4. Barbell roll outs: Assume the quadruped position and grasp a bar or an abdominal wheel. Roll the bar/wheel out in front until chest is parallel to the ground (or earlier if the low back neutral position is lost).
5. Weighted side bends: Grasp a dumbbell in one hand and hold at the side. Side bend towards the weighted side and then side bend back to the upright position.

Examples of functional core strength exercises:

1. Pallov press with rotation: Stand facing perpendicular to a cable machine grasping the handle with both hands and starting with hands touching the sternum. Extend the arms in front of the body and then rotate the trunk 90° both directions.
2. Downward chop: Split stance or kneeling facing the cable machine, reach high and grasp the handle with both hands. Pull the cable down with the abdominal muscles in a chopping motion. Swinging a sledgehammer into a tractor tire can also accomplish this.
3. Medicine ball rotational downward slam: Similar in motion to the downward chop, hold a medicine ball over the shoulder, load by rotating to that side then quickly rotate the trunk and slam the ball downward.
4. Figure-8 plates: Hold a 25-lb plate out in front of your sternum. Initiate movement with the trunk as you trace figure-8s with the plate.
5. Medicine ball tosses into wall: Stand either facing the wall or perpendicular. Initiate rotational movement as you toss the ball into the wall.

Address Hypertonic Tissue

Continue to address any hypertonic tissue typical of volleyball athletes through manual therapy, myofascial release, active release techniques (ART) and joint mobilization including posterior rotator cuff/capsule, pectoralis minor, latissimus dorsi, upper trapezius, and levator scapulae.

- Individualized therapy is critical. Each athlete's needs are determined with a thorough evaluation.
- However, Janda's upper crossed syndrome (UCS) can be found in many volleyball athletes. Rounded, protracted shoulders and a forward leaning head posture characterize this syndrome. The pattern is common in athletes working in one-dimensional training protocols and is theorized to contribute to shoulder girdle injury patterns.[17,30]
  - Dorsal: Tight upper trapezius and levator scapula.
  - Ventral: Tight pectoralis major and minor.
  - Weak Rhomboids, lower trapezius, and serratus anterior.
  - Tight scalenes, subscapularis, latissimus dorsi, and teres major.
  - Weak teres minor, infraspinatus, and posterior deltoid.
  - These muscular imbalances potentially lead to the following postural disturbances: Thoracic kyphosis, forward head posture, elevated and protracted scapulae, and rounded shoulders.
  - UCS and postural disturbances are resolved through a number of therapeutic interventions.
  - The primary goal is to restore muscle balance by lengthening the hypertonic tissue and strengthening the weakened muscles.
  - Lengthening the tight tissue is accomplished through a variety of techniques such as stretching and manual therapy. Several stretching techniques are at the therapist's disposal including static, dynamic, PNF, and post-facilitation stretching.
  - Manual therapy options include myofascial release, trigger point therapy, strain counterstrain, mobilization, manipulation, instrument assisted therapy, and more. Myofascial self release with foam rollers and STICKS are options as it is low cost and can be done by the athletes themselves.[31]
- Commercially available self-massage tools, such as TheStick, or 12″ foam rollers are often recommended, portable and commonplace among elite athletes prescribed manual therapy techniques.
  - A variety of taping techniques have been described for postural correction.
- Kinesio Tape is therapeutic elastic tape for sports injury. High-level exposure during the 2008 Olympic Games in Beijing, China lead to a resurgence of 1970s' techniques.
  - Case reports document improved function with low risk and anecdotal athlete satisfaction; despite the paucity of Level I data to support routine use of Kinesio Tape.[32-34]
- Postural clothing, such as the Intelliskin shirt, provides proprioceptive feedback and enhances scapular control in overhead athletes.[35,36] We commonly incorporate Intelliskin into the scapular rehabilitation of overhead athletes (See Bonus Exercise, Figures 4-56).
- Lastly, we routinely employ a three-part "perfect posture" exercise to encourage postural correction, enhance scapular kinematics, and avoid upper crossed syndrome in our athletes.
  - Start with the midback, head, and low back pressed into the wall, heels 6 inches from the wall, with arms at the sides.
    - Part 1 involves the head pressed into the wall without lifting the chin, scapular retraction, and arms pushing into the wall (elbow extended).
    - Part 2 involves abducting the arms to 90° and pushing the elbows into the wall (while also

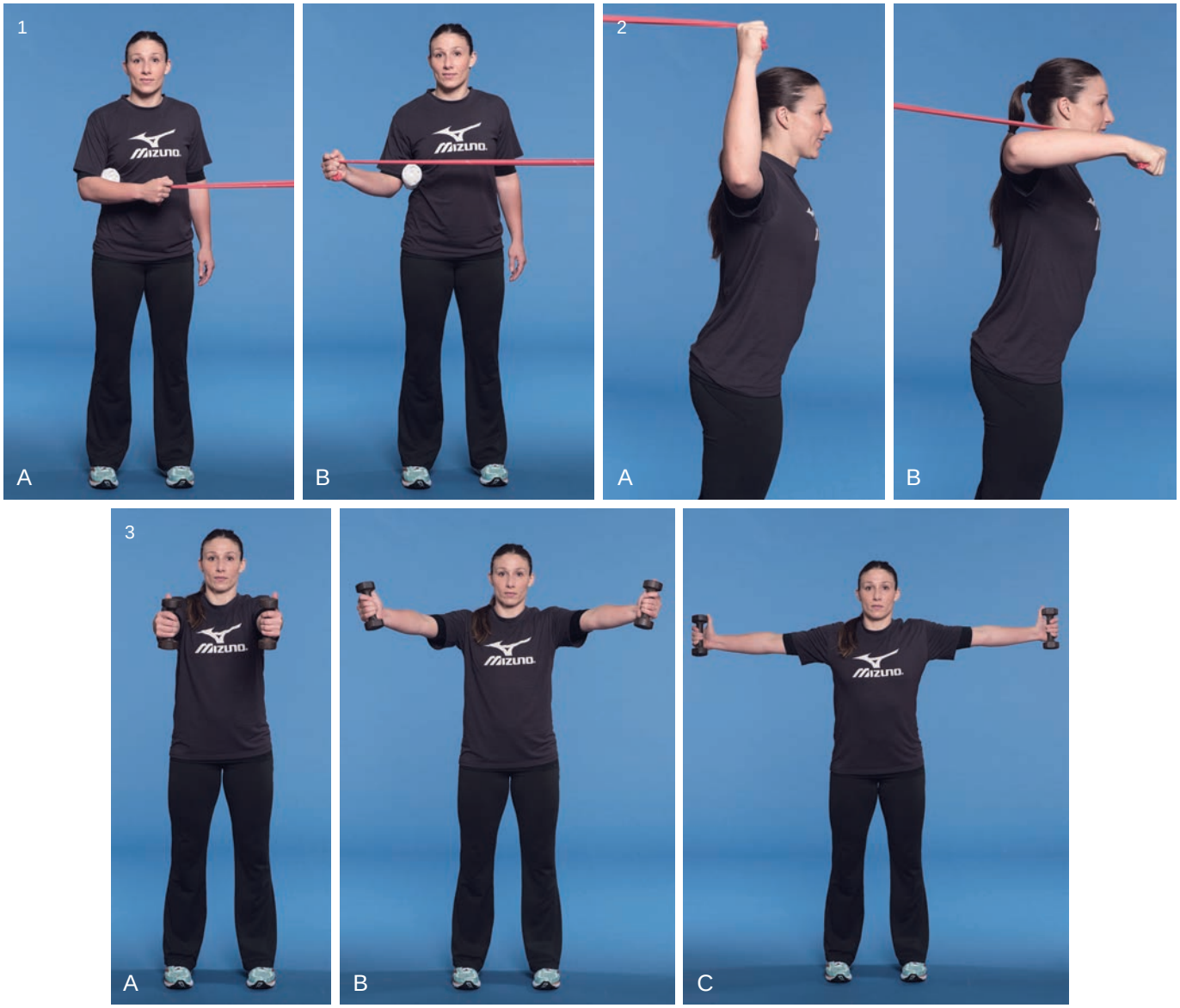

FIGURE 4-56. Hitter's Ten exercises. **Exercise 1:** External Rotation (ER) at side. Elbow bent at 90°, start in a fully internally rotated position and externally rotate with a rolled towel squeezed between the side and elbow.
Exercise 2: IR at 90. Face away from the band, elbow bent at 90°, shoulder raised to 90°, start in fully externally rotated position and internally rotate.
Exercise 3: Three-way raise. Standing with knees slightly bent, raise the dumbbell directly in front of your body, directly to the side of your body and also in between those two positions.

Continued

"setting the core" and continuing to push the back of the head into the wall).
- Part 3 progresses to external rotation and pressing the back of the hands into the wall.

Phase II: Performance Enhancement Training Techniques

Sport-Specific/Position-Specific Court Work

- Upper extremity return to play program (UERPP, Box 4-3).
- Position-specific work.
- Technique: Footwork (feet to ball), central axis rotation, hip/trunk driven spike.
- Serve receive (careful with defense—diving and quick GH flexion).
- Mental training/imagery.
- Any well-organized physical therapy plan assesses the individual and adjusts the plan accordingly.
- The Hitter's Ten (see Box 4-4, and Figures 4-56 and 4-57) is simply a guideline to appropriate exercises as determined by EMG studies and clinical experience.
- Many other valuable exercises are available to the rehabilitation specialist during each stage of the rehabilitation process but the Hitter's Ten provides safe, comprehensive, and practical options for strengthening exercises.

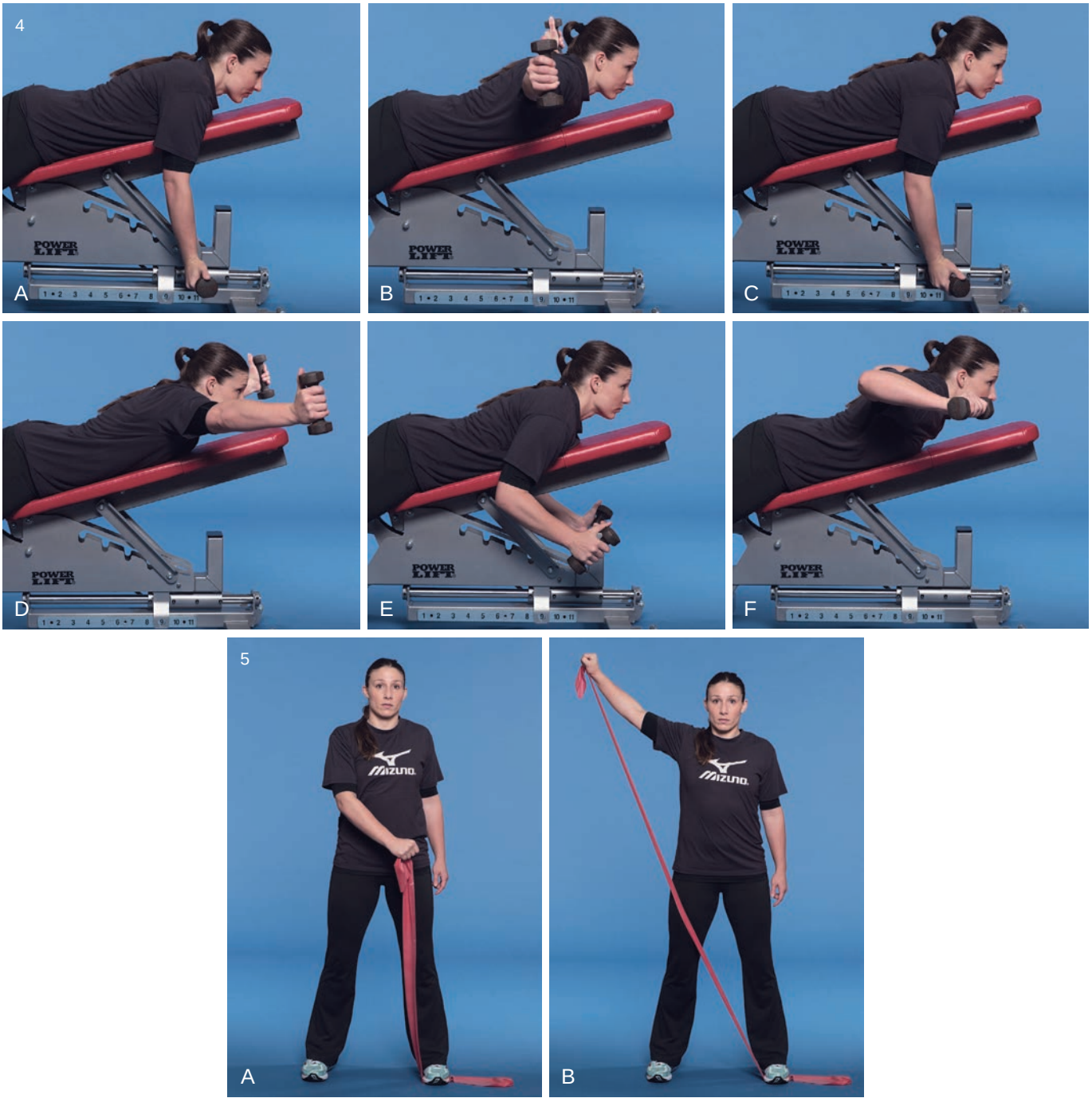

FIGURE 4-56. cont'd. Exercise 4: Three-way scap pinch on bench. Face down on slightly inclined bench, raise the arms up/pinch scaps with bent elbows (W), straight elbows (T) and in the Y position with elbows straight.
Exercise 5: Diagonal pull, low to high. Step on band with opposite foot, start with arm in front of your body and finish by pulling diagonally across your body like pulling a sword from its sheath.

Phase III: Sport-Specific Training

- UERPP provides athletes, coaches, and medical providers with specific guidelines that may facilitate a safe return to play from an upper extremity injury.
- The program is designed to induce appropriate, progressive stresses to the involved tissues thereby minimizing the risk of reinjury upon return to overhead activity.

Parameters:

- Initiation of UERPP is determined by tissue healing time and the successful completion of acute and intermediate phases of rehabilitation.
- UERPP must be accompanied by comprehensive rehabilitation and strength training programs.
- Due to individual variability, there is no set time line for progressing through the stages and ultimate completion of the program.



FIGURE 4-56. cont'd. Exercise 6: Diagonal pull, high to low (6 A, B). Anchor the band high, grasp the band with arm across your body and pull down and away from your body, ending low.
Exercise 7: Push up plus. Begin in the push-up position, keep elbows straight as you allow the scapulae to come together, then push into the ground pressing the scapulae away from each other outwardly.
Exercise 8: POC ABC (extension and flexion). Face pole, position body as if to spike, raise arm into point of contact position (where you contact the ball when spiking; ideally, 1 or 2 o'clock), and trace the ABCs in the air. Flexion is accomplished by the same technique—only facing away from the pole.
Exercise 9: Mid row. Face the band, grasp the band with elbows extended reaching out in front of you. Bend your elbows as you pull your elbows back.
Exercise 10: Pull-aparts. Grasp both ends of a short band. Pinch your scaps as you pull the ends of the band away from each other.



FIGURE 4-56. cont'd. Bonus Exercise: "Perfect posture holds." The forward head, rounded shoulders and hunched back posture places increased stress on your shoulder. Perform this exercise by standing with your back and head against the wall with your heels 6 inches away from the wall. Press your lower back into the wall, pinch your shoulder blades together, and push the back of your head into the wall. You can also raise up your arms, press your elbows into the wall, then externally rotate and press the back of your hands into the wall. Also, many of our athletes wear an Intelliskin posture shirt to help with proper positioning. *(From Brock A: Staying on the court: The complete guide to shoulder maintenance, Part I. VolleyBall USA, Anaheim, CA. Digital Issue at usavolleyball.org/mag.)*

BOX 4-3 Upper Extremity Return to Play Program

Stage 1: Advanced rehabilitation

1. Overhead rehabilitation exercises
   - Point of contact (POC) flexion, extension, stabilization
   - Bodyblade blocking
   - Wall bounces
   - Eccentric ball catches
   - Eccentric swing decelerations
   - Proprioceptive neuromuscular facilitation (PNF) past 90
2. Depending on the injury, 1 to 3 pain-free overhead rehabilitation sessions before Stage 2
3. Can perform controlled passing and setting drills

Stage 2: Remember how to swing (plus block and dig)

1. Shadow swinging
   - 15 to 20 straight on, line of approach (LOA) swings in front of mirror with no ball
   - Focus on core contraction, trunk rotation, and proper arm mechanics
2. Kneeling swinging
   - 15 to 20 swings in front of mirror with no ball
   - Focus on core contraction, trunk rotation, and proper arm mechanics
   - Possible to include the first Stage 2 workout on the same day as late Stage 1 activities
   - Increase volume to 20 to 30 swings for the second Stage 2 workout
   - Usually give day off between Stage 2 workouts
3. Resisted swinging
   - 15 to 20 swings with cord (varying intensity)
   - Focus on core contraction, trunk rotation, and proper arm mechanics
   - Induce shoulder complex fatigue
   - Increase speed of arm swing for fast twitch fiber activation
   - Can use throughout all stages as desired
     - Blocking
     - 10 to 15 controlled light roll shots into the block
     - 10 to 15 controlled 50% swing into the block
     - Digging
     - Lay prone on ground with arm outstretched
     - Start kneeling and slowly move into prone outstretched arm position x5
     - Start kneeling and quickly move into prone outstretched arm position x5

BOX 4-3 Upper Extremity Return to Play Program *(Continued)*

Stage 3: Swing with ball contact

1. 50% hitting off wall or to a partner over the net
   - Start with 15 to 20 swings (all three types of swings: cross body, wrist away, line of approach)
   - Possible to include the first Stage 3 workout on the same day as late Stage 2 activities
2. 75% hitting off wall or to a partner
   - Begin to increase the intensity and volume during the second workout in Stage 3
   - Begin to reach for a high ball contact point and make contact at 10 to 11 o'clock … not low at 9 o'clock
3. 100% hitting off wall or to a partner
   - 30 to 40 swings at progressive intensities
   - Depending on the injury, nonswinging days may need to be included for rest
   - Technique must be perfect before moving into a less controlled environment
   - Stages 2 and 3 become part of the warm up for the future stages
     - Blocking
     - 15 to 20 controlled 75% spikes into block
     - Digging
     - Defensive position controlled diving with outstretched arm x10

Stage 4: Pepper

In this routine, Player 1 and Player 2 face one another.
- Player 1 introduces the ball via a toss or hit
- Player 2 passes the ball back
- Player 1 sets the ball
- Player 2 spikes the ball
- Player 1 digs the ball
- Player 2 then sets the ball
- Player 1 spikes
- Player 2 digs, etc.

1. 50% pepper
   - Could be introduced before 100% hitting off the wall
   - Possible to include the first Stage 4 workout on the same day as late Stage 3 activities
   - Adjust body position to game simulation environment
2. 75% pepper
   - Begin to increase the intensity and volume during the second Stage 4 workout
3. 100% pepper
   - Possibly able to complete in the same day as 50% and 75% since 100% swings have already been attained while hitting off wall
     - Blocking
     - 15 to 20 controlled 100% spikes into block
     - 15 to 20 live 100% spikes into block
     - Digging
     - Defensive position diving during pepper (10 times)

Stage 5: Spike

1. 50% controlled spiking no block
   - 15 to 20 swings for first workout
   - Most likely can be introduced before 100% pepper is attained
   - Focus on footwork and hitting mechanics
   - Stay straight ahead with location
   - Stay on the left if you're an outside hitter; stay on the right if you're an opposite
2. 75% controlled spiking
   - Begin to increase the intensity and volume during the second Stage 5 workout
   - Begin to fan location with slight cross body and wrist away
   - Begin to work against a block
   - OH introduce back row and R side attack
   - The athlete should be able to participate in some controlled team drills
3. 100% controlled spiking
   - 10 to 15 reps at 100% intensity the first workout
   - Access to all the shots
   - 100% velocity
   - Continue to be disciplined on footwork and hitting mechanics
     - Blocking
     - No limitations
     - Digging
     - Diving with outstretched arm during live drills (20 times)

Continued on following page

BOX 4-3 Upper Extremity Return to Play Program *(Continued)*

Stage 6: Serve

1. 50% serving
   - Can be introduced during stage 5, especially if float serve
   - Work on controlled toss
   - 10 to 15 reps the first day
2. 75% serving
   - Begin to increase the intensity and volume during the second Stage 6 workout
3. 100% serving
   - Serving intensity is easier to control
   - Don't hit 100% if the toss isn't good
   - Focus on getting the toss out in front of the body
     - Digging
     - No limitations

Stage 7: Play Volleyball

1. 100% live competition
   - All controlled stages have been cleared
   - The chaotic nature of live play needs to be reintroduced
   - Limit the volume of live swings to 15 to 20 during first Stage 7 workout and increase volume in subsequent workouts
   - Limit the volume of live play … day ON day OFF for first week, 2 days ON 1 day OFF 2 days ON for second week, and possibly 5 days straight in third week.

BOX 4-4 Hitter's Ten Program

Part 1: Early-Stage Rehabilitation

1. Side-lying external rotation
2. Prone Y (120° to 135°of abduction)
3. Prone T (90° of abduction)
4. Prone W (bent elbow 90° of abduction)
5. Prone M (GH extension elbows straight)
6. Prone row (scapular retraction and then bent elbow row)
7. Subscapularis lift off (isolated subscapularis exercise)
8. Ceiling punch
9. Standing shoulder flexion
10. Standing shoulder full can

Note: Exercises in Part I are applicable not only to postoperative SLAP rehabilitation patients but also to maintenance therapy in the overhead athlete.

Part 2: Late-Stage Rehabilitation

1. Three-way raise
   - Abduction
   - Scaption (full can)
   - Flexion
2. Point of contact (POC) extension
3. Point of contact (POC) flexion
4. Diagonal pulls high to low
5. Diagonal pulls low to high
6. IR at 90/90
7. Retract and rotate at 90/90
8. Pushup plus (+)
9. Bent over dumbbell Ys and Ts
10. Body blade
    - Hitting
    - Blocking
    - At side IR/ER
    - Scaption

Note: Many mid/late stage exercises are not mentioned in Part 2 of the Hitter's Ten program. If a rehabilitation specialist is available, many manual exercises could be excellent options at this stage. Also, other exercises are valuable if additional equipment/devices are available. As always, a skilled clinician needs to continually assess the athlete's progress to determine what is most appropriate.

BOX 4-4 Hitter's Ten Program *(Continued)*

Part 3: Maintenance on the Court with Thera-Band Exercises
1. ER at side with bolster under arm
2. IR at side with bolster under arm
3. Mid row to overhead press
4. ER pull aparts with arms adducted, elbows bent and shoulder rotation against resistance
5. Scapular pull-aparts with shoulders forward flexed, elbows straight and scapular retraction against resistance
6. Full can exercises
7. D2 extension diagonal pattern (throwing acceleration)
8. "High/low" (alternating 135° and 45° scapular pinch)
9. Hitting pull backs
10. Dynamic bear hug

Note: Specific exercises can be added if there is access to a medical professional for assisted exercise: Manual PNF patterns, eccentric over the shoulder ball catch and rhythmic stabilization.

Part 4: Hitter's Ten: Maintenance Program
1. External rotation at side with towel roll
2. Internal rotation at 90°
3. Three-way raise: front, scaption to 120, lateral
4. Three-way scap pinch on bench: W, T, Y
5. Diagonal pull low to high
6. Diagonal pull high to low
7. Pushup plus
8. Point of contact (POC) ABCs (flexion and extension)
9. Midrow
10. Pull aparts

Bonus: Perfect posture holds.
Specific exercises can be added to these lists if there is access to a medical professional for assisted exercise: Manual PNF patterns, eccentric over the shoulder ball catch, rhythmic stabilization, etc.

- This program should be performed under supervision of the athlete's physician and rehabilitation team to ensure appropriate progression.
- General muscle stiffness or soreness is acceptable. However, if the athlete experiences sharp pain or pain at the point of injury, take 1 day off and repeat the workout or drop down to the previous stage.
- Volume, intensity, and environment need to be evaluated and monitored.

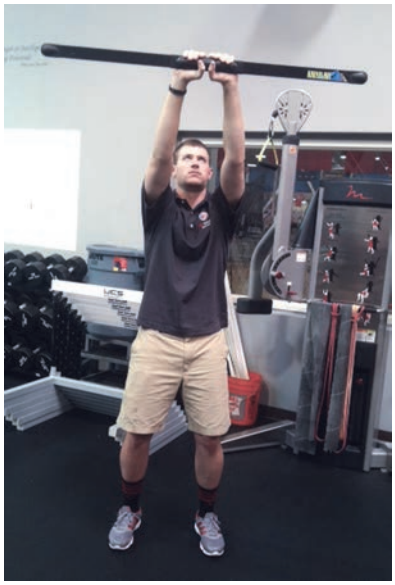

FIGURE 4-57. Blocking position with Bodyblade.

- Be creative on involving the athlete into partial practice depending on limitations.

Daily prep prior to volleyball activity: (see Box 4-5)
- Tissue warming: Heat, US, core temperature increase
- Tissue preparation: Manual therapy, self myofascial release stretches
- Shoulder activation series: Rotator cuff, scapular stabilizers, proprioception
- Full body warm up: Core temperature increases, active stretching, movement preparation, neuronal activation
- Upper extremity return to play program (see Box 4-3)

Sports Performance Testing

General Information

- General history
- Subjective questionnaires
- Medical history
- Sports injury history
- Surgical history
- Chronic conditions/medication

Specific Tests

- Static/dynamic postural assessments
- Dynamic muscle performance testing
- Movement performance testing
- Sport-specific testing

BOX 4-5 Sample Progression for SLAP Nonoperative Return to Play

Week 0-10: Acute and intermediate rehabilitation

WEEK 10:

Day 1—Stage 1 advanced rehab
Day 2—No overhead activity
Day 3—Stage 1 advanced rehab
Day 4—No overhead activity
Day 5—Stage 1 advanced rehab + early Stage 2 activity (15 shadow + 15 kneeling swings)
Day 6—No overhead activity
Day 7—Off

WEEK 11:

Day 1—Daily prep series. Mid Stage 2 workout (20 shadow + 20 kneeling swings plus 10 to 20 resisted swings). Stage 2 blocking and digging activity.
Day 2—No overhead activity
Day 3—Repeat Day 1 plus first Stage 3 workout (15 to 20 swings off the wall, up to 50% intensity)
Day 4—No overhead activity
Day 5—Repeat Day 1 plus second Stage 3 workout (20 to 30 swings up to 75% intensity)
Day 6—No overhead activity
Day 7—Off

WEEK 12:

Day 1—Daily prep series and hitting warm up (20 shadow, 10 resisted). Third Stage 3 workout (30 to 40 swings up to 100% intensity … 20 to 30 swings up to 75% plus 10 @ 100%). Stage 3 blocking and digging activity
Day 2—No overhead activity
Day 3—Repeat Day 1 plus first Stage 4 workout (~10′ 50% pepper—no diving)
Day 4—No overhead activity
Day 5—Repeat Day 1 plus second Stage 4 workout (10′ 75% pepper—no diving)
Day 6—No overhead activity
Day 7—Off

WEEK 13:

Day 1—Daily prep series and hitting warm up (20 shadow, 10 resisted, 20 swings off wall) plus third Stage 4 workout (ten 100% pepper with diving) plus first Stage 5 workout (15 to 20 spikes up to 50%) plus Stage 4 blocking and digging activity
Day 2—No overhead activity
Day 3—Daily prep series, hitting warm up, pepper plus second Stage 5 workout (20 to 25 spikes up to 75%).
Day 4—No overhead activity
Day 5—Daily prep series, hitting warm up, pepper plus third Stage 5 workout (25 to 30 spikes up to 100%) plus first Stage 6 workout (10 to 15 serves up to 50%)
Day 6—No overhead activity
Day 7—Off

WEEK 14:

Day 1—Prep, hit, pepper, spike (30 to 40 spikes up to 100%) plus second Stage 6 workout (15 to 20 serves up to 75%) plus Stage 5 blocking and digging activity. Can begin to get these spikes in a semi-controlled team drill.
Day 2—No overhead activity
Day 3—Prep, hit, pepper, warm up spike (15 to 20 spikes up to 100%) plus third Stage 6 workout (10 to 15 serves up to 100%) plus first Stage 7 workout (15 to 20 spikes in live activity)
Day 4—No overhead activity. Participate in practice but no swinging.
Day 5—Prep, hit, pepper, warm up spike plus second Stage 7 workout (20 to 25 spikes in live activity)
Day 6—Repeat day 5
Day 7—Off

WEEK 15:

Day 1—Warm up + third Stage 7 workout (1/2 of live practice activity)
Day 2—warm up + fourth Stage 7 workout (3/4 of live practice activity)
Day 3—No swinging
Day 4—Warm up + fifth Stage 7 workout (3/4 of live practice activity)
Day 5—Warm up + sixth Stage 7 workout (full practice)
Day 6—Repeat day 5
Day 7—Off

WEEK 16:

Repeat week 15

WEEK 17:

Full practice daily

. Used with permission from USA Volleyball, Anaheim, Ca

Specific Criteria for Release to Unsupervised Complete Participation in Volleyball

- Near full range of motion (80%+)
  - Scapulothoracic
  - Glenohumeral
- Strength testing
  - 4/5 minimum manual muscle testing versus contralateral extremity
- No substitution patterns
- No subjective exacerbation with increasing activity

Evidence

Shepard MF, Dugas JR, Zeng N, et al: Differences in the ultimate strength of the biceps anchor and the generation of type II superior labral anterior posterior lesions in a cadaveric model. *Am J Sports Med* 32:1197–2201, 2004.

Shepard et al. conducted a biomechanical experiment of 16 cadaveric shoulders. They found that the superior labrum and biceps anchor was significantly weaker when loaded with a posterior vector. This finding suggests that the superior labrum may be most vulnerable to injury in late cocking. (Level II evidence)

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Multiple-Choice Questions

QUESTION 1. Suprascapular nerve entrapment at the spinoglenoid notch may be associated with atrophy of the:

A. Subscapularis
B. Supraspinatus
C. Infraspinatus
D. A and B
E. B and C

QUESTION 2. A 21-year-old right handed volleyball player undergoes arthroscopic repair of a right shoulder type II SLAP tear with two labral anchors in the 11 and 1 o'clock positions. Postoperative rehabilitation for this SLAP repair should include:

A. Immediate full active range of motion that simulates sport-specific activities.
B. Full-time sling wear with no active nor passive motion for at least 6 weeks until labral tissues heal.
C. Rotator cuff strengthening by postoperative week two to prevent disuse atrophy and shoulder instability.
D. Limited passive motion for 4 weeks then progressive active motion until 8 weeks followed by sport-specific strengthening until at least 12 to 16 weeks postoperatively.
E. Eccentric open-chain biceps contraction exercises beginning at postoperative week 2 to retrain the biceps muscle and stimulate SLAP healing at the biceps anchor on the glenoid.

QUESTION 3. Which one of the following rehabilitation techniques should be avoided in the patient who is 2 weeks postoperative from the surgical repair of a SLAP lesion?

A. Active assisted elevation in the scapular plane.
B. Passive forearm pronation.
C. Passive external rotation at 90° of abduction
D. Open chain passive elbow flexion
E. Passive assisted elevation in the scapular plane

QUESTION 4. Which of the following rehabilitation exercises is most appropriate immediately following the repair of a SLAP repair?

A. Passive external rotation at 90° of abduction
B. Isotonic rotator cuff strengthening
C. Isokinetic resistive elbow flexion
D. Passive and active assisted flexion in scapular plane
E. Concentric latissimus pull down exercises

QUESTION 5. The goal of sport-specific, Phase III training after SLAP repair is:

A. On-time and in-season return to competition.
B. Progresses through a generic exercise program applicable to every athlete.
C. Induces appropriate, progressive stresses to the tissue minimizing the risk of reinjury.
D. The single most important rehabilitation tool, regardless of progress through prior rehab stages.

Answer Key

QUESTION 1. Correct answer: **C** (see Introduction)

QUESTION 2. Correct answer: **D** (see Part I: Program Design).

QUESTION 3. Correct answer: **C** (see Part I: Rotator Cuff Strength)

QUESTION 4. Correct answer: **D** (see Part I: Program Design).

QUESTION 5. Correct answer: **C** (see Sport-Specific Training)

Chapter 5



Biceps Tendon Disorders

INTRODUCTION

Brian Armstrong, MPT, and Eric C. Hall, MS, ATC, CSCS

Epidemiology

- The proximal biceps tendon is a primary source of anterior shoulder pain.
- Proximal biceps tendon injuries are more often present in the older population in conjunction with rotator cuff disease, anterior impingement, or glenohumeral instability.
- Isolated proximal biceps tendon injuries are more common in patients 18 to 35 years of age involved in specific sports.
- Proximal biceps tendon injuries are more prevalent in males due to the nature of male sports and the general manual labor requirements in the working population.
- Tendon rupture is most common in males in their sixth and seventh decades of life.
- Several studies demonstrate a low incidence of isolated bicep tendon injuries.
- Primary biceps tendinitis accounts for only 5% of all biceps tendon injuries.
- The injury typically occurs in sports such as tennis, gymnastics, badminton, squash, volleyball, weight lifting, canoeing, fencing, golfing, boxing, and all sports that require repetitive overhead throwing.
- Specific positions in which the injury occurs are pitchers in baseball and softball, quarterbacks in football, javelin throwers, outside hitters in volleyball.

Pathophysiology

- The long head of the biceps tendon (LHBT) originates from the superior glenoid rim and the superior labrum. It then exits the glenohumeral joint and passes through the rotator interval, arches over the humeral head and passes through the intertubercular groove (Figure5-1).
- The proximal tendon is richly innervated with sensory nerve fibers containing substance P and calcitonin, thus a major reason for a primary source of anterior shoulder pain.
- The tendon is stabilized by a tendinoligamentous sling consisting of the coracohumeral ligament, superior glenohumeral ligament, fibers from the supraspinatus, and fibers from the subscapularis (Figure 5-2).
- Once in the bicipital groove, the tendon passes under the transverse humeral ligament. The bicipital groove will vary in depth, width, and angle of the walls. A shallow groove may be present in those with LHBT instability.
- The function of the proximal biceps tendon is not completely understood and is somewhat controversial. Neer proposed that the tendon depresses the humeral head with contraction. Andrews et al. noted that contraction of the biceps leads to compression of the glenohumeral (GH) joint. Others feel that the tendon may provide passive stability to the joint by acting as a physical block against certain motions.
- Neer first described anterior impingement syndrome where subacromial spurs were shown to cause degenerative wear on both the rotator cuff and the biceps tendon.
- Proximal biceps tendon injuries can be classified into three different categories:

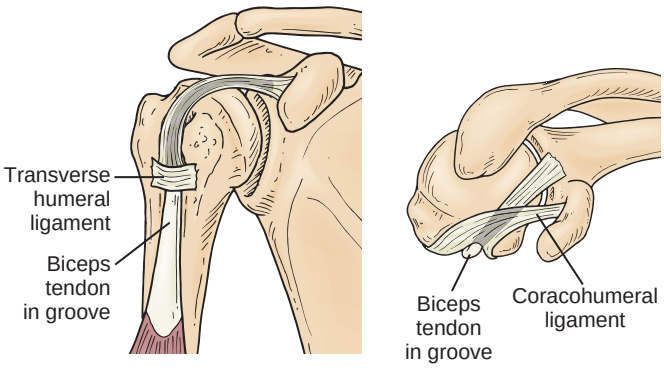

FIGURE 5-1. Anatomy of the proximal biceps tendon. *(Redrawn from Krishnan S, Hawkins R, Warren R: The shoulder and the overhead athlete, Philadelphia, 2004, Lippincott Williams & Wilkins.)*

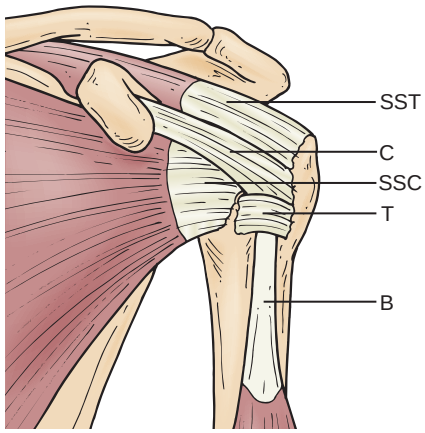

FIGURE 5-2. Anatomy of the tendinoligamentous sling. *B,* long head of biceps brachii tendon; *C,* coracohumeral ligament; *SSC,* subscapularis tendon; *SST,* supraspinatus tendon; *T,* transverse humeral ligament. *(Redrawn from Morag Y, Jacobson J, Shields G, et al: MR arthrography of rotator interval, long head of the biceps brachii, and biceps pulley of the shoulder. Radiology 235:21-30, 2005. Available at http://radiology.rsna.org/content/235/1/21.full)*

  - Tendinopathy: biceps tendinitis, tenosynovitis, and tendinosis
  - Instability: tendon dislocation and subluxation
  - Rupture: most often occurring within the bicipital groove
- Biceps tendinitis is a common diagnosis but is typically a misnomer because most athletes who are having pain typically have already gone through the inflammation stages and are now experiencing tendon sheath inflammation and tendon degeneration—a tendinosis condition.
- Tendinopathies are typically derived from overuse injuries, impingement syndromes, and glenohumeral instability.
- Instability of the biceps tendon can result from a tear in the tendinoligamentous sling, a tear in the transverse ligament, or a shallow bicipital groove.
- Ruptures of the biceps tendon typically occur with traumatic events or with an excessive eccentric load. Oftentimes a rupture follows a long course of tendon degeneration and shoulder pain. When a tendon ruptures in this way, it often results in relief of pain.

Intrinsic Factors

- Subacromial impingement
- Coracoacromial impingement
- Anterior glenohumeral instability
- Rotator cuff weakness

Extrinsic Factors

- Repetitive anterior shear stresses to the shoulder as with the pitching motion, bowling, volleyball, and the tennis swing can lead to stretching of anterior soft tissues, eventually leading to increased glenohumeral instability causing impingement of anterior structures.
- Furthermore, increased anterior translation can lead to internal impingement of the posterior rotator cuff, causing fraying of the posterior cuff fibers. Once anterior structures are stretched and posterior cuff fibers are compromised, increased loads are placed on the bicep anchor, possibly leading to a SLAP (superior labrum anterior and posterior) tear.
- The term *peel-back mechanism* is often used to describe the forces on the labrum and proximal bicep tendon with overhead throwing motion. This has been compared to the way one might pull a weed out of the ground by tugging at it in different directions.
- With throwing, a large eccentric load is placed through the bicep to decelerate elbow extension speeds of approximately 2200 degrees/second.

Traumatic Factors

- Traumatic rupture of the proximal biceps tendon is rare.
- Rupture incidents are most common in the middle-aged to older active population with underlying biceps and rotator cuff pathologies.
- Mechanisms of injury typically involve high intensity eccentric loads on the biceps muscle and tendon.
- Sports that have been found to have the most incidents of biceps tendon ruptures are gymnastics, wrestling, arm wrestling, boxing, and bodybuilding/weightlifting.

Histopathological Findings

- Systemic diseases that specifically cause deterioration of a tendon are rare.
- Foreign bodies that directly cause tendon deterioration are slightly more common, but represent less than 10% of all tendon injuries.
- Overuse injuries are typically the most frequent cause of tendon injuries.
  - Repetitive intense physical use of a tendon, specifically repetitive eccentric loads, causes continuous microtrauma and does not allow for sufficient rest and recovery between tendon use.
  - Poor circulation in and around a tendon in conjunction with increased tendon activity can lead to poor oxygenation and tendon nutrition. This explains why a more sedentary subject may be predisposed to tendon injury when participating in infrequent intense physical activity.

Clinical Presentation and Examination

History

- Normally there is no specific mechanism of injury, but some sort of repetitive overhead activity will be involved.
- Subjects with tendinopathy typically describe difficulty with warming up, a brief period of pain-free activity, increasing pain late with activity, and then stiffness and/or achiness after activity.



FIGURE 5-3. Popeye deformity. *(From From Wysocki RW, Verma NN: Distal biceps repair. In Cole BJ, Sekiya JK, editors: Surgical techniques of the shoulder, elbow, and knee in sports medicine. Philadelphia: 2008, Saunders, p. 401, with permission.)*

Physical Examination

- Tendon rupture
  - Obvious deformity, called a "Popeye" deformity. When the proximal tendon ruptures, the tendon will typically retract distally causing an obvious bulge of muscle tissue, and bruising anteriorly (Figure 5-3).
  - When a rupture occurs, most patients present with initial acute pain from the trauma of the incident, but soon after notice an overall relief of anterior shoulder pain that may have been present from chronic biceps tendon pathology.
- Tendon instability
  - Often presents with an audible or palpable "snap" in a specific arc of motion, such as with turning the steering wheel of a car or moving from an adducted and internally rotated position to an abducted and externally rotated position.
- Tendinopathy
  - Pain is typically located within the bicipital groove and sometimes radiates toward the deltoid insertion. Since most biceps tendinopathies are accompanied by impingement, glenohumeral instability, and/or rotator cuff disorders, the pain is most often diffuse over the anterior shoulder.
  - Pain is intensified with anterior impingement positions.

Abnormal Findings

- Point tenderness over the proximal biceps tendon should rotate laterally with glenohumeral ER. This technique is helpful in differentiating between other soft tissue structures that should not move with glenohumeral external rotation (ER).
- Positive special tests
  - O'Brien's active compression test
  - Speed's test
  - Yergason's test
  - Ludington's test
  - Lift-off test: test the integrity of the subscapularis
  - Jobe's relocation test: test for anterior GH instability
  - Biceps instability test.

Imaging

- Plain-film radiographs: often read as normal in the instance of proximal biceps tendinitis, but may reveal supporting evidence of anterior impingement, glenohumeral arthritis, or a shallow bicipital groove.
- Ultrasonography: cost effective and easily tolerated. Very useful in detecting abnormalities of the biceps tendon.
- Magnetic resonance imaging: a noninvasive study that is an excellent imaging modality for soft tissue structures. Sometimes used with a contrast dye (invasive) to better evaluate tissue structure.
- Arthroscopy: the best method to visually evaluate the integrity of the tendon in vivo
- Electrodiagnostic testing: In rare situations, neurological disorders may cause pain that mimics that of a biceps tendon disorder.

Differential Diagnosis

- Rotator cuff pathology: specifically with the subscapularis
  - Positive lift-off test reveals possible subscapularis injury
  - Weakness and/or pain with resisted ER/IR at 0 degrees of abduction
- Glenohumeral instability/labral pathology
  - Positive Jobe's relocation test reveals possible glenohumeral instability
  - Possible history of traumatic injury
  - Pain with repetitive activities involving extreme end ranges of motion, as with overhead throwing
- Subacromial impingement syndrome: Positive impingement tests can result in pain at the anterior shoulder.

Treatment

Nonoperative Management

- Conservative treatment
  - Rest, ice, antiinflammatory medication for evidence of an inflamed tendon
  - Once acute pain is resolved, physical therapy should be started.
    - This should involve gradual progressions of ROM exercises, scapular stabilization and movement correction exercises, progressing to posterior rotator cuff stretching and strengthening progressions, general upper body conditioning, then to sport-specific/activity-specific functional progressions.
- Steroid injections: sometimes used to facilitate the prescribed rehabilitation program
- Subacromial injections: often used to treat both primary and secondary tendinitis. Again, only used when there is evidence of tendon inflammation.

Guidelines for Choosing Among the Nonsurgical Treatment Options

- Patient is likely to be compliant with a rehabilitation program.
- Patient generally does not require repetitive overhead activity or other repetitive physical activity requiring use of the biceps. Most often middle-aged and older adults.

Surgical Indications

- Consistent pain and spasms following a consistent course of physical therapy
- Young and physically active patient requiring repetitive elbow flexion, supination, and shoulder flexion activities
- Biceps rupture patient to whom cosmetic appearance is important

Guidelines for Choosing Among the Surgical Treatment Options

- Age
- Physical activity level
- Type of physical activity
- Value of cosmetic appearance
- Compliance probability

Evidence

Ahmad C, ElAttrache N: Arthroscopic biceps tenodesis. *Orthop Clin North Am* 34:499–506, 2003.

The purpose of this article was to study the effects of an arthroscopic biceps tenodesis procedure. The authors found the tenodesis procedure has advantages over tenotomy by maintaining length-tension relationships, elbow flexion and forearm supination strength, maintenance of muscle tone, and prevention of deformity. The authors' note the type of procedures necessary will vary depending on other existing shoulder conditions and that further studies and long term follow up is needed to better evaluate the outcomes of these procedures. (Level III Evidence)

Churgay C: Diagnosis and treatment of biceps tendinitis and tendinosis. *Am Fam Physician* 80:470–476, 2009.

The purpose of this paper was to review the anatomy and physiology, and discuss different diagnosis techniques and treatment options available for biceps tendinopathies. The author concentrates on physical examination findings that help the practitioner perform a differential diagnosis along with the use of diagnostic imaging techniques. (Level V evidence)

Ejnisman B, Monteiro G, Andreolie C: Disorder of the long head of the biceps tendon. *Br J Sports Med* 44:347–354, 2010.

This paper recognizes the continuous debates on the function, diagnosis, and treatment of the long head of the biceps tendon disorders. The purpose of this paper was to review and discuss the anatomy, function, pathology, clinical manifestation, physical examination, imaging, and treatment of disorders of the long head of the biceps tendon. (Level V evidence)

Elser F, Braun S, Dewing C: Anatomy, function, injuries, and treatment of the long head of the biceps brachii tendon. *Arthroscopy* 27:581–592, 2011.

This article offers a current review of anatomy and biomechanical properties of the long head of the biceps tendon and provides an evidence-based approach to present treatment strategies for LHBT disorders. The authors suggest there is poor evidence to explain the exact role of the biceps tendon on the shoulder joint. Until the function of the LHB can be better defined, it is hard to argue cases for all types of surgical interventions. (Level V evidence)

Kelly A, Drakos M, Fealy S: Arthroscopic release of the long head of the biceps tendon. *Am J Sports Med* 33:208–213, 2005.

This study consisted of 40 patients who underwent arthroscopic release of the long head of the biceps tendon as an isolated procedure or part of a concomitant shoulder procedure and were followed for 2 years. Results revealed that 100% of patients had no pain in the biceps tendon at rest, 95% had no pain with palpation in the bicipital groove, and only 38% reported pain with fatigue and discomfort following resisted elbow flexion. Clinical relevance of this study suggests that this procedure may be an acceptable intervention for a specifically selected group of individuals. (Level II evidence)

Krupp R, Kevern M, Gaines M: Long head of the biceps tendon pain: Differential diagnosis and treatment. *J Orthop Sports Phys Ther* 39:55–70, 2009.

The purpose of this manuscript was to review the current anatomical, functional, and clinical information regarding the long head of the biceps tendon, including conservative treatment, surgical treatment, and postsurgical rehabilitation programs. Controversy exists regarding the exact function the LHBT has at the glenohumeral joint, and whether or not to perform tenotomy or tenodesis when surgical intervention is necessary. They conclude that removal of the biceps tendon is beneficial as the loss of its function on the GH joint is much less detrimental than retaining a diseased tendon. (Level V evidence)

Paynter K: Disorders of the long head of the biceps tendon. *Phys Med Rehab Clin N Am* 15:511–528, 2004.

This article reviews the anatomy, pathology, function, clinical evaluation, and treatment of disorders of the long head of the biceps tendon. They stress the importance of proper terminology of tendon disorders to improve dialogue between clinicians, which will help overall care. They suggest conservative care is often the most recommended course of treatment and is often sufficient in gaining acceptable outcomes. However, they also note when conservative care is not successful, surgical intervention is necessary for favorable outcomes. (Level V evidence)

Szabo I, Boileau P, Walch GL: The proximal biceps as a pain generator and results of tenotomy. *Sports Med Arthrosc* 16:180–186, 2008.

This article studies the role the proximal bicep tendon plays as a pain generator with rotator cuff pathologies. In their two studies, the authors found that in cases where rotator cuff repairs are not possible and/or desirable, arthroscopic biceps tenotomy and tenodesis yields favorable clinical results in the treatment of full thickness rotator cuff tears. (Level III evidence)

Multiple-Choice Questions

QUESTION 1. Which choice below is not a tendinopathy disorder?

A. Tendinitis
B. Tendinosis
C. Bicep muscle strain
D. Tenosynovitis

QUESTION 2. What are common intrinsic factors that lead to biceps tendon injuries?

A. Subacromial impingement
B. Rotator cuff weakness
C. Coracoacromial impingement
D. All of the above

QUESTION 3. Which sport below is least likely to play a role in proximal biceps tendon injury?

A. Soccer
B. Baseball
C. Boxing
D. Bowling

QUESTION 4. What is a common differential diagnosis for proximal biceps tendon injuries?

A. AC sprain
B. SLAP tear
C. Humeral stress fracture
D. Stingers

QUESTION 5. Which treatment below is often considered when conservative treatments for primary biceps tendinitis have failed?

A. Sling
B. Postural correction
C. Static stretches
D. Tendon sheath injection

Answer Key

QUESTION 1. Correct answer: **C** (see Pathophysiology)

QUESTION 2. Correct answer: **D** (see Pathophysiology)

QUESTION 3. Correct answer: **A** (see Epidemiology and Extrinsic Factors)

QUESTION 4. Correct answer: **B** (see Differential Diagnosis)

QUESTION 5. Correct answer: **D** (see Nonsurgical Treatment Options)

NONOPERATIVE REHABILITATION OF LONG HEAD OF BICEPS TENDINITIS/TENDINOSIS

Brian Armstrong, MPT, and Eric C. Hall, MS, ATC, CSCS

GUIDING PRINCIPLES OF NONOPERATIVE REHABILITATION

- Nonoperative treatment should be based on the recognition and accurate classification of the biceps pathology.[1,2,3]
- Differential diagnosis is critical to a successful outcome–tendinitis vs. tendinosis[2,4,5]
- Patient should follow an individual criterion-based rehabilitation program with attention placed on response to treatment in terms of changes in pain, swelling, or motion.[6]
- Any comprehensive rehabilitation program following biceps injury should focus on restoring dynamic stability to the shoulder.[3,6]

Phase I (Weeks 1 to 3): Acute Phase

Treatment for Pain/Swelling

- Clinical modalities as needed:
  - Disposable iontophoresis patch (Figure 5-4).[4]
  - Electrotherapy: low-frequency transcutaneous electrical nerve stimulation
  - Ultrasound (biceps tendinosis)
  - Laser
  - Phonophoresis
- Cryotherapy: ice massage
- Oral pain medications as needed
- Subacromial injection[5]
- Heat (biceps tendinosis)
- Rest
- Patient education:
  - Withdrawal from aggravating activities
  - Avoidance of reaching and lifting overhead
  - Proper posture during sitting/sleeping



FIGURE 5-4. Disposable iontophoresis patch. *(Empi Medical, St. Paul, MN).*

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Apply glenohumeral, sternoclavicular, and scapulothoracic joint mobilizations to restrictive capsular tissues (grades I/II/III).
- Manual glenohumeral joint range of motion
- Thoracic and cervical spine mobilizations/manipulations

Soft Tissue Techniques for Biceps Tendinosis

- Cross-friction massage

Stretching/Flexibility Techniques for the Musculotendinous Unit

- Rope-and-pulley
- Wand stretching, passive range of motion, flexion and external rotation (Figure 5-5)
- Posterior capsule stretching—cross-arm stretch or sleeper stretch[4]
- Self-stretches-upper trapezius, levator scapulae, and pectoralis minor stretching
- Biceps tendinitis—frequent bouts of light range-of-motion/stretching/flexibility exercises during inflammatory stage[5]

Other Therapeutic Exercises

- Leg strengthening exercises
- Low-intensity cardiovascular conditioning activities such as Stairmaster, stationary bike riding, running in the pool, elliptical (without use of upper extremity), or treadmill walking.
- Core stability exercises

Techniques to Increase Muscle Strength, Power, and Endurance

- Early scapular strengthening, scapular stabilization with emphasis on low/mid trapezius.[7]
- Modified isometrics: arm below 90° and abduction 45°[8]

Neuromuscular Dynamic Stability Exercises

- Utilize biofeedback to increase neuromuscular control of scapular musculature.[9]

Milestones for Progression to the Next Phase

- Restoration of full passive range of motion
- Restoration of normal accessary motion
- Decreased signs of inflammation: no discomfort at rest and no warmth felt upon palpation[9]
- Good tolerance of Phase I program

Phase II (Weeks 4 to 8): Subacute Phase, Active Range of Motion, Early Strengthening

Treatment for Pain/Swelling

- Cryotherapy, ice massage
- Clinical modalities as needed
- Continue activity modification, modification of aggravating activities

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Progressive glenohumeral, scapulothoracic, and sternoclavicular joint mobilizations as needed (grades II/III/IV)
- Manual glenohumeral range of motion
- Pectoralis stretching

Soft Tissue Techniques for Biceps Tendinosis

- Transverse friction massage

Stretching/Flexibility Techniques for the Musculotendinous Unit

- Active assisted to active range of motion exercises
  - Flexion, abduction, external rotation and internal rotation

TIMELINE 5-1 **Nonoperative Rehabilitation of Long Head of Biceps Tendinitis/Tendinosis**

PHASE I (weeks 1 to 3)	PHASE II (weeks 4 to 8)
• Cryotherapy: ice massage	• Cryotherapy
• Heat/cross-friction massage (biceps tendinosis)	• PT modalities
• PT modalities	• Activity modification
• Patient education about activity modification	• Progressive GH/ST/SC joint mobilizations (grade II-IV)
• GH/ST/SC joint mobilizations (grade I-III)	• AAROM exercises
• Thoracic and cervical spine mobilizations/manipulations	• Self-stretches: anterior, posterior, inferior capsule
• Active assistive Codman's exercises	• Submaximal biceps curls with dumbbells: eccentric for biceps tendinosis
• Passive ROM/wand/rope-and-pulley exercises	• TBS/TAS/TLS activities as recommended and tolerated
• Posterior capsule stretching	• Scapular exercises with PNF
• Self-stretches: upper trapezius, levator scapulae, pectoralis minor	• PNF diagonals
• Modified isometrics	• Rotator cuff strengthening: R/ER, scaption, prone I/T/Y/W
• Scapular neuromuscular control: biofeedback	



FIGURE 5-5. Wand flexion, wand ER at 0° of abduction, and wand ER in the scapular plane.

- Self-stretches for anterior, posterior, and inferior capsule
- Rhomboid and latissimus dorsi stretching

Muscle Activation of Primary Muscles Involved

- Submaximal bicep curls with dumbbells (eccentric for biceps tendinosis[4])

Techniques to Increase Muscle Strength, Power, and Endurance

- Begin rotator cuff strengthening[6,7]
  - Theraband-internal rotation and external rotation
  - Scaption
  - Prone I,T,Y,W (Figure 5-6)
- Submaximal triceps kickback
- Dumbbell forearm exercises
- Scapular protraction/retraction exercises[10]

TIMELINE 5-1 **Nonoperative Rehabilitation of Long Head of Biceps Tendinitis/Tendinosis** (Continued)

PHASE III (weeks 6 to 12)	PHASE IV (weeks 10 to 16)
• PT modalities as needed • PROM (full) • Mobilizations as needed • TBS/TAS/TLS activities as recommended and tolerated • Scapular exercises: push-up progression and prone rowing • TAS: biceps/triceps PREs • GH joint exercises: PREs • Rotator cuff exercises: isotonic dumbbell strengthening • Thrower's 10 • PNF exercises: bodyblade • OKC rhythmic stabilization exercises • CKC exercises • CKC manual perturbation exercises • Upper-body ergometer	• PROM (full) • Mobilizations as needed • TBS/TAS/TLS activities as recommended and tolerated • Initiate upper-body gym strengthening program (modified) • Scapular exercises: PREs • TAS: biceps/triceps PREs • GH joint exercises: PREs • Rotator cuff exercises: PREs • Thrower's 10: progress intensity • Plyometrics: two-arm progressing to one-arm • PNF exercises • OKC rhythmic stabilization exercises • CKC exercises • CKC manual perturbation exercises • Overhead strengthening exercises • Begin sport-specific exercises • Overhead throwing athletes can begin and progress through an interval program

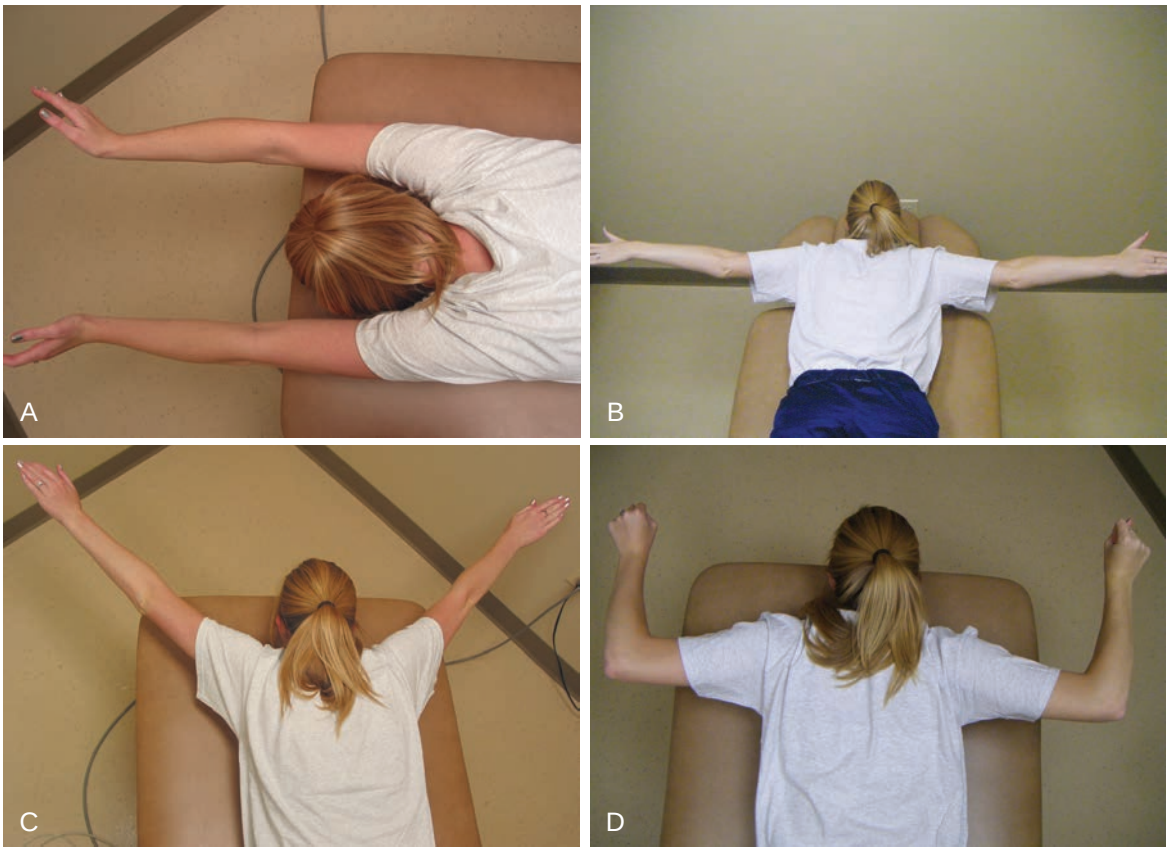

FIGURE 5-6. Prone I/T/Y/W exercise with scapular retraction.

Neuromuscular Dynamic Stability Exercises

- Initiate neuromuscular control exercises:[11]
  - Scapular stabilization with submaximal proprioceptive neuromuscular facilitation (PNF)
  - Diagonal I (DI) and diagonal II (DII) PNF pulley
  - Scapular clock (Figure 5-7)

Milestones for Progression to the Next Phase

- Restoration of normal active assisted range of motion
- No symptoms during activities of daily living
- Improved muscular performance

Phase III (Weeks 6 to 12): Progressive Exercise Stage

Treatment for Pain/Swelling

- Cryotherapy as needed

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Aggressive joint mobilizations, if needed

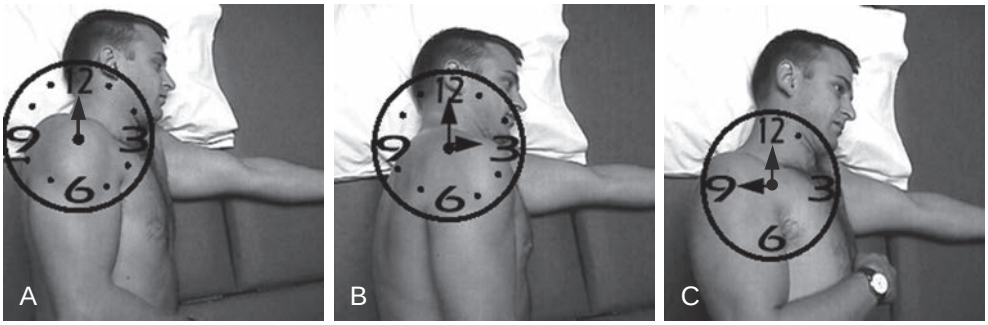

FIGURE 5-7. Scapular clock to promote neuromuscular reeducation (12 o'clock/3 o'clock/9 o'clock).



FIGURE 5-8. Rhythmic stabilizations at 90/120/60° of flexion.

Stretching/Flexibility Techniques for the Musculotendinous Unit

- Continue self-capsular stretching
- Aggressive wand ROM in all planes

Other Therapeutic Exercises

- Initiate upper body ergometer for endurance

Muscle Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Advance biceps dumbbell strengthening

Techniques to Increase Muscle Strength, Power, and Endurance

- Initiate isotonic dumbbell strengthening program[12]
  - Side-lying external rotation
  - Prone extension and horizontal abduction in external rotation
  - Standing scaption and flexion
- Scapular strength: push-up progression and rowing
- Initiate "Thrower's 10" program[5]

Neuromuscular Dynamic Stability Exercises

- Advance shoulder/scapular PNF
- Initiate shoulder and scapular rhythmic stabilizations (Figure 5-8).[4,11]
  - Isometric to dynamic
  - Slow to fast
  - Multiple direction
- Manual scapular resistance (Figure 5-9)
- Standing body blade (Figure 5-10).[11]
  - Can initiate PNF patterns

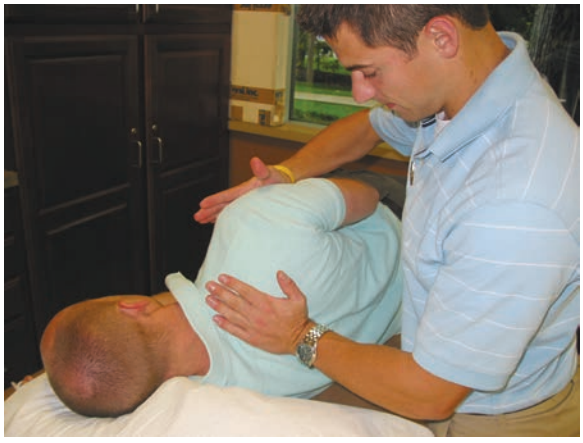

FIGURE 5-9. Manual side-lying scapular resistance.



FIGURE 5-10. Bodyblade at 90° of abduction/adduction and 90° of flexion/extension to promote neuromuscular dynamic stability.

Milestones for Progression to the Next Phase

- Full, nonpainful ROM
- No pain or tenderness
- Continued improved muscular performance

Phase IV (Weeks 10 to 16): Advanced Strengthening/Return to Activity Phase

Treatment for Pain/Swelling

- Cryotherapy as needed

Techniques for Progressive Increase in Range of Motion

Stretching/Flexibility Techniques for the Musculotendinous Unit

- Self-capsular stretching to maintain capsular mobility/ROM

Other Therapeutic Exercises

- Initiate upper body gym strengthening program (modified to avoid positions of impingement).[3,11,13]
  - Minimize overhead activities
  - Keeps hands within eyesight

Muscle Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Continued advancement of biceps strengthening

Techniques to Increase Muscle Strength, Power, and Endurance

- Advance isotonic rotator cuff dumbbell program
- Push up progression

Neuromuscular Dynamic Stability Exercises

- Advance scapular PNF exercises
- Resisted PNF patterns
- Advance rhythmic stabilization in all planes

Plyometrics

- Initiate plyometric exercises (Figure 5-11)[14]
  - Duplicate the explosive dynamics of overhead athletes
  - Progress from 2-arm to 1-arm

Sport-Specific Exercises

- Initiate Interval Functional Progression Program:[9]
  - Throwing
  - Golf
  - Tennis

Milestones for Progression to Advanced Sport-Specific Training and Conditioning

- Full, nonpainful ROM
- No pain or tenderness



FIGURE 5-11. Plyometric weighted ball toss against wall in 90/90 position.

- Satisfactory clinical exam
- Satisfactory strength evaluation (manual muscle testing and/or isokinetic testing 5% to 10% greater than nondominant side)
- Adequate dynamic stabilization and muscular endurance as measured by isokinetic testing and closed kinetic chain (CKC) functional testing for sport-specific actions to analyze muscle performance and activation characteristics

Criteria for Abandoning Nonoperative Treatment and Proceeding to Surgery or Other More Invasive Intervention

- No improvement after 3 to 6 months of a comprehensive rehabilitation program
- Plateau in recovery at an undesirable level of function

Transition to Performance Enhancement: Tips and Guidelines

Before transitioning to performance enhancement, the patient must have met criteria to return to play during the rehabilitation progression. An interval sport program that progressively applies more forces to the healing structures and gradually returns the athlete to full athletic competition as quickly and safely as possible must be completed. For sport-specific rehabilitation programs to be successful, the entire body must be reeducated in a stepwise fashion to perform the various activities related to the sport.

Performance Enhancement and Beyond Rehab: Training/Trainer and Optimization of Athletic Performance

- Maintenance program
  - Flexibility exercises, self-capsular stretches
  - Isotonic exercises, rotator cuff/total arm strengthening (TAS)
  - Theratubing exercises, IR/ER 90/90 position, D2 PNF pattern
  - Serratus pushups
- Optimize specific sport/occupational biomechanics to performance.
- Continue enhancing strength and conditioning parameters that improve power and performance related to activity.
- Need for a supervised and structured off-season, preseason, and in-season training regime.

Specific Criteria for Return to Sports Participation

- Full, nonpainful ROM
- Satisfactory clinical exam and isokinetic strength test
- Clearance from MD
- Adequate dynamic stabilization and muscular endurance as measured by isokinetic testing and sport-specific CKC testing
- Completion of interval sport program or functional progression to sport/activity

Evidence

Cohen B, Romeo A, Bach B, Jr: Shoulder injuries. In Brotzman S, Wilk K, editors: *Clinical orthopaedic rehabilitation*, ed 2, Philadelphia, 2003, Mosby, pp 125–250.

This chapter gives evidence-based rehabilitation protocols and exercise programs for various shoulder injuries. Included is the rehabilitation protocol for nonoperative management of biceps tendinitis/tendinosis. Throughout the chapter several "tricks" and "pearls" are provided to assist the clinician in the rehabilitation process.

Ellenbecker T, Cools A: Rehabilitation of shoulder impingement syndrome and rotator cuff injuries: an evidence-based review. *Br J Sports Med* 44(5):319–327, 2010.

This article presents an evidence-based review of the key treatment strategies to rehabilitate and restore shoulder function of the athlete with rotator cuff impingement and biceps tendon disorders. (Level V Evidence)

Hsu A, Ghodadra N: Biceps tenotomy versus tenodesis: A review of clinical outcomes and biomechanical results. *J Shoulder Elbow Surg* 20(2):326–332, 2011.

The purpose of this review was to analyze tenotomy vs tenodesis in incidence of cosmetic deformity and load to tendon failure for each technique. The review also provided clinical outcomes and available literature to clarify the evidence-based strength and weaknesses of each procedure to provide general guidelines for when to use each treatment. (Level III Evidence)

Krupp R, Kevern M, Gaines M, et al: Long head of the biceps tendon pain: Differential diagnosis and treatment. *J Orthop Sports Phys Ther* 39(2):55–70, 2009.

The purpose of this manuscript was to review current evidence-based anatomical, functional, and clinical information regarding the long head of biceps tendon, including conservative treatment, surgical treatment, and postsurgical rehabilitation regimens. (Level V evidence)

Ott J, William C, Wilk K: Soft tissue injuries of the shoulder. In Wilk K, Reinold M, Andrews J, editors: *The athlete's shoulder*, ed 2, Philadelphia PA, 2009, Elsevier, pp 283–292.

The purpose of this chapter was to provide the latest evidence-based research regarding soft tissue injuries about the shoulder, including information regarding biceps tendon injuries. An evidence-based nonoperative rehabilitation approach is given based on the diagnosis of biceps tendinitis or tendinosis.

Reinold M, Escamilla R, Wilk K: Current concepts in the scientific and clinical rationale behind exercises for glenohumeral and scapulothoracic musculature. *J Orthop Sports Phys Ther* 39(2):105–117, 2009.

The purpose of this extensive review was to provide the clinician with a thorough overview of the available literature relevant to develop a safe, effective, and appropriate exercise program for injury rehabilitation and prevention of the glenohumeral and scapulothoracic joints. (Level V evidence)

Ryu J, Pedowitz R: Rehabilitation of biceps tendon disorders in athletes. *Clin Sports Med* 29:229–246, 2010.

This article focuses on nonsurgical rehabilitation and postoperative rehabilitation of biceps tendon injuries. The article provides a review of the function, anatomy, and pathology of the biceps. Evidence-based research is provided in guiding a patient though a comprehensive rehabilitation program. (Level V Evidence)

Swanik KA, Lephart SM, Swanik CB, et al: The effects of shoulder plyometric training on proprioception and selected muscle performance characteristics. *J Shoulder Elbow Surg* 11:579–586, 2002.

The purpose of this study was to determine the effect of plyometric training of the shoulder internal rotators on proprioception, kinesthesia, and selected muscle performance characteristics in female swimmers. This study suggests that plyometric activities may facilitate neural adaptations that enhance proprioception, kinesthesia, and muscle performance characteristics. Significant neuromuscular benefits may be attained if they are implemented earlier into shoulder rehabilitation programs. (Level III evidence)

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Multiple-Choice Questions

QUESTION 1. During what phase of rehabilitation do you begin active assisted/active range of motion exercises?

A. Phase I
B. Phase II
C. Phase III
D. Phase IV

QUESTION 2. What must be achieved for progression to Phase IV?

A. Full, nonpainful ROM
B. No, pain or tenderness
C. Satisfactory clinical exam
D. All the above

QUESTION 3. When treating biceps tendinosis during what phase of rehabilitation is it appropriate to begin cross-friction massage?

A. Phase I
B. Phase II
C. Phase III
D. Phase IV

QUESTION 4. Which exercise would be inappropriate to perform upper extremity strengthening in the gym during phase IV rehabilitation?

A. Eccentric bicep curls
B. Triceps kick backs
C. Military bench press
D. Scaption

QUESTION 5. During what phase of rehabilitation would it be appropriate to initiate the upper body ergometer for endurance?

A. Phase I
B. Phase II
C. Phase III
D. Phase IV

Answer Key

QUESTION 1. Correct answer: **B** (see Phase II Rehabilitation)

QUESTION 2. Correct answer: **B** (see Phase III Rehabilitation)

QUESTION 3. Correct answer: **A** (see Phase I rehabilitation)

QUESTION 4. Correct answer: **C** (see Phase IV rehabilitation)

QUESTION 5. Correct answer: **C** (see Phase III Rehabilitation)

POSTOPERATIVE REHABILITATION AFTER BICEPS TENOTOMY AND TENODESIS

Brian Armstrong, MPT, Eric C. Hall, MS, ATC, CSCS, and Peter Sallay, MD

Indications for Surgical Treatment

- Failure of nonoperative management for 3 to 6 months that included rest, rehabilitation, antiinflammatory medication, and/or cortisone injection failure[1]
- Failed adequate shoulder decompression and continues to have pure shoulder pain consistent with biceps tendinitis[2-6]
- Significant chronic long head of biceps dysfunction along it length or from its labral attachment[7]
- Cosmetic: patient does not accept "Popeye deformity"
- Indication for biceps tenodesis: greater than 25% to 50% partial-thickness tear of tendon, subluxation, disruption of the bicipital groove or soft tissue stabilizers, chronic atrophy of the tendon[4,8-10]

Brief Summary of Surgical Technique

Major Surgical Steps

- A posterior portal is used for visualization, and routine diagnostic arthroscopic examination is performed. An anterolateral working portal is used for instrumentation (Figure 5-12).
- Biceps tenotomy is performed by sectioning the tendon at its origin at the supraglenoid tubercle and superior labrum. The tendon is allowed to retract out of the glenohumeral joint.[6,11-15]
  - An associated acromioplasty can be performed in patients with an anterior acromial spur.
  - The superior labrum and biceps stump are then examined for further lesions.
  - Unstable flaps at the superior stump that could potentially cause mechanical irritation are debrided with an arthroscopic shaver.
- Biceps tenodesis may be performed open or arthroscopically with interference screw fixation to bone, keyhole fixation to bone, suture anchor fixation, and suture fixation to adjacent tissue.[3,16-22]
  - The biceps proximal attachment on the superior labrum is released. The residual stump on the superior labrum is debrided to a stable and smooth margin.
  - The open method involves a unicortical hole placed approximately 1 cm distal to the proximal aspect of the bicipital groove created in the floor of the groove. The biceps tendon is then inserted into the newly created hole. An interference screw is the inserted and secured until it is flush with the humeral cortex.[17]
    - A similar technique can be done using an interference screw system (Biotenodesis Screw, Arthrex, Naples, FL).[21]
  - A mini-open incision/arthroscopic procedure can be done in the deltopectoral interval by splitting the deltoid. The tendon is released arthroscopically and retrieved at the entry point into the joint. A locking stitch is placed in the free end after excising the intraarticular portion. The anchor is then seated, and the attached sutures are used to secure the biceps tendon. The free ends of the locking suture are then used to reinforce the tenodesis by sewing to the rotator interval capsule or to the tissue overlying the bicipital groove.[17]
    - A soft tissue tenodesis can be performed in the same manner as an anchor technique. The tendon is secured using the locking suture but without anchoring it to bone.[20]
  - When performed arthroscopically a unicortical hole is placed in the proximal portion of the bicipital groove and the transected end of the biceps tendon is inserted into the newly created hole. A screw is introduced and secured until it is flush with the bottom of the groove.[18,19]

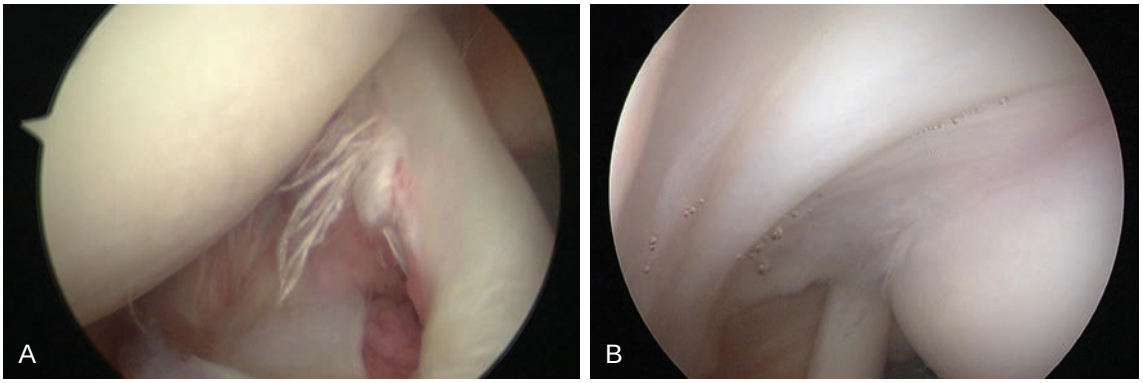

FIGURE 5-12. A, A posterior portal is used for visualization, and routine diagnostic arthroscopic examination is performed. **B,** An anterolateral working portal is used for instrumentation.

- The purpose of this procedure is to anchor the biceps tendon at a new location so that complete rupture and its consequences, that is, deformity and weakness, can be prevented.
- With all of these procedures, it is critical to obtain the correct length-tension relationship of the LHBT to preserve strength, function, and cosmesis.

Factors That May Affect Rehabilitation

- Biceps tenotomy is commonly used in older, low-demand individuals or in those who are unable to comply with immediate postoperative restrictions.
- Advantages of tenotomy are:
  - Technical simplicity
  - Shorter and less complex rehabilitation time
  - Accelerated return to daily activities
- Biceps tenodesis is appropriate in young, athletic, active individuals.
- In relation to tenotomy, the advantages of tenodesis include
  - Minimal to no loss of elbow flexion and supination strength
  - Less risk of postoperative cramping
  - No associated "Popeye" deformity
- Disadvantages include
  - More complex operation
  - A period of postoperative immobilization
  - Lengthier rehabilitation
  - Possible wound problems and rare chance of nerve injury

Other Surgical Techniques and Options

- Arthroscopic debridement of the biceps long head tendon
  - Suggested for partial tears, including delamination and fraying that involves less than 25% of the tendon in young, active patients or less than 50% of the tendon in older, sedentary patients[2,10]
  - Can begin an aggressive rehabilitation program during the first postoperative week
  - Usually accompanied by a decompression of subacromial soft tissue alone in younger patients
- Subacromial decompression
  - May be done arthroscopically or open to address tendinopathy of the biceps secondary to "impingement syndrome."[23,24]
  - Rehabilitation is advanced as rapidly as pain and swelling/inflammation allow
- Type II and IV superior labrum from anterior to posterior (SLAP) tears[2,25-27]
  - Type II SLAP tears have a detached biceps anchor and therefore require stabilization.
  - Type IV SLAP tears include a bucket-handle portion of the labrum that extends into the biceps tendon.
    - If the tendon is not too degenerative and the tear involves less than 30% to 40% of the tendon anchor, the tendon can be simply debrided and the superior labrum either debrided or reattached, provided the flap is large enough.
    - Although controversial and no clear tendon tear size exists for tendon repair, if more than 40% of the tendon is involved, a side-to-side repair is performed along with treatment of the labrum.

TIMELINE 5-2 **Postoperative Rehabilitation After Biceps Tenotomy/Tenodesis**

PHASE I (weeks 0 to 2)	PHASE II (weeks 2 to 6)
• Sling (biceps tenotomy patients will wear for discomfort and be weaned off as symptoms decrease) • PT modalities: IFC stim and TENS • PROM exercises in all planes for shoulder with elbow slightly bent/elbow/forearm • Active assistive Codman's exercises • Cryotherapy • Seated scapular retractions • Cervical ROM exercises • Gripping exercises	• Sling (d/c use as tolerated) • PT modalities: IFC and TENS as needed • Cryotherapy for pain and inflammation • Progress shoulder PROM to AAROM to AROM exercises in all planes as tolerated • Lawn chair progression/wand exercises/table slides in flexion/pulley flexion and scaption/wall climb • Begin posterior capsule stretching as needed: side-lying IR stretch and cross-body adduction stretch • Active elbow flexion and extension • Active forearm supination/pronation • Submaximal isometrics with arm at side • Scapular exercises: prone row/active punches (protraction/retraction)

- In cases in which the biceps origin is more significantly damaged of if there is a great deal of degeneration of the tendon, biceps tenodesis or tenotomy offers a better option to direct repair.
- Postoperative rehabilitation following SLAP repair is determined by the type of SLAP lesion, the surgical procedure performed (debridement vs. repair), and other concomitant pathology.[27]
  - Generally, the patient's shoulder is immobilized for a period of time, followed by emphasis on restoring motion and, lastly, initiating strengthening exercises.
  - In cases in which the biceps is resected, biceps muscular contractions typically begin between 6 and 8 weeks postoperative.
  - In cases in which the biceps is repaired, no resisted biceps activities are allowed for at least 3 months following surgery.

Phase I (first 14 days): Immediate Postoperative Period[1]

Goals

- Decrease pain and inflammation.
- Achieve gradual restoration of passive range of motion (PROM).
- Allow healing of soft tissue.
- Prevent negative effects of immobilization (biceps tenodesis).
- Enhance scapular function.

[1]*The pre-habilitation outline is included in the nonoperative treatment section of this chapter.*

Clinical Pearl

During Phase I rehabilitation there are differences in the management of biceps tenotomy compared with tenodesis; therefore patient education is critical. Biceps tenotomy rehabilitation is more aggressive and advances at a quicker pace, whereas rehabilitation following biceps tenodesis progresses more slowly to protect the biceps tendon. The patient must be instructed on several behavioral and activity modifications to help protect the repair and ensure an optimal outcome.

Protection

- Sling for 2 to 4 weeks (removed two to three times per day in order to perform exercises).
- Sling must be worn during sleep.
- Biceps tenotomy patients will use sling just for discomfort and wean off as symptoms decrease.
- Avoid shoulder extension beyond the plane of the body; sleep with towel under elbow.
- No excessive external rotation (ER) range of motion (ROM) stretching.
- No shoulder active range of motion (AROM), lifting of objects, and active or active assistive biceps contraction.
- Limit terminal motion.

TIMELINE 5-2 Postoperative Rehabilitation After Biceps Tenotomy/Tenodesis (Continued)

PHASE III (weeks 6 to 10)	PHASE IV	
	(weeks 10 to 14)	(weeks 14 to 24)
• D/C sling • PT modalities as needed • Cryotherapy as needed • PROM/AROM exercises (full for shoulder/elbow/forearm) • Mobilizations as needed • Focus on incorporation of the entire kinetic chain (lower extremity/trunk/shoulder) • Scapular exercises: PREs • TAS: begin biceps/triceps/forearm supination/pronation PREs starting with very light resistance • GH joint exercises: PREs (high repetition-low resistance) • Rotator cuff exercises: PREs • PNF exercises • OKC rhythmic stabilization exercises (Bodyblade) • CKC exercises • CKC manual perturbation exercises	• PT modalities as needed • PROM/AROM (full, nonpainful) • Mobilizations as needed • TBS/TAS/TLS activities as recommended and tolerated • Scapular exercises: PREs • TAS: biceps/triceps PREs • GH joint exercises: PREs • Rotator cuff exercises: PREs • Thrower's 10 • PNF exercises • OKC rhythmic stabilization exercises • CKC exercises • CKC manual perturbation exercises • Plyometrics: two-arm progressing to one-arm • Initiate upper extremity weightlifting program (emphasize large muscle groups) • Begin sport-specific exercises • Overhead athletes can begin interval throwing progression • Nonathletes can initiate endurance program	• PROM (maintain full motion) • Mobilizations as needed • TBS/TAS/TLS activities as recommended and tolerated • Scapular exercises: PREs • TAS: biceps/triceps PREs • GH joint exercises: PREs • Rotator cuff exercises: PREs • Thrower's 10 progress intensity • PNF exercises • OKC rhythmic stabilization exercises • CKC exercises • CKC manual perturbation exercises • Plyometrics: two-arm progressing to one-arm 90/90 plyos • Overhead strengthening exercises • Sport-specific exercises progressed • Overhead throwing athletes complete an interval throwing program • Return to sport

Management of Pain and Swelling

- Cryotherapy
- Use of home transcutaneous electrical nerve stimulation (TENS) unit
- Oral pain medications
- Therapeutic modalities: electrotherapy stimulation, TENS
- Patient education: using pillows and bolsters to find a position of comfort to reduce stress on repaired structures of the shoulder
- Manual therapy treatments to decrease spasms

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Glenohumeral, sternoclavicular, and scapulothoracic mobilizations as indicated
- Begin manual shoulder PROM in all planes to tolerance.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Codman's pendulum exercise
- PROM elbow flexion/extension and forearm supination/pronation
- AROM wrist/hand
- Cervical ROM
- Shoulder PROM in all planes with elbow slightly bent

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Shoulder shrugs with elbow bent
- Gripping (ball squeezes)

Neuromuscular Dynamic Stability Exercises

- Scapular PNF techniques
- Scapular retraction and clock exercises with elbow bent

Milestones for Progression to the Next Phase

- Appropriate healing of surgical incision
- 80% PROM (full PROM for biceps tenotomy) of shoulder and elbow compared to non-involved side
- No increase in pain/swelling after treatments
- Completion of Phase I activities without pain

Phase II (weeks 2 to 6 postop)

Goals

- Minimize shoulder pain and inflammatory response.
- Gain full PROM of shoulder.
- Achieve gradual restoration of AROM.
- Wean off of the sling by the end of postoperative weeks 2 to 4.
- Increase activity tolerance and work-related tasks.

Clinical Pearl

A key rehabilitation exercise used during Phase II is the lawn chair progression. This rehabilitation exercise allows transitioning from supine PROM/active assisted range of motion (AAROM)/AROM to a more functional AROM exercise sitting upright. If any upper trapezius activation is taking place, side-lying shoulder flexion is a good alternative exercise. Once side-lying shoulder flexion is achieved correctly, the lawn chair progression should be initiated.[28]

Protection

- Discontinue use of sling as tolerated.
- Continue patient education: posture, joint protection, positioning, activity/behavioral modification.

Management of Pain and Swelling

- Continued cryotherapy for pain and inflammation
- Oral pain medications as needed.
- Electrotherapy (TENS and IFC) as needed

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Manual PROM in all planes to patient tolerance with emphasis on obtaining full PROM
- Glenohumeral, sternoclavicular, and scapulothoracic joint mobilizations as needed

Soft Tissue Techniques

- Scar massage if necessary

Stretching and Flexibility Techniques for the Musculotendinous Unit

Progress shoulder PROM to AAROM and AROM in all planes to patient tolerance—wand exercises, table slides in flexion, pulley flexion/scaption, wall climb

- Lawn chair progression for shoulder (Figure 5-13)
- Begin incorporating posterior capsule stretching as needed—side-lying internal rotation stretch (sleeper stretch) and cross-body adduction stretch (Figure 5-14)
- May begin light lower extremity strengthening
- Core stability exercises

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Active elbow flexion/extension and forearm supination/pronation—full ROM allowed

Techniques to Increase Muscle Strength, Power, and Endurance

- Submaximal isometrics with the arm at the side for rotator cuff or deltoid strengthening (Figure 5-15)
- Manual scapular resistive exercises—scapular protraction, retraction, and depression in side lying with a towel roll or pillow between arm and body [29]

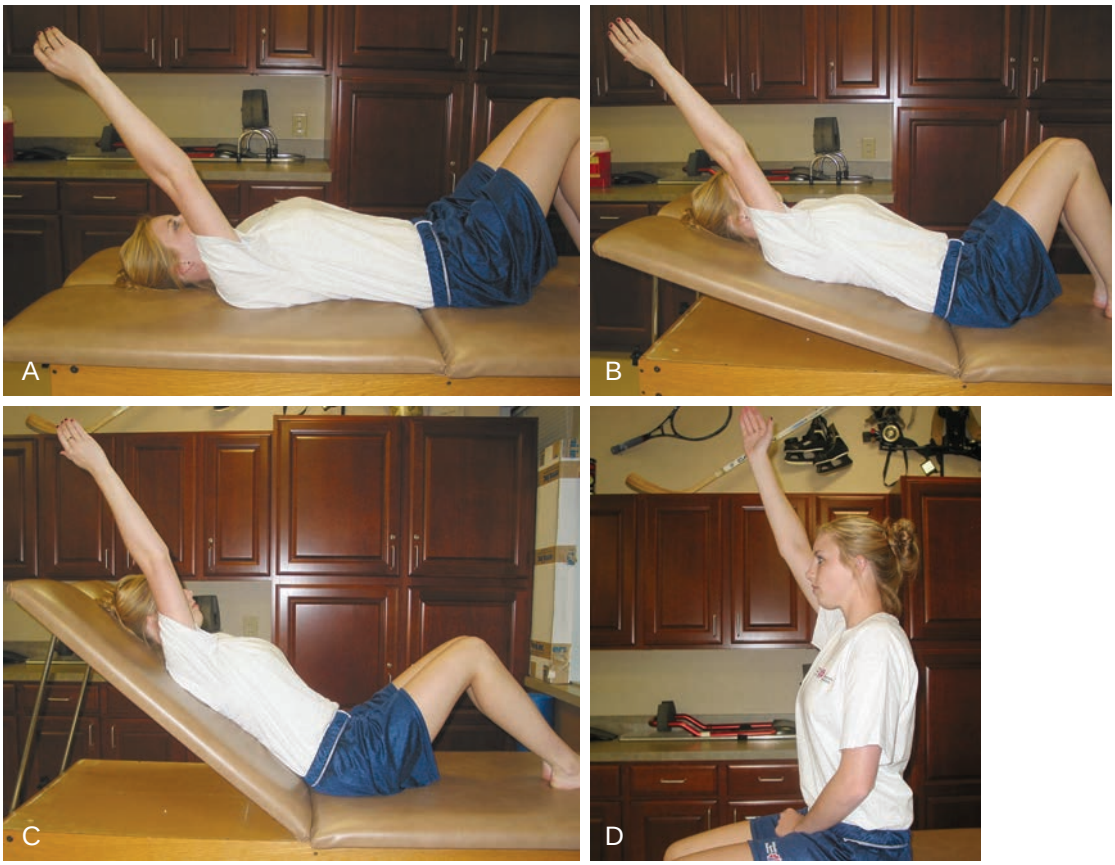

FIGURE 5-13. Lawn chair range of motion exercise progression from supine to sitting.

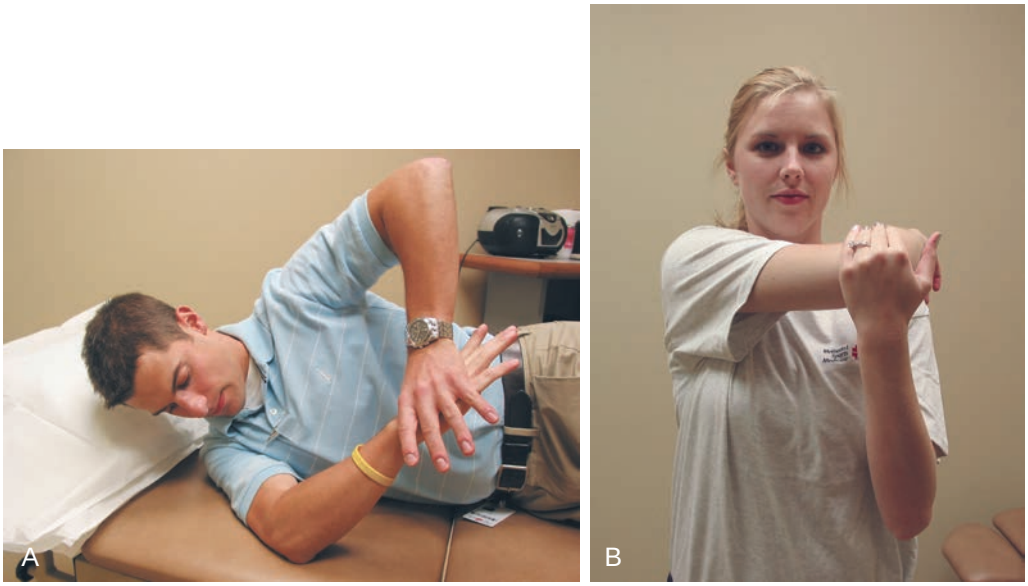

FIGURE 5-14. Sleeper stretch done in scapular plane (**A**) and in cross-body adduction (**B**) for posterior capsule stretching. Cross-body adduction can be done in a door frame to control scapular positioning.



FIGURE 5-15. Submaximal isometric flexion (**A**), abduction (**B**), internal rotation (**C**), and external rotation (**D**) with arm against side.

- Active punches—scapular protraction and retraction[30]
- Prone row and extension by side

Neuromuscular Dynamic Stability Exercises

- Advance scapular PNF exercises
- Rhythmic stabilizations, ER/IR with arm supported, 90° of flexion

Milestones for Progression to the Next Phase

- Restore full AROM of shoulder and elbow
- Appropriate scapular posture at rest and scapulohumeral rhythm with ROM and functional activities
- Completion of Phase II activities without pain

Phase III (weeks 6 to 10 postop)

Goals

- Increase strength, endurance, and neuromuscular control
- Normalize arthrokinematics

Clinical Pearl

Proprioception and neuromuscular re-education exercises are important during Phase III to counteract the inhibitory effects that pain and inflammation have on the rotator cuff and scapular stabilizers. Neuromuscular re-education exercises should include multijoint and multiplanar endurance exercises. Proper scapular stabilization will provide a stable base for glenohumeral joint movement, as well as maintain optimal length-tension relationships for the rotator cuff muscles.[29-33]

Management of Pain and Swelling

- Continued cryotherapy for pain and inflammation as needed

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Continue PROM and glenohumeral, sternoclavicular, and scapulothoracic mobilizations if needed.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Continue A/PROM of shoulder and elbow as needed/indicated.

Other Therapeutic Exercises

- Strengthening exercises should focus on incorporation of the entire kinetic chain, including coordinated lower extremity, trunk, and shoulder movements in multiple planes.[31,34]

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Initiate biceps curls with light resistance, progress as tolerated.
- Initiate resisted supination/pronation.[35]

Techniques to Increase Muscle Strength, Power, and Endurance

- Gain muscular endurance with high repetition (30 to 40) and low resistance (1 to 3 lb).
- Initiate standing Thera-Band strengthening exercises—ER/IR with towel between arm and body, extension and rows to the plane of the body.
- Initiate resisted side-lying ER with towel roll—weighted and manual resistance (light).
- Progress prone rotator cuff strengthening program—progress prone horizontal abduction from palm down to thumb up. Prone rowing at 30/45/90 degrees of abduction to neutral arm position.[34]
- Isotonic active flexion/scaption/abduction/D2 to standing when able to perform without shoulder hiking. Limit flexion/scaption/abduction to 90° and make sure thumb is up to avoid impingement.[34,36]
- Push-up plus exercise with emphasis on serratus (wall, counter, knees on floor, floor)
- Initiate Throwers 10 Program for overhead athletes.

Neuromuscular Dynamic Stability Exercises

- Body blade rhythmic stabilization exercises at varying shoulder/elbow positions
- Rhythmic stabilizations—ER/IR in the scapular plane and flexion/extension/abduction/adduction at various angles of elevation

Milestones for Progression to the Next Phase

- Full nonpainful ROM
- Good scapulohumeral rhythm
- Appropriate rotator cuff and scapular muscular performance (4/5 or better)
- Completion of Phase III activities with minimal pain

Phase IV (weeks 10 to 14 postop)

Goals

- Improve muscular strength, endurance, power, and stability
- Optimize neuromuscular control and dynamic shoulder stability
- Initiate interval or functional progressions to return to sport
- Initiate functional activities and gradually return to full functional activity
- Athletes—return to previous level of sport participation

Clinical Pearl

> The increased risk for impingement outweighs the potential benefits of heavy resistance strengthening exercises in positions above 90° of elevation or long lever arms. Exercises with longer level arms and exercises above 90° arm elevation are used for muscle endurance and neuromuscular re-education only.[28,31,32]

Management of Pain and Swelling

- Cryotherapy as needed

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Glenohumeral and scapulothoracic mobilizations as needed

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Continue P/AROM of shoulder/elbow as needed.

Other Therapeutic Exercises

- Progressive return to upper extremity weight lifting program emphasizing the larger, primary upper extremity muscles (deltoid, latissimus dorsi, pectoralis major).

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Advance biceps/supination strengthening as tolerated.

Techniques to Increase Muscle Strength, Power, and Endurance

- Progress previous strengthening program—continue to increase resistance with isotonics if patient does not

demonstrate compensatory strategies, is not painful, and has no residual soreness.
- Focus exercises on eccentric strengthening of posterior rotator cuff and scapular muscles.[34]
- Nonathletes initiate endurance program that simulates desired work activities/requirements.

Plyometrics

- Plyometric exercises should be chosen individually for each athlete based on sport-specific demands.
- Plyometric exercises are advance from two-arm, short-lever-arm activities below 90° of arm elevation to single-arm long-lever-arm activities above 90° of elevation.[37]

Sport-Specific Exercises

- Initiate appropriate interval throwing, pitching, tennis, and golf program as appropriate.

Criteria for Return to Sport

General

- Clearance from treating surgeon
- No complaints of pain
- Isokinetic test that fulfills criteria to throw: minimum of 90% (side-to-side) symmetry on isokinetic testing and ER/IR ratio of at least 70%
- Normal ROM, strength, and endurance of rotator cuff and scapular musculature as compared with hand-held dynamotor and/or isokinetic test in comparison with noninvolved upper extremity
- Compliance with continued home exercise program
- Successful completion of functional progression back to sport specifics—interval throwing/pitching, tennis, and golf programs.

Overhead Throwing

- Need to have normal scapulothoracic and glenohumeral mechanics with full AROM.
- Minimum of 90% (side-to-side) symmetry on isokinetic testing and ER/IR ratio at least 70%
- Completion of functional interval throwing program specific to player's position (see The Methodist Sports Medicine Center's Functional Throwing Progression and Functional Mound Progression protocols in Boxes 5-1 and 5-2).

Golf

- Golfer needs to have full, nonpainful shoulder range of motion, a satisfactory clinical examination, normal strength measures for the rotator cuff and scapular musculature, and appropriate progression with rehabilitation program.

BOX 5-1 The Methodist Sports Medicine Center Functional Throwing Progression

The purpose of the throwing progression is to gradually allow the athlete to increase the intensity of throwing while minimizing the chance for a re-occurrence of injury. The athlete must follow the intensity and number of throws closely to help prevent the chance for re-injury and to properly condition the arm and the entire body. The athlete can progress from one level to the next as long as no pain occurs and proper throwing mechanics can be maintained throughout the phase. If pain occurs or if there's a breakdown of throwing mechanics, then the progression should be backed off, and then resumed as able.

Before throwing, the athlete must partake in an appropriate warmup routine. This should consist of whole body movements that will increase the heart rate and increase blood flow. Light stretching before throwing is optional. The athlete should start throwing at the shorter distances and work their way up to the workout distance. When at 75 ft and further, a step and throw technique should be used to help incorporate the lower body. Following throwing, the athlete should perform any strengthening and stretching exercises as prescribed, along with optional ice application.

A. 30-Foot Phase: Perform 3x Week at a Light Intensity

WEEK 1	WEEK 2
Warmup 15 throws at 30 feet Perform strengthening and stretching Ice	Warmup 25 throws at 30 feet Perform strengthening and stretching Ice

B. 45-Foot Phase: Perform 3x Week at a Light Intensity

WEEK 3	WEEK 4
Warmup 15 throws at 30 feet 15 throws at 45 feet Perform strengthening and stretching Ice	Warmup 15 throws at 30 feet 15 throws at 45 feet Rest 5 minutes 10 throws at 30 feet 10 throws at 45 feet Perform strengthening and stretching Ice

BOX 5-1 The Methodist Sports Medicine Center Functional Throwing Progression *(Continued)*

C. 60-Foot Phase: Perform 3x Week at a Light to Medium Intensity

WEEK 5	WEEK 6
Warmup 15 throws at 30 feet 15 throws at 45 feet 10 throws at 60 feet Perform strengthening and stretching Ice	Warmup 15 throws at 30 feet 10 throws at 45 feet 10 throws at 60 feet Rest 5 minutes 10 throws at 30 feet 10 throws at 45 feet 10 throws at 60 feet Perform strengthening and stretching Ice

D. 75-Foot Phase: Perform 3x Week at a Medium Intensity

WEEK 7	WEEK 8
Warmup 15 to 20 throws 30 to 60 feet 15 throws at 60 feet 10 throws at 75 feet Perform strengthening and stretching Ice	Warmup 15 to 20 throws at 30 to 60 feet 10 throws at 60 feet 10 throws at 75 feet Rest 5 minutes Warmup throwing (15 throws 30 to 60 feet) 10 throws at 60 feet 10 throws at 75 feet Perform strengthening and stretching

E. 90-Foot Phase: Perform 3x Week at a Medium to High Intensity

WEEK 9	WEEK 10
Warmup 10 throws at 30 to 45 feet 10 throws at 45 feet 10 throws at 60 feet 10 throws at 75 feet 10 throws at 90 feet Perform strengthening and stretching	Warmup 10 throws at 30 to 45 feet 10 throws at 45 to 60 feet 10 throws at 60 to 75 feet 10 throws at 75 feet 10 throws at 90 feet Rest 5 minutes 10 throws at 30 to 45 feet 10 throws at 45 to 60 feet 10 throws at 60 to 75 feet 10 throws at 75 to 90 feet 10 throws at 90 feet Perform strengthening and stretching

F. 110-Foot Phase: Perform 3x Week at a High Intensity

WEEK 11	WEEK 12
Warmup 15 throws at 30 to 60 feet 10 throws at 60 to 75 feet 10 throws at 75 to 90 feet 10 throws at 90 feet 15 throws at 110 feet	Warmup 15 throws at 30 to 60 feet 10 throws at 60 to 75 feet 10 throws at 75 to 90 feet 10 throws at 90 to 100 feet 20 throws at 110 feet

G. 120-Foot Phase: Perform 3x Week at a High Intensity

WEEK 13	WEEK 14
Warmup 20 throws at 30 to 75 feet 10 throws at 75 to 90 feet 10 throws at 90 to 110 feet 10 throws at 110 to 120 feet 10 throws at 120 feet Perform strengthening and stretching	Warmup 20 throws at 30 to 75 feet 10 throws at 75 to 90 feet 10 throws at 90 to 110 feet 15 throws at 110 feet 20 throws at 120 feet Perform strengthening and stretching

BOX 5-2 The Methodist Sports Medicine Center Functional Mound Progression

The purpose of the mound progression is to gradually allow the athlete to increase the intensity of throwing while minimizing the chance for a re-occurrence of injury. The flat ground phase is used to help the athlete work on mechanics, different pitch types, and to regain confidence before throwing off the mound. All major mechanical flaws should be corrected before moving to the mound. Before throwing, the athlete must partake in an appropriate warmup routine. Light stretching before throwing is optional. The warmup step for each phase will differ from person to person. For some this may consist of long toss, for others this may be throwing to 100 feet, then coming back in to 60 feet. Follow the prescribed number of throws closely because this is designed to help increase strength and endurance. All throwing with the exception of the warmup and long toss should be done with the catcher down in a squat position. Last, be sure to perform the prescribed strengthening and stretching exercises after you throw. As always, never progress to the next phase if there is pain or mechanical issues.

Flat Ground Portion

Day 1 Fastball only—light intensity: 20 to 25 pitches
Day 2 Day off
Day 3 Fastball only—light intensity: 25 to 30 pitches
Day 4 Day off (may long toss up to 120 feet, no more than 20 throws at 120 feet)
Day 5 Day off
Day 6 Fastball only: 15 pitches light intensity; 15 pitches medium intensity
Day 7 Day off
Day 8 Fastball only: 15 pitches at light intensity; 20 pitches at medium intensity
Day 9 Day off
Day 10 Fastballs: 20 pitches at medium intensity
Change-ups: 15 pitches at light to medium intensity
Day 11 Day off (may long toss up to 120 feet, no more than 20 throws at 120 feet)
Day 12 Day off
Day 13 Fastballs: 15 pitches at medium-high intensity
Change-ups: 10 pitches at medium intensity
Breaking balls: 10 pitches at light intensity
Day 14 Day off

Move to the Mound

Day 15 Fastballs: 30 to 45 pitches at light intensity
Day 16 Day off
Day 17 Fastballs: 15 to 20 pitches at light
Day 18 Day off (may play long toss up to a maximum of 120 feet no more than 15 to 20 throws at 120 feet)
Day 19 Fastballs: 15 to 20 pitches up to medium intensity; 10 pitches at medium-high
Change-ups: 10 pitches at medium intensity
Day 20 Day off (may have a light catch, no more than 15 to 20 throws at 90 feet)
Day 21 Fastballs: 10 pitches at medium intensity; 10 pitches at medium-high intensity; 10 pitches at high intensity
Change-ups: 10 pitches at medium intensity
Breaking balls: 10 pitches at medium intensity
Day 22 Day off (may have a light catch, no more than 15 to 20 throws at 90 feet)
Day 23 Fastballs: 15 pitches at high intensity
Change-ups: 15 pitches at high intensity
Breaking balls: 10 pitches at medium intensity
Day 24 Day off (may have a light catch, no more than 15 to 20 throws at 90 feet)
Day 25 Fastballs: 20 pitches at high intensity
Change-ups: 10 pitches at high intensity
Breaking balls: 10 pitches at high intensity
Day 26 Day off (may have a light catch, no more than 5 to 20 throws at 120 feet)
Day 27 Fastballs: 30 pitches at high intensity
Change-ups: 10 pitches at high intensity
Breaking balls: 10 at high intensity
Day 28 Day off (may have a light catch, no more than 15 to 20 throws at 90 feet)
Day 29 Live batting practice 40 to 45 pitches mixing in change-ups and breaking balls at a high intensity
Day 30 Day off (may have a light catch, no more than 15 to 20 throws at 90 feet)
Day 31 Simulated game consisting of three innings up to 50 pitches total mixing in change-ups and Breaking balls with 5-minute rest periods between innings
Day 32 Day off, rest and recover

Pitcher may return to games if no pain or problems exist at this time. The athlete needs to take into account the number of pitches and innings he or she has built the arm and body up to at this time. It is recommended to start with a pitch count of 50/game and no more than 25/inning. Additional rest between outings or not pitching back to back days may also need to be figured in initially upon returning to games.

Summary of the Golfer's Program

- Warm-up: general, dynamic and golf specific progression before play
- General strength and neuromuscular training: squat dominant, upper body push, lunge, upper body pull, shoulder-specific rehabilitation and training
- Stability and core training: golf-specific and shoulder-specific flexibility training
- Plyometric training and cardiovascular training
- Interval golf program will gradually reintroduce the stresses of the golf swing and help the golfer gradually restore the normal biomechanics of the golf swing.

After Return to Sport

Continuing Fitness or Rehabilitation Exercises

- Strengthening of biceps/triceps, rotator cuff, deltoid, and scapular stabilizers should be performed 2 to 3× per week and advanced as tolerated
- Maintenance of dynamic neuromuscular control—strength, mobility, and proprioception
- Endurance program advanced as necessary
- Continue stretching and flexibility rehabilitation exercises

Exercises and Other Techniques for Prevention of Recurrent Injury

- Maintenance of appropriate rotator cuff/scapular stabilization musculature specific to overhead athletes—"Throwers 10" program
- Core stabilization exercise training

Evidence

Ellenbecker T, Cools A: Rehabilitation of shoulder impingement syndrome and rotator cuff injuries: An evidence-based review. *Br J Sports Med* 44:319–327, 2010.

This manuscript provides a thorough review on evidence-based clinical rehabilitation exercises and their inherent objective muscular activity characteristics to guide clinicians in the development of an individualized rehabilitation program for treatment of the patient with shoulder impingement. (Level II evidence)

Hsu A, Ghodara N, Provencher M, et al: Biceps tenotomy versus tenodesis: A review of clinical outcomes and biomechanical results. *J Shoulder Elbow Surg*. 20:326–332, 2011.

The purpose of this review was to analyze research on biceps tenotomy vs. tenodesis in incidence of cosmetic deformity and load to tendon failure for each technique. The results of this review demonstrated a higher incidence of cosmetic deformity in patients treated with biceps tenotomy, with an associated lower load failure compared with patients treated with biceps tenodesis. Complications were similar for each treatment, with a higher likelihood of bicipital pain associated with tenodesis. Individual patient factors and needs should guide surgeons on whether to use tenotomy or tenodesis. (Level III evidence)

Kelly A, Drakos M, Fealy S, et al: Arthroscopic release of the long head of the biceps tendon: Functional outcome and clinical results. *Am J Sports Med* 33(2):208–213, 2005.

This case series 44 patients were evaluated the clinical and functional outcomes of arthroscopic release of the long head of the biceps tendon. At 2 years the American Shoulder and Elbow Surgeons scores were 75.6. 68% were rated as good, very good or excellent. No patient reported arm pain at rest distally or proximally. Tenotomy may be an acceptable surgical intervention for a specific cohort of individuals. (Level III evidence)

Krupp R, Kevern M, Gaines M, et al: Long head of the biceps tendon pain: Differential diagnosis and treatment. *J Orthop Sports Phys Ther* 39(2):55–70, 2009.

The purpose of this manuscript was to review current evidence-based anatomic, functional, and clinical information regarding the long head of biceps tendon, including conservative treatment, surgical treatment, and postsurgical rehabilitation regimens. (Level II evidence)

Mazzocca A, Bicos J, Santangelo S, et al: The biomechanical evaluation of four fixation techniques for proximal biceps tenodesis. *Arthroscopy: J Arthroscop Rel Surg* 21(11):1296–1306, 2005.

The purpose of this study was to compare the cyclic displacement and ultimate failure strength of four proximal bicep tendon tenodesis fixation methods: the open subpectoral bone tunnel biceps tenodesis, the arthroscopic interference screw technique, the open subpectoral interference screw fixation technique, and the arthroscopic suture anchor tenodesis. Out of 22 fresh-frozen cadaver shoulders the subpectoral bone tunnel biceps tenodesis group showed statistically significant greater displacement than other tenodesis methods. There were no statistically significant differences in ultimate failure strength between any of the biceps tenodesis methods tested. (Level II evidence)

Reinold M, Escamilla R, Wilk K: Current concepts in the scientific and clinical rationale behind exercises for glenohumeral and scapulothoracic musculature. *J Orthop Sports Phys Ther* 39(2):105–117, 2009.

The purpose of this extensive review was to provide the clinician with a thorough overview of the available literature relevant to develop a safe, effective, and appropriate exercise program for injury rehabilitation and prevention of the glenohumeral and scapulothoracic joints. (Level II evidence)

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Multiple Choice Questions

QUESTION 1. During what phase of rehabilitation is the lawn chair progression most appropriate?

A. Phase I
B. Phase II
C. Phase III
D. Phase IV

QUESTION 2. What are current indications for a biceps tenodesis?

A. Young athletic individual who requires supination and elbow flexion strength
B. Chronic atrophy/dysfunction of the biceps tendon
C. Patient does not accept "Popeye" deformity
D. All of the above

QUESTION 3. During what phase of rehabilitation can you begin active elbow flexion following a biceps tenodesis?

A. Phase I
B. Phase II
C. Phase III
D. Phase IV

QUESTION 4. During what phase of rehabilitation can you begin plyometrics following a biceps tenodesis?

A. Phase I
B. Phase II
C. Phase III
D. Phase IV

QUESTION 5. When should full AROM of the shoulder and elbow be achieved following a biceps tenotomy?

A. 2 weeks
B. 4 weeks
C. 6 weeks
D. 8 weeks

Answer Key

QUESTION 1. Correct answer: **B** (see postoperative Phase II rehabilitation)

QUESTION 2. Correct answer: **D** (see Indications for Surgical Treatment)

QUESTION 3. Correct answer: **B** (see postoperative Phase II rehabilitation)

QUESTION 4. Correct answer: **D** (see postoperative Phase IV rehabilitation)

QUESTION 5. Correct answer: **B** (see postoperative Phase I rehabilitation)

BEYOND BASIC REHABILITATION: RETURNING TO WEIGHTLIFTING AFTER BICEPS TENODESIS

Brian Armstrong, MPT, and Eric C. Hall, MS, ATC, CSCS

Introduction

Aspects of Weight Lifting that Require Special Attention in Rehabilitation

- Power – the ability to generate force in a brief amount of time
- Strength – the ability to produce maximal force
- Coordination – the ability to generate proper muscle firing patterns to manipulate joint motion
- Flexibility – the ability to move a joint in the desired range of motion.
- Proper balance of joint stability and mobility[1,2]

Biceps Tenodesis in the Weightlifter: Key Aspects

- Biceps injuries alone are not the most frequent injuries among the serious weightlifting population, but are very frequently involved with other comorbidities within the shoulder complex. Common physical adaptations that occur with the serious weightlifting population are increased muscle mass, decreased flexibility, and decreased strength, all three of which can lead to impingement syndromes, a common cause of proximal biceps tendon injury.[3-5]
- Kolber et al. reported in their review that 36% of all documented resistance training injuries occurred within the shoulder complex.[6]
- Andrews and McLeod reported that out of 297 athletes who underwent shoulder arthroscopy for anterior shoulder pain, 13 had pain related to weightlifting.[7]
- Cope et al. reported that approximately 50% of all biceps ruptures involve the long head of the muscle. In three reported case studies of bodybuilders, they note that one patient admitted to use of anabolic steroids. In this industry, use of various types of steroids are common, and along with that comes tendon ruptures.[8]

Return to Weightlifting After Biceps Tenodesis: Literature

- In the Cope et al. case studies described, all three cases involved tenodesis as their course of treatment for a biceps rupture. At 6 months postoperatively, all three patients exhibited equal strength and power bilaterally and returned to their preinjury levels of weightlifting.[8]
- Ahmad and ElAttrache performed a review of tenodesis procedures and reported that this procedure has certain advantages over the biceps tenotomy procedure, such as proper maintenance of length-tension relationship, prevention of muscle atrophy, maintenance of elbow flexion and supination strength, and avoidance of cramping sensations and deformity.[9]
- In the event of failed conservative treatment for proximal biceps tendon disorders, an arthroscopic release of the tendon is a common treatment option. In a study by Kelly et al., it was found that 38% of their subjects who underwent an arthroscopic release had early fatigue and discomfort with resistance exercises. They do not advocate this procedure for heavy lifters or those who frequently perform resistance activities of the biceps muscle.[10]

Advanced Strength and Conditioning Programs

Periodization

The strategy of periodization should be based on the level of the athlete and the constraints of the competitive season. When returning to weightlifting following a shoulder injury, one must consider how to manipulate volume loads, progress from general basic lifts to more multijoint explosive movements, and dissipate fatigue.[2,11]

- Linear and undulating—depends on the goals, the desired finished product, and the scheduling demands of the athlete
  - Linear programs are more step by step in nature. An athlete may train for one specific adaptation within one microcycle, then train for another adaptation in the next microcycle, and so forth.
  - Undulating (Nonlinear)—consists of variations of training techniques within a given week or microcycle. An athlete may train for more than one specific adaptation during this time period.[1,2]
- Macrocycles—specifically geared to help an athlete peak at the most important competition within the calendar year

Table 5-1 Integrated Periodization for a Power Sport

Months	1	2	3	4	5	6	7	8	9	10	11	12
Training phases	Preparatory					Competitive					PS	Transition
Subphases	*General*		*Specific*		*PC*	*League Competition*						*Transition*
Strength	Anato-mical adapta-tion	Max stre-ngth	Power	Max stren-gth	Conversion	Maintenance						Compensation

PC, precompetition; PS, postseason (playoffs, finals, championships)
Data from references 1, 2, 11, 13, and 24.

- Mesocycles—can last anywhere from weeks to months, depending on the preferred structure for the individual. Often times scheduled accordingly with smaller preparatory competitions throughout the calendar year.
- Microcycles—utilized to vary exercise frequency, volume, and intensity to achieve the desired responses of performance gains.[1,2,11,12]
- See Table 5-1 for an example of a periodization table for a strength and power sport.

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- The first thing to look at is the athletes' base level of function. How far have they gotten with their formal rehabilitation program? It is common now for athletes to start to incorporate sport-specific training principals prior to their full release or clearance from their doctor and physical therapist.
- The certified athletic trainer (ATC) and the certified strength and conditioning specialist (CSCS) are appropriate professionals to help bridge this gap from rehabilitation to sport. Good communication and a good working relationship between the ATC or strength coach and the physical therapist (PT) is critical in the late stages of the formal rehabilitation program.
- While the PT is still working on the shoulder specifically, an ATC or CSCS can start the athlete on core training and aerobic/anaerobic conditioning, and assist in maintenance exercises prescribed by the PT. This communication helps avoid any potentially dangerous exercises.[13]
- The following are some concepts the athlete might be able to get a head start on while completing the terminal phases of rehabilitation:
  - Lifting form and technique—posture training
  - Core training—without loading the upper extremity
  - Movement correction exercises
  - Balance training
  - Aerobic/anaerobic conditioning[1,13-16]
- Once the physical therapist has tested the athlete and they have met the discharge criteria, the athlete is released to begin upper body resistance training activities, the ATC or CSCS may now begin to focus on the following:
  - Muscular strength
    - Bench press/incline press
    - Dead lifts—traditional or Romanian
    - Squat variations—front squat, back squat; single leg squats
    - Isolating muscle groups: bicep, triceps, latissimus, trapezius (low, mid, upper), hamstrings, quadriceps, gastrocnemius, core muscle groups
  - Muscular power and (Strength Power Potentiating Complex Training) SPPC
    - Similar lifts used above but with heavier weight, lower reps, higher intensities, and longer rest intervals
    - Progress to SPPC Exercises
      - Olympic lifts
      - Explosive jumps
      - Explosive lunges
      - Medicine ball throws
      - Kettle bell training[17]
  - Multiplanar and multijoint resistance activities
  - Continued focus on prescribed maintenance exercises—typically performed at the end of a workout—it is suggested to at least pick one exercises from each of the concepts listed below
    - Dynamic joint stability—with repositioning of the bicep tendon from the tenodesis procedure, it is thought that the GH joint stability could be

TIMELINE 5-3 **Beyond Basic Rehabilitation—Returning to Weightlifting after Biceps Tenodesis**

PHASE I (weeks 1 to 2)	PHASE II (weeks 3 to 6)	PHASE III (weeks 6 to 12)
• Protection phase: wear sling, gentle PROM and postural exercises only, • Bonus exercises: elbow, forearm, wrist, cervical—gentle AROM of AAROM • Pain control modalities as needed	• Protect tissue • Control pain • Progress with ROM exercises • Implement posture correction exercises	• Protect tissue • Achieve end ranges of motion • Maintenance posture exercises • Address movement impairments • Implement PREs for GH joint/elbow/wrist • Implement joint stability /proprioception exercises • Implement cardiovascular conditioning

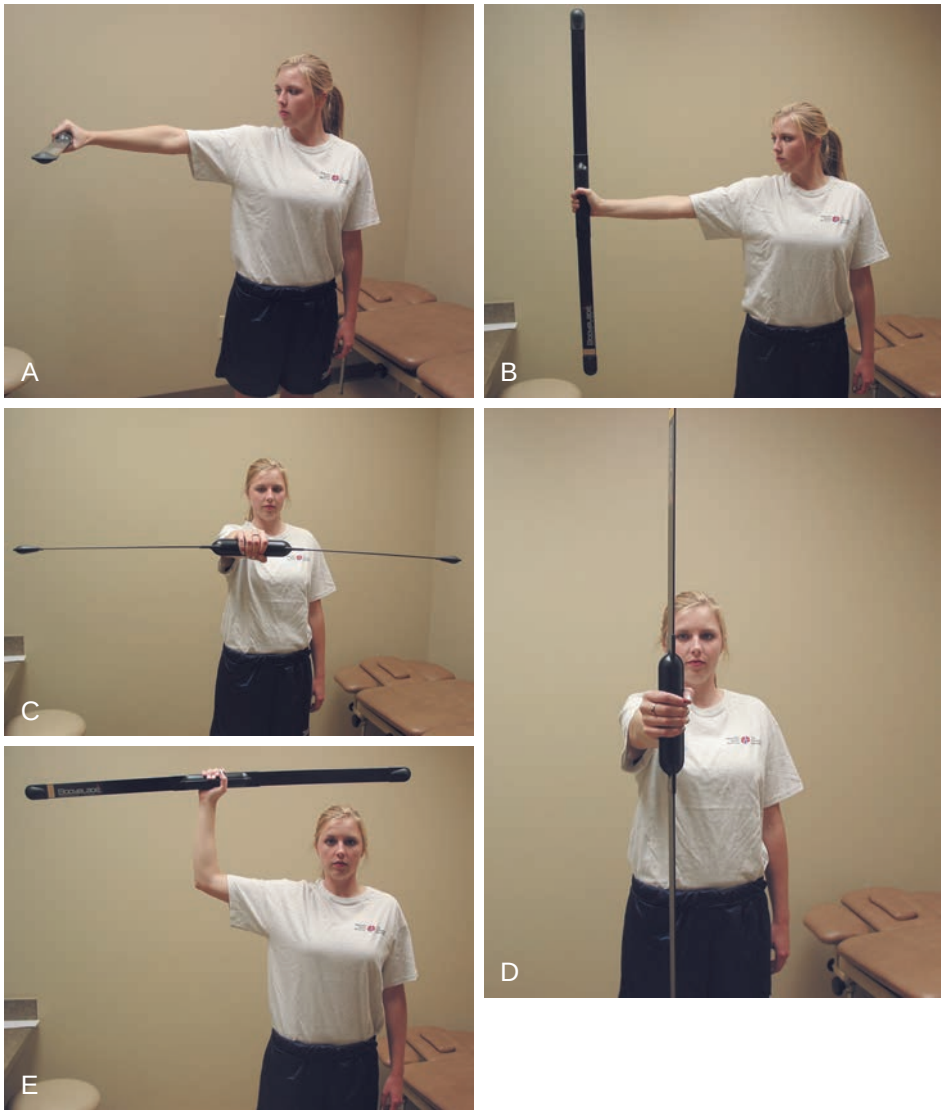

FIGURE 5-16. (**A-E**) Bodyblade routine. Perform each position consecutively for 10 seconds for 3 sets

affected. The following exercises will help address this potential issue.
  - Bodyblade routines (Figure 5-16)
  - Rhythmic stabilization exercises
  - Low-level ballistic/plyometric exercises
- Flexibility/Mobility—a common finding among the weightlifting population is decreased mobility in all ranges and poor agonist/antagonist muscle balance ratios. The smaller muscles, such as the lower trapezius, should not be forgotten.[18]
  - General whole body flexibility
  - Specific stretches for glenohumeral internal rotation, horizontal adduction/abduction, and forward elevation (Figure 5-17 for common shoulder stretches).
  - Specific mobility exercises for scapular mobility—focusing on lower trapezius activation and pectoralis major/pectoralis minor flexibility (Figure 5-18 for low trap activation and pectoralis minor stretches)

TIMELINE 5-3 Beyond Basic Rehabilitation—Returning to Weightlifting after Biceps Tenodesis (Continued)

PHASE IV (weeks 12 to 16)	PHASE V (weeks 16 to 24)	PHASE VI (weeks 24)
• Maintenance of ROM, joint mobility, joint stability, posture, and correct movement patterns • Progress with PRE intensity for GH joint/elbow/wrist • Implement basic large- muscle group weightlifting activities • Focus on lifting techniques • Implement light plyometric exercises	• Continue maintenance exercises • Progress with weight-lifting activities—increasing intensity • Progress intensity with plyometric exercises • Initiate competition-specific lifting techniques—light weight	• Begin customized periodization training program for desired weightlifting • Competitions • Continue regular maintenance exercises

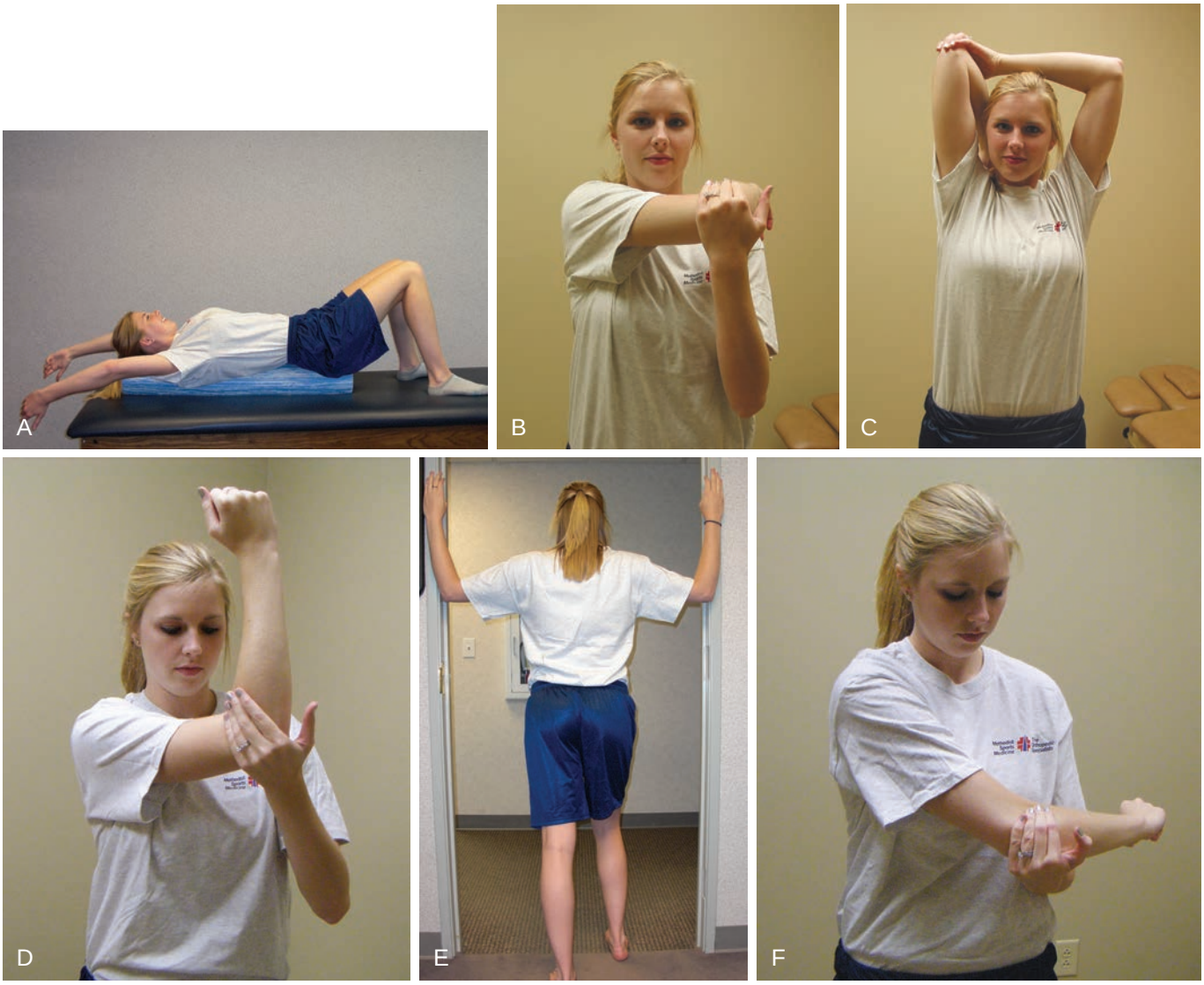

FIGURE 5-17. (**A-F**) Common maintenance shoulder stretches.

- Sensorimotor/balance training
  - Training D1 and D2 patterns
- Core training [1,4,14,15,19]
- See Figure 5-19 for a description of a performance restoration pyramid

Olympic Lifts Used in the Training Program

- Olympic lifts are typically not recommended for an injured athlete until optimum strength, flexibility, and appropriate muscle balances are achieved.
- Once athletes have reached a decent level of training for the concepts listed above, then they may start low-intensity Olympic lifts, focusing on form and technique, and then gradually increasing intensity through appropriate progressions.
- Common Olympic lifts are:
  - Power cleans
  - Clean and jerk
  - Snatch[1,2,17]

Training Principles Used in the Design of the Program

- Principle of progression
- Principle of overload
- Principle of variation
- Principle of individualization
- Principles of specificity—specific adaptation to imposed demands

Application of Acute Training Variables

- Hypertrophy/Endurance Phase
  - Intensity—low to moderate (50% to 75% of 1 rep max)
  - Volume—moderate to high (3% to 6sets of 10 to 20 reps)
- Basic Strength Phase
  - Intensity—high (80% to 90% of 1 rep max)
  - Volume—moderate (3 to 5sets of 4 to 8 reps)

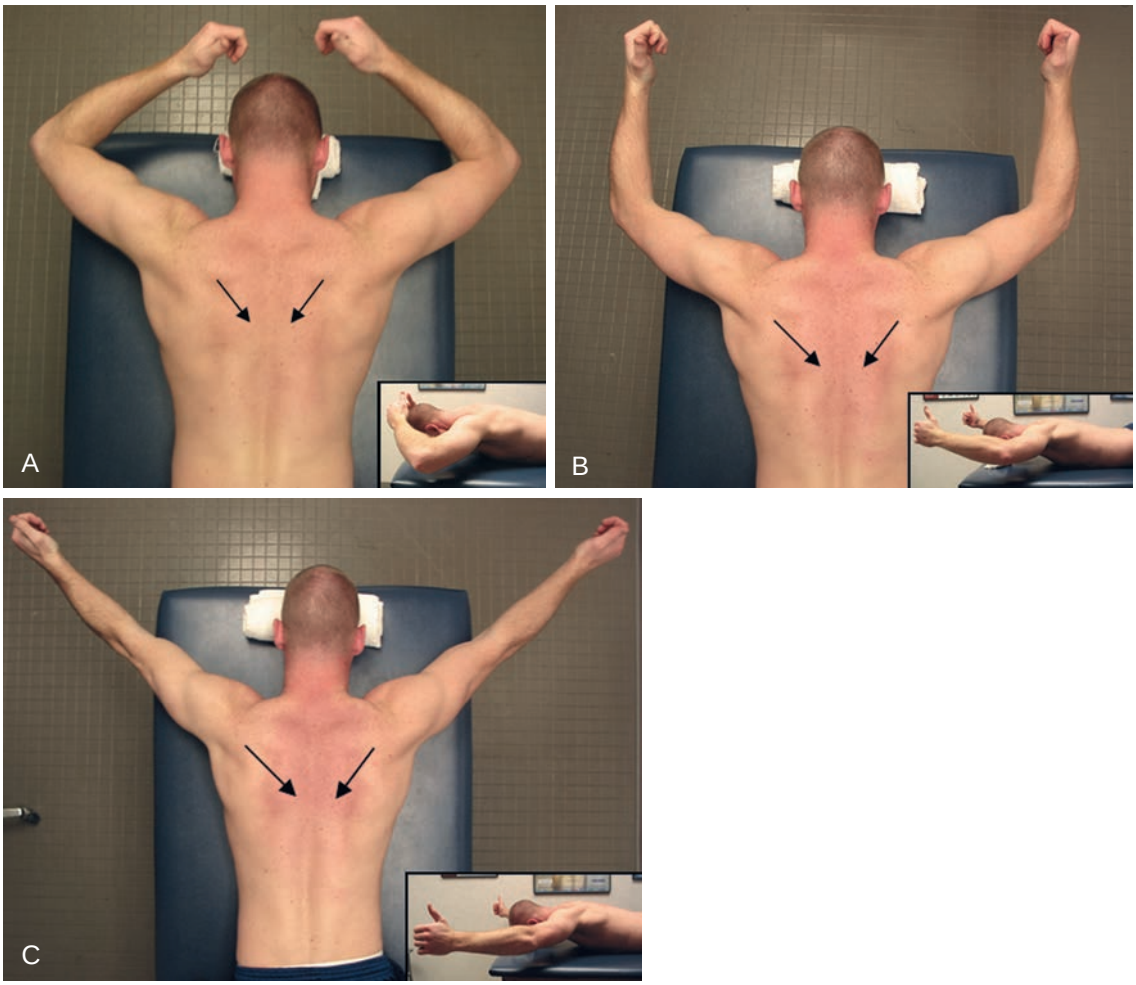

FIGURE 5-18. (**A-C**) Common low trap activation/strengthening exercises. Verbally cue the athlete to squeeze shoulder blades down and together, with minimal glenohumeral involvement.

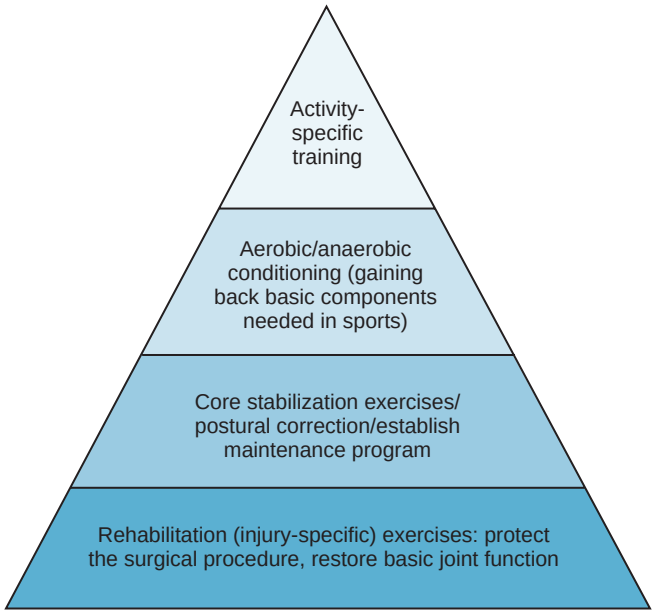

FIGURE 5-19. Performance restoration pyramid following shoulder injuries. *(Data from references 1, 4, 5, and 17.)*

- Strength/Power Phase:
  - Intensity—high (75% to 95% of 1 rep max)
  - Volume—low (3 to 5 sets of 2 to 5 reps)
- Maintenance Phase
  - Intensity—moderate (80% to 85% of 1 rep max)
  - Volume—moderate (2 to 3 sets of 6 to 8 reps)
- Competition Period
  - Intensity—very high (>90% of 1 rep max)
  - Volume—very low (1 to 3 sets of 1 to 3 reps)[1,2,11,12]

Sports Performance Testing

General Information

- General history
- Subjective questionnaires
- Medical history
- Sports injury history
- Surgical history
- Chronic conditions/medication

Specific Criteria for Progression to the Next Phase to Determine Readiness for Weightlifting

- Static/dynamic postural assessments
  - Standing alignment (back view)
    - Symmetry of slope of shoulders
    - Scapula
      - Abduction/adduction (normally 3 in. from spinous process to vertebral border at spine of scapula
      - Prevalence of winging
      - Anterior tilt (normal within 9° to 20°)
      - Depression/elevation (normal: root of spine of scapula aligned with T3)
    - Spine
      - Normal, kyphotic, lordotic
  - Standing Alignment (side view)
    - Scapula—confirm anterior tilt
    - Humerus—humeral head relative to acromion process
      - Normal—no greater than 1/3 humeral head anterior to anterolateral corner of acromion
    - Spine—normal, kyphotic, lordotic,
    - Standing alignment (front view)
      - Clavicles—upward slope from medial to lateral approximately 25°
  - Standing movement tests
    - Bilateral shoulder flexion and return from flexion
      - Acromion should elevate slightly
      - Scapula should upwardly rotate without excessive abduction or adduction
      - Scapula should posteriorly tilt
      - Clavicle should retract and elevate
      - Symmetric glenohumeral creases[20]
- Isokinetic muscle performance testing—Cybex testing
  - ER/IR in 90deg of GH abduction—supine
    - 3 sets
      - #1 6 reps at 90°/sec
      - #2 6 reps at 210°/sec
      - #3 6 reps at 300°/sec
  - Performance Criteria—see Figure 5-19
    - ER/IR ratio of 65% to 75%
    - Dominant vs nondominant = 15% to 20% difference
    - Body weight ratio
      - 90°/sec—30% of IR and 20% of ER
      - 210 and 300°/sec—10% of IR and 10% of ER[19,21,22]
- Movement performance testing—functional movement screen
  - A score of greater than 15 is recommended for all competitive athletes.
  - A study by Kiesel et al. found that professional football players with dysfunctional fundamental movement patterns, as measured by the Functional Movement Screen, are more likely to suffer an injury than those scoring higher on the FMS.[16]
- Sport-specific testing
  - When returning from any injury, a functional progression needs to take place to help ensure safe return to play. For example, a baseball player may want to complete a throwing program prior to returning to pitching. An offensive lineman may want to progress through a series of dummy drills and individual drills, prior to being involved in team drills and games. For competitive weightlifting, one would want to start with safer lifts, lighter weight, and make use of a spotter. Then as strength and power progresses, all while maintaining good form and technique, one may start to work into more high-powered and explosive lifts with heavy weight.[1,2]

Specific Criteria for Release to Unsupervised Complete Participation in Weightlifting

- The athlete must present with postural alignments within normal limits and demonstrate proper scapulohumeral movement patterns.
- The athlete must have a score of greater than 14 on the Functional Movement Screen and produce Cybex testing results that meet the suggested performance criteria.
- Specifically for weightlifting, the athlete must demonstrate the ability to perform all lifts with light weight and demonstrate proper form and technique.
- Last, the athlete must understand the importance of maintenance exercises and how to incorporate them into the training program.

Recommended Ongoing Exercises for the Weightlifter

- Studies (references) show that people who are seriously involved in resistance training exercises often develop some form of muscular imbalance. It is important that proper exercises are prescribed to maintain an appropriate balance of agonist and antagonist muscle groups, to maintain proper joint mobility and stability, while at the same time keeping in consideration the necessary physical requirements needed to perform specific movements for the particular sport they are training for.

- A common imbalance of the weightlifting population is decreased glenohumeral internal rotation and poor lower trapezius strength in relation to body mass. It is recommended that all serious weightlifters perform regular lower trapezius strengthening exercises and stretches for the posterior rotator cuff.[18]
- Specifically for athletes following a tenodesis procedure, the athlete must routinely perform rotator cuff strengthening and dynamic stabilization exercises. Even without much reliable and valid evidence of the exact role the proximal bicep tendon plays in the function of the glenohumeral joint,[4,5,9,10,23] we must address any possible deficits in shoulder stability that may occur with relocation of the origin of the bicep tendon.[4,5,23]

Evidence

Craig B: The basics of resistance training program design: Where do I start? *Strength Cond J* 31:75–77, 2009.

This article addresses the basics of program design for strength and conditioning. The author addresses concepts such as periodization, progressive resistance, and tapering techniques. He explains the importance of knowing the athlete prior to program design, such as sport played, position played, energy systems used, and timing of competitive events. He provides resources for the general public to use to find information on program designs that might closely relate to them. (Level V Evidence)

Kolber M, Beekhuizen K, Cheng M: Shoulder joint and muscle characteristics in the recreational weight training population. *J Strength Cond Res* 23:148–157, 2009.

The purpose of this study was to investigate the common adaptations of the shoulder joint with weightlifters and the associated risk factors that come with them. They evaluated 60 subjects who regularly participated in resistance training exercises and 30 subjects with no record of resistance training. They found the resistance training group had a significant decrease in shoulder mobility, except for shoulder external rotation, and strength ratios for major muscle groups were greater with the resistance training group. They concluded it is important to implement specific exercises within a weight training program that address and prevent these common adaptations that could lead to injury. (Level III Evidence)

Kolber M, Beekhuizen K, Cheng M, et al: Shoulder injuries attributed to resistance training: A brief review. *J Strength Cond Res* 24:1696–1704, 2010.

The purpose of this article was to get a general idea of the level of frequency of shoulder injuries that occur within the resistance training population. Their review indicated a 36% incident of shoulder injury of all injuries related to the resistance training population. Trends that were associated with the injuries were muscle imbalances and poor posture and lifting techniques. They note very little evidence exists as to predictive variables that might lead to shoulder injuries. (Level IV Evidence)

Krieger J: Determining appropriate set volume for resistance exercise. *Strength Cond J* 32:30–32, 2010.

This article provides evidence-based information to help determine the appropriate number of sets and reps for the weightlifting population. It concludes that the noncompetitive weightlifter who would like some strength gains, but is limited with time and resources, would benefit from performing 1 set of exercises, to failure, for a specific muscle group. For someone who is more serious about strength gains, then 3 sets are necessary. He also suggests that anything above 3 sets is not necessary for optimal gains. (Level II Evidence)

Turner A: The science and practice of periodization: A brief review. *Strength Cond J* 33: 34–46, 2011.

The purpose of the article was to review the evidence behind periodization and its effectiveness. They concluded there is enough evidence to prove its effectiveness in a given year or single cycle of a competitive season, but further evidence is needed for the elite level of athletes who are training to peak at longer intervals, such as 4 years. (Level V Evidence)

Wittstein J, Queen R, Abbey A, et al: Isokinetic strength, endurance, and subjective outcomes after biceps tenotomy versus tenodesis. *Am J Sports Med* 39:857–865, 2011.

The purpose of this article was to study the outcomes of both the tenodesis and tenotomy procedures and which one is more effective at restoring muscle strength and endurance. With 19 tenotomy and 16 tenodesis procedures, at 2 years postoperatively, there was no difference in subjective outcome scores between the two groups. Both groups had similar shoulder flexion strength compared to contralateral side. The tenotomy group had significant lower forearm supination strength compared bilaterally, whereas the tenodesis group maintained close to equal supination strength. Furthermore, 4 of the 19 tenotomy subjects developed a "Popeye" deformity and two complained of cramping sensations. Two of the 16 tenodesis subjects exhibited point tenderness at the tenodesis site. (Level III Evidence)

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Multiple-Choice Questions

QUESTION 1. When designing a resistance training program for an athlete following a tenodesis procedure, which of the following concepts should be considered?

A. Current status of rehabilitation program
B. What sport is the athlete getting back to?
C. What energy systems are predominantly used for their sport?
D. All of the above

QUESTION 2. What concept below plays the most critical role in how a strength and conditioning program should be structured for an athlete who is preparing for a competitive event?

A. Periodization
B. Progressive resistance
C. Tapering
D. Hypertophy phase

QUESTION 3. Following a biceps tenodesis procedure, what is a normal timeframe to expect close to normal strength measurements compared bilaterally?

A. 3 months
B. 6 months
C. 1 year
D. 2 years

Answer Key

QUESTION 1. Correct answer: **D** (see Program Design/Performance Training section)

QUESTION 2. Correct answer: **A** (see Periodization section)

QUESTION 3. Correct answer: **B** (see Cope et al. study listed under the return to play section)

Chapter 6



Rotator Cuff Injuries

INTRODUCTION

Laura M. Lundgren, PA-C, BS, MPAS, and Timothy S. Mologne, MD

Epidemiology

Age

- Rotator cuff pathology can be seen in a vast array of age groups, from the young athletes to sedentary, geriatric patients.

Sport

- Sports associated with rotator cuff pathology include overhead sports (such as throwing sports, tennis and volleyball), weightlifting, and swimming.

Important Definitions

- **Primary outlet impingement/impingement syndrome:** Pain and inflammation in the subacromial space as a result of the rotator cuff impinging against the undersurface of the acromion, coracoacromial ligament, and undersurface of the acromioclavicular joint.[1]
- **Secondary impingement:** Pain and inflammation in the rotator cuff and subacromial space due to an inability to keep the humeral head centered, thus causing altered humeral mechanics and compression on rotator cuff. It is usually seen in younger patients who may have glenohumeral laxity or instability and often have poor scapular control. It can also be associated with weakness of the rotator cuff.[2]
- **Internal impingement:** Repetitive contact of the greater tuberosity and articular surface of the posterior rotator cuff on the posterosuperior glenoid in the abducted, externally rotated position. It is usually seen in throwers and can result in partial articular sided rotator cuff tears and posterosuperior glenoid labral tears. It can be associated with subtle glenohumeral instability, posterior capsular tightness and internal rotation deficits, and scapular dyskinesia.[3,4]
- **Glenohumeral internal rotation deficit (GIRD):** Usually seen in pitchers and athletes in overhead sports (tennis) and is defined as less than 25° of internal rotation or a total arc or motion 25° less than the contralateral shoulder (total arc of motion, both internal and external rotation, should be equal between shoulders, with the throwing shoulder having more external rotation with correspondingly less internal rotation).[5]

Pathophysiology

Intrinsic Factors

I. Primary outlet impingement/impingement syndrome
- Tendon degeneration
- Hypovascular zone in the supraspinatus tendon
- Posterior capsular tightness
- Acromial and coracoacromial arch morphology (association of rotator cuff pathology and bony excrescences from the undersurface of the acromion) (Figure 6-1)
- Kinematic abnormalities
- Subacromial bursitis
- Acromioclavicular arthrosis
- Overuse syndrome
- Os acromiale
- Suprascapular neuropathy
- Cervical degeneration/cervical radiculopathy

II. Internal impingement
- Excessive external rotation
- Tight posterior capsule, leading to loss of internal rotation and a posterosuperior shift of the humeral head with humeral elevation.
- Subtle anteroinferior shoulder instability

III. Secondary impingement
- Glenohumeral instability and laxity
- Rotator cuff weakness



FIGURE 6-1. Type 3 acromion with a large bony excrescence from the undersurface of the acromion.

- Scapular stabilizer muscle weakness with scapular dyskinesia

Extrinsic Factors

I. Outlet impingement/impingement syndrome
- Repetitive use injuries
- Smoking
- Tensile overload
- Indiscriminate cortisone injections

II. Internal impingement
- Repetitive throwing or positioning in the abducted, externally rotated position

III. Secondary impingement
- Repetitive overhead activities, including sports like swimming, and throwing sports

Traumatic Factors

- Repetitive throwing
- Fall on outstretched arm
- Fall directly onto the shoulder

Classic Pathological Findings

I. Stages of rotator cuff impingement[1]
- Stage I: Acute rotator cuff inflammation/subacromial bursitis and hemorrhage (Figure 6-2).
- Stage II: Fibrosis and tendonitis of the rotator (Figure 6-3)
- Stage III: Partial and complete rotator cuff tendon tears (Figure 6-4*A*,*B*)

II. Internal impingement
- Repetitive contact of the undersurface of the infraspinatus on the posterior superior glenoid, resulting in articular sided partial infraspinatus tendon tears and posterosuperior glenoid labral tears (Figure 6-5)

III. Secondary impingement
- Glenohumeral laxity or instability
- Rotator cuff impingement signs in young patients

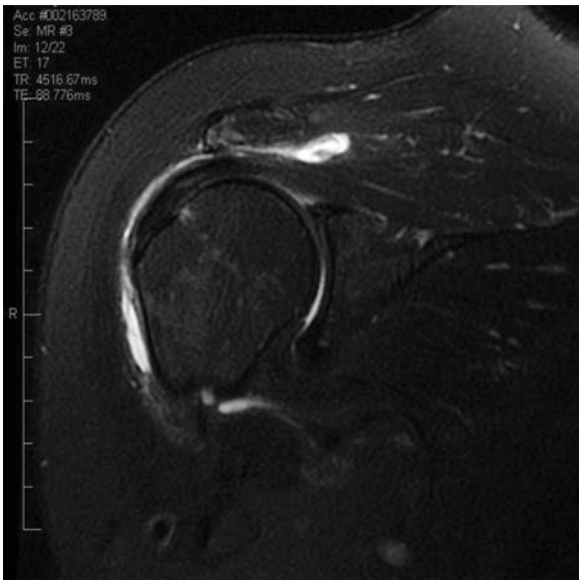

FIGURE 6-2. Acute subacromial bursitis and inflammation.



FIGURE 6-3. Rotator cuff tendinosis and fibrosis.

Clinical Presentation

History

I. Primary outlet impingement/impingement syndrome
- Painful overhead motion
- Grinding, catching and popping in the subacromial space with rotational and overhead motion
- Weakness, which may be caused by pain or can be due to rotator cuff tearing
- Night pain (very common complaint in patients with a rotator cuff tear)
- Posterior capsular tightness is common

II. Internal impingement
- Usually seen in throwers or athletes that put their shoulders in the abducted externally rotated position repetitively

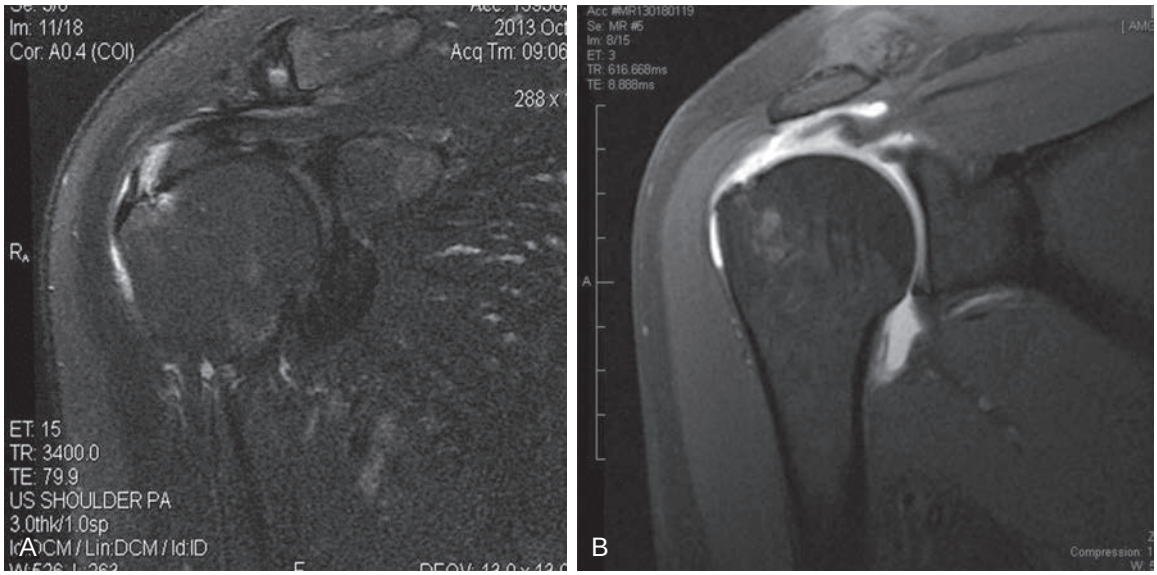

FIGURE 6-4. A, B, Partial and full thickness rotator cuff tears.



FIGURE 6-5. MR with intraarticular gadolinium in the ABER position (abduction-external rotation), showing an articular sided partial tear of the infraspinatus in a professional baseball pitcher.

- Pain in the abducted, externally rotated (ABER) position, relieved with a posterior directed force on the humerus (Jobe relocation test).
- Possible complaints of catching and grinding due to labral tearing
- Complaints of weakness and easy fatigue
- Thrower may notice decreased velocity

III. Secondary impingement

- Painful overhead motion
- Can present with grinding, catching, and popping in the subacromial space caused by subacromial bursitis
- Complaints of weakness and easy fatigue
- "Dead arm" symptoms with throwing
- Possible complaints of shoulder subluxation
- Poor scapular control with scapular dyskinesia and often winging of the scapula when lowering the arm from overhead

Physical Examination

I. Primary outlet impingement/impingement syndrome

1. **Abnormal findings:**
   - Painful arc (Neer and Hawkins impingement signs)
   - Posterior capsular tightness
   - Pain with rotator cuff strength testing
   - Weakness caused by pain and/or tendon disruption
2. **Pertinent normal findings:**
   - Intact and normal strength in patients without cuff tearing
   - Normal motor and sensory exam
   - Normal and asymptomatic biceps function
   - Complete and symmetric range of motion
   - Normal and asymptomatic cervical range of motion
   - Stable shoulder to anterior, posterior and inferior translations

II. Internal impingement

1. **Abnormal findings:**
   - Pain in the abducted, externally rotated position (ABER position)
   - Possible glenohumeral internal rotation deficit (GIRD)
   - Pain with rotator cuff strength testing, particularly resisted external rotation
   - Weakness of the external rotators can be seen in patients with significant partial tearing of the infraspinatus
   - Labral tearing can result in positive active compression test (O'Brien test), Speed's test, and compression-rotation test
2. **Pertinent normal findings:**
   - Intact and normal strength in patients without cuff tearing
   - Normal motor and sensory exam
   - Normal and asymptomatic cervical range of motion

- Stable shoulder to anterior, posterior and inferior translations

III. Secondary impingement

1. **Abnormal findings:**
   - Painful arc (Neer and Hawkins impingement signs can be positive)
   - Pain with rotator cuff strength testing
   - Weakness caused by pain
   - Possible increase in glenohumeral joint translations in various directions (can be multidirectional laxity or instability)
   - Scapular dyskinesia: Poor scapular control with activities and possible winging when lowering the arm from overhead
2. **Pertinent normal findings:**
   - Usually with intact and normal strength
   - Normal motor and sensory exam
   - Normal and asymptomatic biceps function
   - Complete and symmetric range of motion
   - Normal and asymptomatic cervical range of motion

Imaging

- Imaging of the shoulder is always done and starts with radiographs in all patients, regardless of the presumed diagnosis
- X-rays (AP, axillary, and supraspinatus outlet views of the shoulder)
- Supraspinatus view used to assess acromial morphology
- MRI if indicated by exam
- MR with intraarticular gadolinium can be helpful in diagnosing undersurface partial rotator cuff tear and the presence of internal impingement (MR sequencing in the ABER position)
- Ultrasound can be used to help identify pathology in the rotator cuff, biceps, and subacromial space
- CT arthrogram can be used to assess for rotator cuff pathology in patients that cannot have an MRI

Differential Diagnosis

- Cervical radiculopathy
  - The patient's history may include a history of neck pain or decreased neck range of motion. The exam may show neural tension signs, weakness in a nerve root distribution, distal motor weakness, dermatomal sensory deficits, and possible diminished deep tendon reflexes.
- Biceps pathology (tenosynovitis, partial and complete tearing, and subluxation)
  - The physical exam may reveal tenderness over the biceps groove, positive Speed's test, and pain with resisted supination. Patients may complain of pain radiating from the shoulder and into the anterior brachium.
- Acute brachial neuritis (Parsonage Turner Syndrome)
  - Acute onset of intense, nontraumatic shoulder pain, which, occasionally, follows a viral illness. The intense pain is followed by weakness in the upper extremity. It can affect multiple areas of the brachial plexus, but can be isolated to a single nerve (suprascapular nerve).
  - MRI of the shoulder may show edema in the supraspinatus and infraspinatus if they are deinnervated.
- Suprascapular neuropathy
  - Can be caused by compression of the nerve at the suprascapular notch. This results in weakness of the supraspinatus and infraspinatus muscles.
  - Spinoglenoid ganglion cyst causing compression of the suprascapular nerve and weakness of infraspinatus only.
  - The physical exam will find increased weakness of external rotation only if the suprascapular nerve is affected at the spinoglenoid notch.
- Calcific tendinitis
  - The patient's history will indicate an acute onset of pain often associated with actual redness of the shoulder and the presence of calcium in the rotator cuff on X-ray.
- Adhesive capsulitis
  - Patients present with shoulder pain with overhead activities. As the overhead motion causes intense pain, providers often do not test range of motion for symmetry. Loss of motion in all planes (but especially external rotation at the side and internal rotation) is diagnostic.
- Contusions
  - The patient's history will indicate a specific injury.

Treatment

Nonoperative Management

- Activity modifications/rest
- Physical therapy
- Nonsteroidal antiinflammatory medicines (oral and topical)
- Subacromial injection

Guidelines for Choosing among Nonoperative Treatments

- Activity modifications/rest
  - Most patients have already begun to modify their activities based upon pain and symptoms. However, if their occupation or hobbies require overhead repetitive movements work restrictions or a discussion on specific modifications may be helpful. In most circumstances this will be combined with additional treatment.
- Physical therapy[6]
  - Helpful in restoring full and symmetric motion, preventing muscle atrophy, and improving pain. In the event of a rotator cuff tear, therapy can still be helpful in achieving full range of motion prior to any surgical intervention to avoid postoperative complication of adhesive capsulitis.
- Nonsteroidal antiinflammatory medicines
- Patients with evidence of stage I or stage II impingement are offered an antiinflammatory medicine.

- Subacromial injection
  - Diagnostic injection with anesthetic can help to assess strength in an acutely inflamed shoulder that is examining with weakness. An injection with corticosteroid and anesthetic can be diagnostic as well as therapeutic. An injection is not indicated in the presence of a rotator cuff tear and should not be used indiscriminately. Due to damaging effects of atrophy and decreased quality of tissue, no more than three injections are recommended and they should be spaced at least three months apart.

Surgical Indications

- There are no absolute indications for surgical intervention in rotator cuff pathology. Relative indications are as follows:
  - Failure of conservative treatment
  - Symptomatic full thickness rotator cuff tear
  - Symptomatic partial thickness rotator cuff tears that are greater than 50% of the thickness of the tendon
  - Persistent symptoms in patients with internal impingement that fail to improve with 3 months of therapy.
  - Persistent symptoms in patients with secondary impingement that fail to improve with 3 to 6 months of therapy

Aspects of History, Demographics, or Exam Findings that Affect Choice of Treatment

- Length of symptoms and amount of dysfunction
- Age of patient
- Comorbidities affecting anesthesia clearance
- The patient's desire to return to sports/hobbies or a physically demanding profession
- In the presence of a rotator cuff tear the amount of atrophy or fatty infiltration of the muscle belly, tendon retraction and elevation of the humeral head

Aspects of Clinical Decision Making When Surgery Is Indicated

- Coracoacromial arch morphology
- Symptomatic acromioclavicular arthrosis
- Concomitant pathology including involvement of biceps tendon and/or labrum
- Arthroscopic versus open rotator cuff repair and distal clavicle resection
- Benefit of tendon transfers for irreparable tendon tears
- Risks and benefits of concomitant versus staged surgery when there is a component of adhesive capsulitis associated with rotator cuff tendon tear
- Type of fixation for repair (anchor configuration, stitch configuration, anchor material, etc.)

Evidence

Arroyo JS, Hershon SJ, Bigliani LU: Special consideration in the athletic throwing shoulder. *Orthop Clin North A* 28:69–78, 1997.

In this review article, the authors remind us that the rotator cuff can become inflamed and injured due to instability in the young athlete. These patients are usually successfully treated with a coordinated rehabilitation program. (Level IV evidence)

Morrison D, Frogameni A, Woodworth P: Nonoperative treatment of subacromial impingement syndrome. *J Bone and Joint Surg* 79:732–737, 1997.

This retrospective study looked at the results of conservative treatment for subacromial impingement syndrome in 616 patients (636 shoulders). Overall 67% had a satisfactory result. Results were better in patients with symptoms less than 4 weeks and in those with a type I acromion. (Level III evidence)

Myers JB, Laudner KG, Pasquale MR, et al: Glenohumeral range of motion deficits and posterior shoulder tightness in throwers with pathologic internal impingement. *Am J Sports Medicine* 34:385–391, 2006.

The authors compared humeral rotations in 11 throwing athletes with clinical and MR evidence of internal impingement to 11 matched throwing athletes that had no history of shoulder ailments. The symptomatic throwing athletes had greater internal rotation deficits and posterior capsular tightness as compared to the controls. (Level III evidence)

Neer CS: Anterior acromioplasty for the chronic impingement syndrome in the shoulder. A preliminary report. *J. Bone and Joint Surg* 54:41–50, 1972.

In this classic article, Dr. Neer described the concept of impingement and outlet obstruction by bone from the acromion, resulting in irritation of the supraspinatus and, occasionally, the biceps tendon. (Level III evidence)

Paley KJ, Jobe FW, Pink MM, et al: Arthroscopic findings in the overhead throwing athlete: evidence for posterior internal impingement of the rotator cuff. *Arthroscopy* 16:35–40, 2000.

The authors described the arthroscopic findings in 41 professional overhead throwing athletes that underwent surgery for painful shoulders. All had contact of the undersurface of the rotator cuff with the posterosuperior glenoid or osteochondral lesions. Undersurface cuff fraying was found in 93% and posterosuperior glenoid labral fraying was seen in 88%. These findings support the concept and diagnosis of internal impingement as a cause of shoulder pain in the throwing athlete. (Level III evidence)

Walch G, Liotard JP, Boileau P, et al: Postero-superior glenoid impingement. Another shoulder impingement. *Rev Chir Orthop Reparatrice Appar Mot* 77:571–574, 1991.

Walch initially described a case of internal impingement, with partial tearing of the articular side of the rotator cuff caused by impingement of the tendon on the posterosuperior aspect of the glenoid in the throwing position. (Level III evidence)

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Multiple-Choice Questions

QUESTION 1. The physical exam finding that changes the diagnosis from internal impingement only to glenohumeral internal rotation deficit (GIRD) is:

A. Less than 35° of internal rotation on the affected shoulder.
B. Less than 25° of internal rotation or the total arc of motion is 25 ° less than the contralateral shoulder.
C. External rotation is 20° more in the contralateral shoulder.
D. Evidence of a partial articular sided rotator cuff tear on MRI.

QUESTION 2. Which of these factors is an intrinsic factor for primary impingement syndrome?

A. Smoking
B. Trauma
C. Os acromiale
D. Repetitive overhead activities

QUESTION 3. A patient presents with a painful arc of motion, poor scapular control and winging with lowering the arm from overhead, asymptomatic biceps function and complete and symmetric range of motion. The most likely diagnosis would be:

A. Primary impingement syndrome
B. Glenohumeral internal rotation deficit
C. Secondary impingement
D. Adhesive capsulitis

QUESTION 4. A patient who presents with weakness of the external rotators only would have a likely diagnosis of:

A. Suprascapular neuropathy affected at the spinoglenoid notch
B. Calcific tendonitis
C. Cervical radiculopathy
D. Biceps pathology

QUESTION 5. Appropriate first line treatment of impingement syndrome would be:

A. Surgery
B. Activity modifications and narcotic pain medicines
C. Activity modifications, physical therapy and NSAIDs
D. Narcotic pain medications

Answer Key

QUESTION 1. Correct answer: **B** (see Important Definitions)

QUESTION 2. Correct answer: **C** (see Pathophysiology)

QUESTION 3. Correct answer: **C** (see Physical Examination)

QUESTION 4. Correct answer: **A** (see Differential Diagnosis)

QUESTION 5. Correct answer: **C** (see Treatment)

NONOPERATIVE REHABILITATION OF ROTATOR CUFF IMPINGEMENT SYNDROME

Kari L. Sturtevant, DPT, OCS, Molly Van Zeeland, DPT, Laura M. Lundgren, PA-C, BS, MPAS, and Timothy S. Mologne, MD

Phase I: Acute Phase (weeks 0 to 2)

Goals

- Alleviate pain and inflammation (nonsteroidal antiinflammatory agents)
  - Possible subacromial injection of local anesthetic and a corticosteroid
- Use of modalities (cryotherapy, iontophoresis, phonophoresis, TENs unit, ultrasound, E-stim) to help alleviate pain
  - Note that research does not support the use of passive modalities including ultrasound, low-level laser therapy, and electromagnetic field therapy as effective treatments for impingement syndrome so these modalities should only be used to adjunct treatment and not the premise of treatment in this phase.[3]

GUIDING PRINCIPLES OF NONOPERATIVE REHABILITATION

- All aspects of rehabilitation for shoulder impingement are evaluation driven and include a logical progression of exercises to correct the biomechanical deficits identified in the evaluation.
- Avoid positions and activities that compromise the subacromial space and stress injured structures of the shoulder.
- A systematic evaluation must be performed to identify the specific cause and subtle underlying cause of shoulder impingement.[1] One must be cognizant that multiple causes may be responsible for the shoulder pathology.
  - Determine type of impingement
    - Primary
    - Secondary
    - Internal
  - Special tests to determine the mobility of the glenohumeral joint are key aspects of evaluation of the patient with rotator cuff impingement.
    - Evaluate to identify glenohumeral hypermobility and subtle instability as well as glenohumeral hypomobility.[1]
    - "Failure to identify patients with glenohumeral joint hypermobility and underlying instability properly can result in the inappropriate use of capsular stretching and mobilization techniques that could further jeopardize shoulder stability and decrease the potential success of the rehabilitation program."[1]
  - Resting scapular position and dyskinesis.
- Exercises must be performed with proper technique, including good scapular control. If proper technique cannot be maintained, the exercise must be modified.
- Based on the results of systematic review by Kuhn[2], it is recommended that patients receive supervised physical therapy for exercise and manual therapy 2 to 3 times per week initially. When manual therapy is no longer warranted and the patient demonstrates good technique with their home exercise program, frequency of physical therapy visits may be reduced to progress the patient's home exercise program as needed.
- Kuhn[2] concludes that range of motion and flexibility exercises be performed daily and strengthening performed 3 times a week.
- Proprioception and neuromuscular control exercises should be practiced multiple times daily.
- Conservative treatment of shoulder impingement is thought to be unsuccessful if no improvement is seen with 12 weeks of an evaluation-driven rehabilitation program and coordinated medical care. By 6 to 9 months, maximum medical improvement is typically obtained.
  - Activity modifications and rest, avoiding activities that exacerbate symptoms
    - Patient education on activity modification and avoidance is very important in this phase so healing is not delayed
- Acquire full passive ROM
- Retard muscle atrophy by beginning submaximal, pain-free isometrics for internal and external rotation
- Address abnormal resting scapular positioning and scapular dyskinesis by neuromuscular control exercises to normalize scapular muscle firing patterns
  - Consider scapular taping to improve resting scapular positioning as evidenced by Selkowitz et al.[4]

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Techniques used are evaluation based.
  - Glenohumeral joint mobilizations are
    - Empty end feels—Use grades I and II mobilizations for pain control and relaxation
    - Firm capsular end feels—Use grades III and IV to address motion deficits
  - Thoracic spine mobilization/manipulation is often necessary and should be included in this phase in patients who demonstrate increased thoracic kyphosis. Thoracic kyphosis causes an anterior tilt of the scapula, which reduces the subacromial space.
    - Thoracic spine extension exercises/flexibility exercises should be encouraged as part of a home excercise program
    - Patient education on proper sitting posture to maintain thoracic spine extension

Soft Tissue Techniques

- Some research supports the use of deep friction massage to the rotator cuff tendon insertion and radial nerve stretching for pain management in patients with impingement syndromes.[5]

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Stretching and flexibility exercise prescription is evaluation based. Can include exercises for flexion, scaption, internal rotation and external rotation.
- Manual PROM, stretching and exercise prescription of stretching/flexibility for glenohumeral internal and external rotation should be ONLY done when patient has loss of total shoulder joint motion (external rotation ROM plus internal rotation ROM) compared to contralateral side. Note: IR/ER measurements should be done in the scapular plane at 90° abduction avoiding scapular compensation. Place hand on coracoid to feel for compensation (Figure 6-6).
- Stretching/flexibility exercises should be modified to limit pain or avoid subacromial impingement with endrange stretching.
  - Keep in mind that glenohumeral internal rotation deficiency (GIRD) or loss of internal rotation and increased external rotation caused by humeral retroversion in overhead athletes is normal and provided



FIGURE 6-6. Technique for measuring glenohumeral joint internal rotation with scapular stabilization at 90° abduction.

the patient does not lack total arc of motion, internal rotation should not be stretched.[6]

- Note end feel of ROM to determine if the patient truly has tightness. An empty end feel is limited by pain, and stretching and aggressive joint mobilizations are not necessarily appropriate. Address capsular end feel and treat firm capsular end feels with grades III and IV joint mobilizations or firm muscular end feels with stretching. Oftentimes patients with motion loss have tightness of both noncontractile tissue (i.e., capsule, fascia) and contractile tissue (i.e., musculo-tendon) unit and both joint mobilizations and stretching exercises are appropriate.
- Gentle range of motion exercises to address motion deficits. Motion exercises should be only done in a manner that limits symptoms and may need to be done initially as passive or active-assisted motions.
- Pure abduction usually leads to increased symptoms and is usually avoided in the early phases. Stretching should be done in the scapular plane to avoid impingement of the structures in the subacromial space. (This may require a towel roll under elbow to stretch internal and external rotation.)
- Stretching, particularly the posterior capsule, is often necessary in patients presenting with glenohumeral joint hypomobility and should be made a part of the HEP in this phase. There is little evidence supporting frequency and duration of flexibility exercises, but common practice encourages 3 times 60-second stretches for each exercise, 2 to 3 times per day.
  - Stretches may include the posterior capsule sleeper's stretch (Figure 6-7), the cross body stretch (Figure 6-8), the rope IR stretch (Figure 6-9), the T-bar ER stretch and passive/active assisted flexion stretch (Figure 6-10)

Other Therapeutic Exercises

- Address flexibility of lower extremities, trunk and contralateral arm and prescribe a program to be done 3 times a week.

TIMELINE 6-1: **Nonoperative Rehab of Rotator Cuff Impingement**

PHASE I (weeks 0 to 2)

- Alleviate pain and inflammation
  - Subacromial injection
  - NSAIDS
  - Cryotherapy
  - Activity modification
  - Grade I and II joint mobilizations
- Acquire full passive ROM
  - For firm capsular end feels, use grade III and IV joint mobilizations
  - Stretch muscular and capsular end feel with
  - Flexion
  - Scaption
  - External rotation at side and 90° abduction
  - Internal rotation
- Address posture and increased thoracic kyphosis
  - Posture education
    - Scapular positioning
    - Spine posture
  - Thoracic joint mobilizations
- Neuromuscular reeducation for scapular muscular and rotator cuff
  - Prone extension with external rotation
  - Sidelying external rotation
  - Submaximal isometrics for IR/ER
- Total body strengthening
  - Flexibility
  - LE and contralateral UE strengthening
  - Cardiovascular exercise
- Home exercise program

PHASE II (weeks 2 to 8)

- Alleviate pain and inflammation
- Manual therapy as in Phase I
- Address scapular muscle imbalances
  - Forward flexion in side lying
  - Prone horizontal abduction with external rotation
  - Prone extension with external rotation
  - Wall or counter top pushup plus
- Progressive rotator cuff isotonics
  - Side lying external rotation with towel roll under arm
  - Theraband internal and external rotation with towel roll under arm
  - Once 3 × 20 can be performed of above isotonics with reasonable resistance, progress to:
    - Scaption
    - Prone external rotation at 90° abduction
    - D2 flexion
- Begin rhythmic stabilization, CKC rhythmic stabilization, Bodyblade, TB external rotation with oscillation
- Continue whole body flexibility, strength, and cardiovascular fitness

PHASE III (weeks 6 to 24)

- Continue manual therapy
- Progress rotator cuff strengthening
  - Thera-Band IR/ER at 90° abduction
  - Isokinetics if available
- Progress scapular muscle strengthening
  - Pushup plus in modified quadruped PIC
  - Prone horizontal abduction at 135° abduction
  - High and low rows
  - Military press
  - Lat pulldowns
- Progress proprioception and closed chain exercises
  - Stabilization on wobble board in quadruped or plank positions
  - Perturbations throughout range with Thera-Band exercises
  - Stabilization on stability ball
- Plyometrics
  - Trampoline toss
  - Catch and toss ball in 90°/90°



FIGURE 6-7. Posterior capsule/sleeper stretch to improve internal rotation range of motion and posterior capsule tightness.

- Lower extremity strengthening and cardiovascular exercise should continue and be encouraged especially in athletes planning to return to sport. Typically, strengthening and cardiovascular exercise for an athlete should be done 3 times a week at a minimum.

Activation of Primary Muscles Involved

- Choices of strengthening exercises should be made on an evaluation-based approach.
- Scapular dyskinesis
  - Defined as alterations in dynamic scapular motion patterns
  - Alterations of resting position may also exist and need to be addressed
  - Three axes of rotation of the scapula provide three individual motions:
    - Upward/downward rotation about a horizontal axis perpendicular to the plane of the scapula, near the center of the scapula
    - Internal/external rotation about a vertical axis through the plane of the scapula
    - Anterior/posterior tilt about a horizontal axis through the scapula
  - The most common scapular dyskinesis patterns involve a downward rotation, internal rotation, and anterior tilt of the scapula. Lack of proprioception and delayed or decreased activity of the serratus anterior and lower trapezius are thought to contribute to scapular dyskinesis.
  - Some degree of scapular dyskinesis is evident in the majority of injured shoulders.
  - The physical examination should determine whether an altered resting position and scapular dyskinesis exist.
  - Restoring normal scapular position and control is a vital portion of a successful rehabilitation program for the shoulder joint.
    - Identify if the scapular dyskinesis is a result of poor neuromuscular recruitment or decreased muscle strength.



FIGURE 6-8. Cross arm stretch to improve posterior capsule tightness.



FIGURE 6-9. Internal rotation stretch with hand behind back using a rope and handle to improve internal rotation range of motion.



FIGURE 6-10. Flexion AAROM and stretching exercise to improve flexion range of motion.

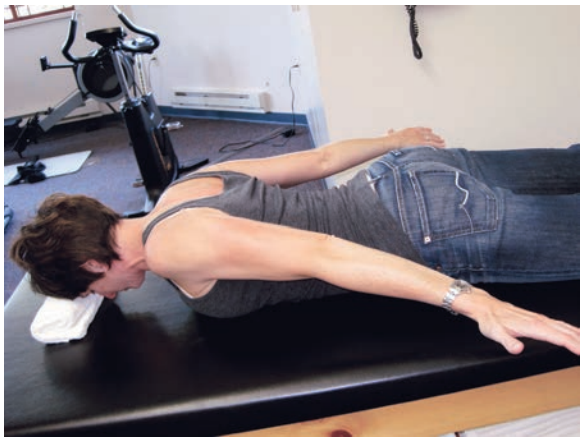

FIGURE 6-11. Prone extension with external rotation for middle trapezius and lower trapezius neuromuscular reeducation, strengthening and restoration of trapezius muscle imbalances.

  - Phase 1 of scapular muscle training involves restoring normal resting position and proprioception exercises with the arm at the side.
  - Phase 2 focuses on muscle control and normalizing muscle imbalances. Typically, the upper trapezius (UT) is overactive in comparison to the lower trapezius (LT), middle trapezius (MT) and serratus anterior (SA). Exercises that minimize the UT/LT, UT/MT and UT/SA ratios by selectively activating the less active muscle are ideal for this phase.[6,7]
  - Phase 3 of scapular muscle training includes general scapular muscle strengthening.
- Exercises appropriate for this phase of rotator cuff impingement:
  - Prone shoulder extension with external rotation. Focus on posterior tilting scapula and middle trap recruitment. Work endurance by encouraging 10-second static hold with each repetition and repeat 10 times; 1 to 2 times per day (Figure 6-11).
  - Side-lying external rotation with rolled towel under arm in a pain-free range of motion. Perform 3 sets of 10 to 15 repetitions. Perform 1 time per day. (Figure 6-12).
  - Scapular orientation exercises to focus on correcting faulty resting position should be performed several times per day to make it habit.



FIGURE 6-12. Side-lying external rotation with dumbbell.

Milestones for Progression to the Next Phase

- Shoulder AAROM/PROM restored and symmetric to contralateral shoulder.
- Shoulder active range of motion should be painless for internal and external rotation. End range flexion may still be painful caused by impingement and painful arc may still exist with abduction.
- Manual muscle testing of the rotator cuff should not be painful and should be at least 3 or greater on a 5 point scale for manual muscle test before progressing patient.
- Good scapular resting position which constitutes scapula is flush to the thorax without evidence of a scapular internal rotation (prominent medial border), anterior tilt (prominent inferior angle) or downward rotation (inferior angle closer to thoracic spine than superior angle).

Phase II: Intermediate Strengthening (weeks 2 to 8)

Goals

- Patients can begin strengthening in a completely pain-free manner: shoulder external, internal rotators, and scapular stabilizers. Strengthening should generally begin with the arm at the side and emphasize the small stabilization muscles as opposed to deltoid, pectorals, lats, etc.
- Patient must be able to demonstrate good scapular control with all strengthening exercises. When patient fails to maintain good scapular mechanics, it is a sign of fatigue or too rapid progression during this phase.
- Goal in this phase is to achieve full pain-free AROM.

Management of Pain and Swelling

- Continue modalities as recommended in Phase I as needed

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Manual therapy techniques should continue until patient has full, nonpainful ROM.
- Aggressive endrange joint mobilizations for patients with hypomobility may be required

Soft Tissue Techniques

- Continue as in Phase I
- To restore normal, pain-free AROM

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Stretching/flexibility exercises should continue until patient has full, nonpainful ROM.
- Continue exercises from Phase I as needed. Emphasis should be on self-capsular stretching and HEP during this phase.

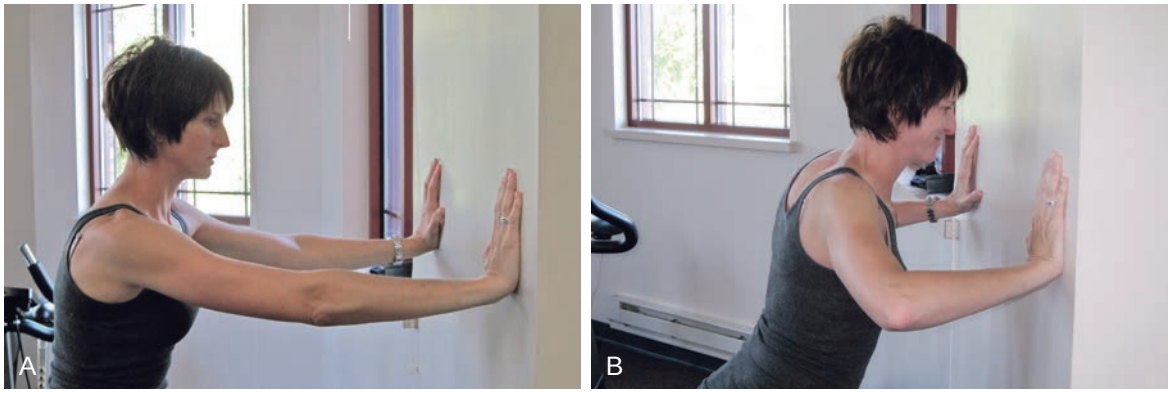

FIGURE 6-13. Wall pushup for serratus anterior strengthening.

- Once patient achieves this pain-free ROM, stretching/flexibility exercises should continue for maintenance of ROM and should be encouraged as part of HEP.

Other Therapeutic Exercises

- Progressive scapular stabilizer exercises that address patients' neuromuscular control deficits, weaknesses, or muscular imbalances.
  - Exercises focusing on lower trap facilitation and strengthening with low upper trap/lower trap ratio
    - Forward flexion in side-lying with dumbbell.
    - Prone horizontal abduction with external rotation. Add a dumbbell when appropriate.
  - Exercises focusing on middle trap strengthening with low upper trap/middle trap ratio
    - Prone extension with external rotation with dumbbells.
  - Wall pushup plus for serratus anterior (Figure 6-13)
- Progressive rotator cuff isotonics. Exercise prescription should be 3 sets of 15 to 20 reps to create a fatigue response as these muscles are designed to be fatigue resistant, and restoring muscular endurance is important for shoulder stabilization with repetitive overhead movements.[1]
  - Progress side-lying external rotation with dumbbell and towel roll under elbow
  - Begin standing Thera-Band internal and external rotation (Figures 6-14 and 6-15)
- Once patient can demonstrate good scapular control and minimal fatigue with 3 full sets of 20 of the progressive scapular stabilizer exercises and progressive rotator cuff isotonics, progress to the following exercises. The patient must be able to perform the following exercise with perfect scapular control. If the patient cannot demonstrate perfect control, the patient may need to begin with AROM with or without gravity.
  - Standing and/or prone full can scaption with dumbbell for supraspinatus[8]
  - Prone external rotation at 90° abduction with dumbbell for infraspinatus[8]
- Final progression includes the start of multiple angle submaximal strengthening such as D2 flexion PNF with Thera-Band with good scapular control (Figure 6-16).

Activation of Primary Muscles Involved

- Muscle activation/strengthening of lower trap, middle trap, and serratus anterior muscles to improve scapular mechanics/upward rotation with overhead activities.
- Strengthening of the rotator cuff muscles are necessary to improve or normalize glenohumeral joint stability



FIGURE 6-14. Thera-Band internal rotation at 0° abduction with towel roll to increase the subacromial space.



FIGURE 6-15. Thera-Band external rotation 0° abduction with towel roll to increase subacromial space and optimize infraspinatus muscle activity.

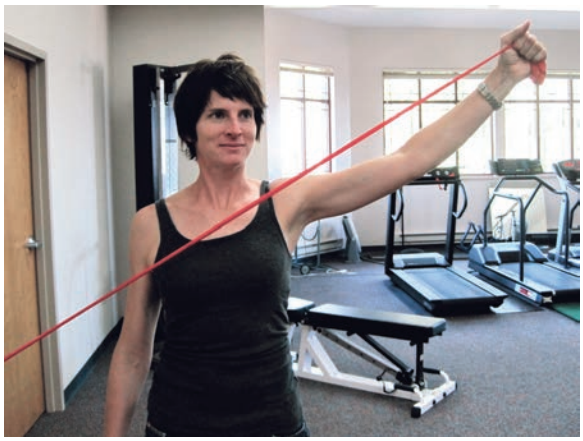

FIGURE 6-16. Thera-Band diagonal 2 flexion PNF for combined glenohumeral joint flexion, external rotation, and horizontal abduction and scapular upward rotation.

and arthrokinematics. Since impingement syndrome often leads to specific weakening of the supraspinatus and infraspinatus muscles caused by impingement on their tendons in the subacromial space, special attention should be given to these muscles.

Sensorimotor Exercises

- Begin with rhythmic stabilization—3 sets for 30 to 60 seconds
- Progress to higher level closed kinetic chain (CKC) stabilization exercises—3 sets for 30 to 60 seconds
  - Stabilization exercises using small medicine ball against the wall with manual perturbations (Figure 6-17).



FIGURE 6-17. Rhythmic stabilization with medicine ball against the wall at 90° abduction using the scapular plane. Perturbations applied until fatigue.



FIGURE 6-18. Bodyblade stabilization in the 90°/90° position using the scapular plane.

Techniques to Increase Muscle Strength, Power, and Endurance

- Begin rotator cuff endurance exercises. Exercises should be done for 3 reps of 30 to 60 seconds at a time or until fatigued.[1]
  - Bodyblade—IR/ER at 0° abduction with progression to IR/ER at 90° abduction (Figure 6-18)
  - TB external rotation oscillation (Figure 6-19)

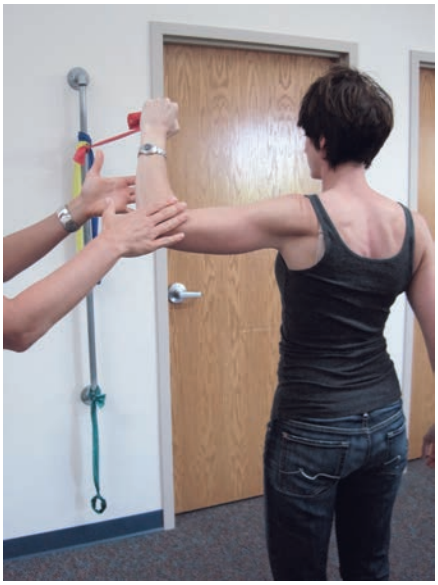

FIGURE 6-19. Stabilization exercise with perturbations applied while the patient maintains their upper extremity in the 90°/90° position using the scapular plane.

Milestones for Progression to the Next Phase

- Full, nonpainful AROM
- Seventy percent strength compared to contralateral side. The most valid and reliable measurement would be to use a hand-held dynamometer for manual muscle tests of all shoulder muscles (including rotator cuff muscles, biceps, triceps, and deltoids), and then comparing the results to the contralateral side.
- No pain or tenderness

Phase III: Advanced Strengthening (weeks 6 to 24)

Goals

- Goals of this phase of rehabilitation are to regain full shoulder strength. The patient should be able to resume all daily activities with no pain, weakness, or fatigue issues after this phase. Most patients do not require formal physical therapy beyond this phase unless they plan to return to higher-level sport, activity, or vocation.

Techniques for Progressive Increase in Range of Motion

- Patient should have full AROM/PROM in all planes and independence with a stretching/flexibility program for maintenance at this point.

Manual Therapy Techniques

- Continue as in Phases I and II for maintenance of ROM as needed.

Soft Tissue Techniques

- Continue as in Phases I and II for maintenance of ROM as needed.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Continue as in Phases I and II for maintenance of ROM as needed.

Other Therapeutic Exercises

- Progress rotator cuff isotonics
  - Increase weight or resistance of side-lying ER, Thera-Band IR/ER at neutral but keep repetitions high (3 sets of 10 or more repetitions, 3 times a week) as the rotator cuff is an endurance group of muscles.
  - Progress to Thera-Band IR/ER at 90° abduction—3 sets of 10 or more repetitions. Do 3 times a week.
  - Prone horizontal abduction in 135° abduction with external rotation—10 times 10-second holds, once a day
- Progress serratus anterior strengthening to quadruped or plank position—3 times 10 reps; 3 times a week
- Progress scapular stabilizer strengthening exercises
  - High and low rows for upper trap, middle trap and lower trap strengthening—3 times 10 reps; 3 times a week
  - Military press for upper trap strengthening—3 times 10 reps; 3 times a week

Activation of Primary Muscles Involved

- Progression of exercises should be towards doing exercises at 90° abduction in scapular plane especially when preparing an athlete to return to overhead sports.[1]

Sensorimotor Exercises

- Stabilization on wobbleboard in quadruped or plank position with manual perturbations—3 times 30-second holds; 3 times a week
- Perturbations throughout range with many exercises (D2 flexion, ER/IR with Thera-Band, etc.)
- Stabilization on stability ball—3 times 30-second holds; 3 times a week

Techniques to Increase Muscle Strength, Power, and Endurance

- Progress rotator cuff endurance exercises
  - Thera-Band external rotation stabilization exercise in 90°/90° position and manual perturbations by therapist—3 times 30- to 60-second holds with good scapular positioning.[1]
  - Isokinetic internal and external rotation strengthening if available

Plyometrics

- Initiate upper extremity plyometrics late in this phase of rehab only if patient plans to return to overhead athletics/vocation.
  - Trampoline toss and catch with light medicine ball—shoulder in 90°/90° position (Figure 6-20)
  - Supine catch and toss with medicine ball with shoulder in 90°/90° position
  - Eccentric internal and external rotation TB exercises with medicine ball or Thera-Band focusing on both cocking and follow-through phases of throwing/overhead sports

Milestones for Progression to Advanced Sport-Specific Training and Conditioning

- Full, nonpainful AROM
- Full shoulder strength and endurance
- No pain or tenderness
- Satisfactory clinical examination
- Able to resume all daily activities with no problems

Phase IV: Return to Sport/Vocation (weeks 24 and beyond)

- This phase of rehabilitation is only necessary for patients hoping to return to sport or high level manual labor vocations.
- Rehab focuses on sport-specific training and improving full body cardiovascular endurance, power, and strength.
- This phase may include a work hardening/work conditioning program and functional capacity evaluation or

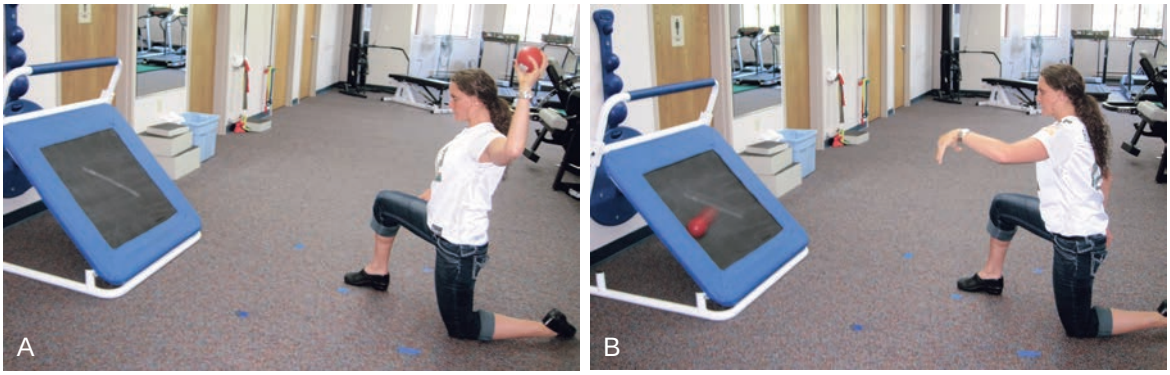

FIGURE 6-20. Medicine ball toss using rebounder for upper extremity plyometric training.

a progressive throwing, golf, or tennis program, etc. (see following sections).

Specific Criteria for Return to Sports Participation: Tests and Measurements

- At this point, the athlete should have full shoulder strength and endurance compared to contralateral side as evidenced by hand-held dynamometry measurements.
- Depending on their sport, athletes should pass specific upper extremity functional tests before returning. Examples include:
  - Closed kinetic chain upper extremity stability test (applies to any sport using upper extremities)
  - Seated shot put test (applies to any sport using upper extremities)
  - Functional throwing performance index (for baseball players)
  - Underkoeffler overhand softball throw (for softball players)
- Completion of interval program for the patient's specific sport. Brotzman and Wilk's *Clinical Orthopaedic Rehabilitation*, ed 2, 2009, *(pages 189–195)* provides several interval programs including a program for pitchers, a program for catchers, infielders, and outfielders, a program for tennis players, and a program for golfers.
- Returning to sport is dependent on the specific sport and the level of competition.

Evidence

Boettcher C, Ginn K, Cathers I: Which is the optimal exercise to strengthen supraspinatus? *Med Sci Sports Exerc* 41:1979–1983, 2009.

This article supports the use of selected rotator cuff and deltoid strengthening exercises based on their EMG results of five different exercises. (Level IV evidence)

Cools A, Dewitte V, Lanszweert F, et al: Rehabilitation of scapular muscle balance: Which exercises to prescribe? *Am J Sports Med* 35:1744–1751, 2007.

This controlled laboratory study looked at electromyographic activity of the upper trap, middle trap, lower trap, and serratus anterior muscles in 45 subjects during 12 commonly prescribed exercises. This study stresses selecting exercises in rehabilitation that not only strengthen weaker muscles but that also strengthen muscles to optimize muscle ratios of upper trap to lower trap, middle trap, and serratus anterior in individuals demonstrating muscle imbalances. This article supports the use of specific exercises with a low upper trap/lower trap ratio in patients diagnosed with subacromial impingement and demonstrate upper trapezius dominance. (Level IV evidence)

Ellenbecker T, Cools A: Rehabilitation of shoulder impingement syndrome and rotator cuff injuries: an evidence-based review. *Br J Sports Med* 44:319–327, 2010.

This comprehensive review of the literature supports the use of using a comprehensive evaluation to drive the treatment of athletes with shoulder impingement and suggest that treatment should be multifactorial including techniques to restore ROM, rotator cuff and scapular strength and glenohumeral joint stabilization. (Level V evidence)

Kelly S, Wrightson P: Clinical outcomes of exercise in the management of subacromial impingement syndrome: a systematic review. *Clin Rehabil* 24:99–109, 2010.

This review of eight studies that used exercise in the treatment of subacromial impingement syndrome suggests that exercise treatment is an effective treatment to some degree but suggests lack of consistency for exercise prescription including type of exercise, repetitions, supervision and length of programs. (Level 1A evidence)

Kibler B, Sciascia A: Current concepts: scapular dyskinesis. *Br J Sports Med* 44:300–305, 2010.

This article describes the role of the scapular as it relates to normal glenohumeral rhythm and supports the use of evaluating and treating scapular movement dysfunction when treating patients with shoulder impingement. (Level V evidence)

Kromer T, Tautenhahn U, deBie R, et al: Effects of physiotherapy in patients with shoulder impingement syndrome: A systematic review of the literature. *J Rehabil Med* 41:870–880, 2009.

This review of 16 randomized controlled trials of common physiotherapy interventions for shoulder impingement syndrome supports the use of physiotherapist-led exercises in combination with manual therapy for effective treatment of shoulder impingement. The review also determined limited evidence for the use of passive modalities including

ultrasound, low-level laser therapy, and electromagnetic field therapy. (Level 1A evidence)

Lombardi I, Guarnieri A, Fleury A, et al: Progressive resistance training in patients with shoulder impingement syndrome: A randomized controlled trial. *Arthritis Rheum* 59:615–622, 2008.

This randomized controlled trial of 60 patients diagnosed with shoulder impingement syndrome supports the use of a progressive resistance-training program as an effective treatment in improving pain, function, and quality of life. (Level 1B evidence)

Selkowitz DM, Chaney C, Stuckey SJ, et al: The effects of scapular taping on the surface electromyographic signal amplitude of shoulder girdle muscles during upper extremity elevation in individuals with suspected shoulder impingement syndrome. *J Orthop Sports Phys Ther* 11:694–702, 2007.

This multifactorial, repeated-measures, within-subjects design study discusses how scapular taping decreases upper trapezius and lower trapezius muscle activity in subjects with suspected shoulder impingement during functional overhead activity. (Level IV evidence)

Senbursa G, Baltaci G, Atay A: Comparison of conservative treatment with and without manual physical therapy for patients with shoulder impingement syndrome: a prospective, randomized clinical trial. *Knee Surg Sports Traumatol Arthrosc* 15:915–921, 2007.

This randomized control trial suggests that manual therapy consisting of joint mobilization and soft tissue mobilization in conjunction with a 12 session stretching and strengthening program is superior to exercise alone for improvements in pain and shoulder function. (Level IIB evidence)

Tate A, McClure P, Young I, et al: Comprehensive impairment-based exercise and manual therapy intervention for patients with subacromial impingement syndrome: a case series. *J Orthop Sports Phys Ther* 40:474–493, 2010.

This case series supports the use of a comprehensive impairment-based treatment philosophy in patients diagnosed with subacromial impingement syndrome. Eight of ten patients demonstrated improvements in shoulder symptoms and function with the use of a three-phase strengthening program in conjunction with manual stretching and manual therapy techniques for both the thoracic spine and the glenohumeral joint. (Level IV evidence)

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Multiple-Choice Questions

QUESTION 1. What is the purpose of using grade III and IV joint mobilizations to the glenohumeral joint?

A. To gain all motion not equal to contralateral extremity
B. To treat the hypomobile shoulder with firm capsular end feel
C. To facilitate proprioception and neuromuscular control
D. To treat motion losses with empty end feel

QUESTION 2. To measure glenohumeral internal rotation:

A. Allow scapular motion with glenohumeral motion since it is more functional
B. Measure in side-lying since the scapula is stabilized by the patient's body
C. There is no need to measure internal rotation; it is not a useful motion for the athlete
D. Avoid scapular contribution and measure in the scapular plane

QUESTION 3. The most common scapular dyskinesis pattern is:

A. Anterior tilt, upward rotation, and external rotation
B. Posterior tilt, upward rotation, and internal rotation
C. Anterior tilt, downward rotation, and internal rotation
D. Anterior tilt, downward rotation, and external rotation

QUESTION 4. Lack of neuromuscular control and strength of which muscles are thought to contribute most to scapular dyskinesis?

A. Serratus anterior and lower trapezius
B. Middle trapezius and rhomboids
C. Upper trapezius and serratus anterior
D. Middle trapezius and lower trapezius

Answer Key

QUESTION 1. Correct answer: **B** (see Phase I)

QUESTION 2. Correct answer: **D** (see Phase I: Stretching Techniques)

QUESTION 3. Correct answer: **C** (see Phase I)

QUESTION 4. Correct answer: **A** (see Phase I)

POSTOPERATIVE REHABILITATION AFTER SUBACROMIAL DECOMPRESSION

Stephen C. Weber, MD, and Donald Torrey, PT

Indications for Surgical Treatment

- Failure of nonoperative treatment over 3 to 6 months
- Persistent activity-related pain that limits function
- Previous attempts at nonoperative care, including nonsteroidals, activity modification, and a consistent rehabilitation program
- Although prospective studies have found it difficult to establish the long-term benefits of steroid injections, the authors' experience would indicate minimal risk and general benefit to their use in both diagnosis and treatment
- Normal passive range of motion
- Imaging studies negative for other findings, and consistent with the diagnosis of impingement, such as appropriate acromial morphology on radiographs (Figure 6-21), and imaging findings on MRI consistent with impingement
- Temporary pain relief with the instillation of local anesthetic into the subacromial space

Brief Summary of Surgical Treatment

Major Surgical Steps

- General anesthesia or scalene block at the preference of the surgeon
- Lateral decubitus or beach chair position
- Diagnostic arthroscopy to establish pathology, and to rule out other causes of shoulder pain
- Treat associated intraarticular lesions as indicated
- Arthroscope is then shifted to the subacromial space, and other subacromial pathology excluded (Figure 6-22)
- Transection or anterior release of the coracoacromial ligament
- Inflamed bursal tissue (usually anterior half) is removed with a shaver or radiofrequency wand
- Viewing posteriorly, initially remove 4 to 8 mm of the undersurface of the anterolateral acromion, depending on preoperative radiographs
- Anterior acromion removed to this level and flush with remaining acromion
- Avoid acromioclavicular (AC) joint unless this joint is symptomatic. However, a coplaning can be done to remove an inferior osteophyte at the AC joint that may also be causing "impingement" of the rotator cuff
- Scope switched to anterolateral portal, and using "cutting block" technique the acromioplasty completed (Figure 6-23); ensure that enough bone remains so that the risk of fracture (and stress fracture) is minimized
- Sling for comfort postoperatively

Factors That May Affect Rehabilitation

Anesthetic

- Regional anesthesia can create issues with rebound pain and other unique complications to this anesthetic



FIGURE 6-21. Scapular lateral film, showing acromial prominence.

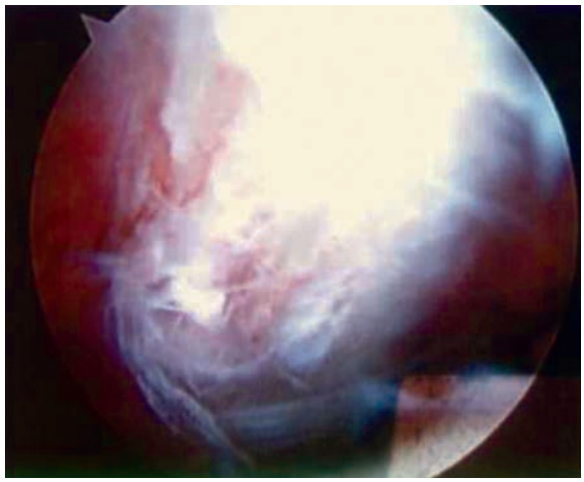

FIGURE 6-22. Preoperative view of undersurface of acromion, suggesting impingement.

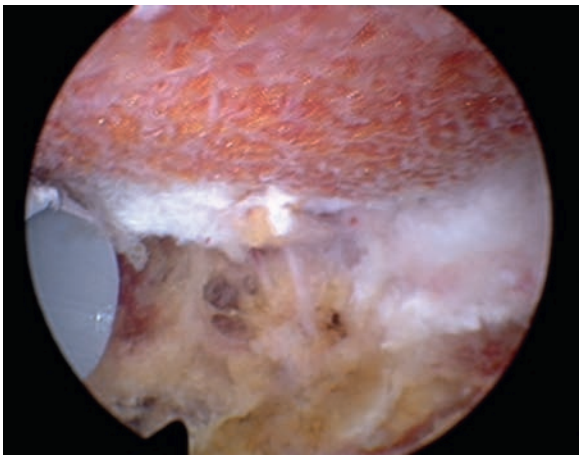

FIGURE 6-23. Completed acromioplasty, viewed from posterior.

Surgical

- Ancillary procedures performed, such as labral or rotator cuff repair, may impose restrictions on early mobilization.
- If case is performed open, additional restrictions may apply to protect from injury to the attachment of the deltoid.

GUIDING PRINCIPLES OF POSTOPERATIVE REHABILITATION

- Understand whether the procedure involves simple acromioplasty, or repair of other structures that require additional rehabilitation restrictions
- Although early motion is permitted, forced passive motion or early strengthening inhibit the healing process and can actually cause stiffness and protracted recovery
- One needs to respect rate of ROM progression within these guidelines

After Surgery—Postoperative Rehabilitation: Overview of Goals, Important Milestones, and Guidelines

See Table 6-1.

Table 6-1 Postoperative Rehabilitation Guidelines

Postoperative Time	Immobilization	ROM, rehab	Restrictions
0–14 days	Sling as needed	Pendulum exercises	ADLS
2–4 weeks	None	Passive and active assisted ROM	ADLS, LE exercises only, stationary bike for aerobic exercise
4–8 weeks	None	Thera-Band exercises	Add running
8–12 weeks	None	Assisted stretching if not full ROM	Avoid overhead weight work sport-specific exercise
>12 weeks	None	Resume full ROM	Sport-specific exercise until return to sport unrestricted

Phase I: Immediate Postoperative Period (days 0 to 14)

Clinical Pearls

- Patients need to be carefully monitored for stiffness regularly (no more than 3-week intervals). Early gentle ROM to minimize long-term problems is helpful. Early recognition of the development of postoperative stiffness can minimize this complication.
- Passive stretching is to be avoided early to prevent increased pain and inflammation that can lead to later stiffness and prolonged recovery.

Goals

- Minimize the effects of immobilization
- Decrease pain and inflammation
- Check for signs of complications (infection, neurologic injury, poor pain management). Review of postoperative scapular lateral radiograph can identify any early complications or inadequate bone resection. If these issues are not a problem, the next phase can be initiated.

Protection

- Sling as needed for comfort
- No other protection needed for isolated acromioplasty

Management of Pain and Swelling

- Pain pumps are generally contraindicated
- Oral pain medications or tylenol
- As nonsteroidals can inhibit healing and decrease platelet function, these should be avoided for 5 to 7 days
- Ice every 20 minutes an hour is reasonable
- Cryotherapy units can burn skin and are outside FDA black box warning for 24 hours postoperatively if any local anesthetics are used
- Patient Education: Using pillows or bolsters to find a position of comfort; sleep is often aided by a more vertical positioning

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Codman's Pendulum exercises are generally adequate
- Exercises for hand, wrist and elbow can be initiated

Other Therapeutic Exercises

- Stationary biking can begin immediately after surgery
- LE strength training with machines
- Treadmill walking in sling as tolerated

Phase II (weeks 2 to 4)

Goals

- Maintain program of treatment of pain and inflammation
- Minimize effects of early loss of motion
- Decreasing pain and improving ROM

Protection

- Sling can be discontinued

Management of Pain and Swelling

- Oral narcotics can be tapered or discontinued
- Continue nonsteroidals or Tylenol
- Although modalities can be useful, they are not a substitute for a supervised home therapy program

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Patients are instructed in active-assisted ROM exercises with a pulley and stick (Figure 6-24)



FIGURE 6-24. Use of pulleys to improved external rotation.

- These are to be performed several times a day
- Exercises for hand, wrist, and elbow to continue

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Passive stretching to be avoided

Phase III (weeks 4 to 8)

Goals

- AROM 150° forward flexion
- AROM 50° external rotation arm at side
- Normalizing glenohumeral and scapulothoracic mechanics
- Initiation of strengthening exercises

Management of Pain and Swelling

- Nonsteroidals as indicated
- Ice as needed 20 minutes an hour and post exercise 2 to 3 times a day
- Heat before initiation of stretching and exercise

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Done as needed, primarily for patients having trouble with ROM. If needed, a prescription for 1 to 2 times per week normally will start at 3 weeks if not improving. Less than 20% of patients should need help.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Pulley and wand exercises continue, with table slides, and wall walking exercises. All ROM exercises are done for 3 minutes 3 times per day. ROM work usually lasts for 1 to 2 months.

Techniques to Increase Muscle Strength, Power, and Endurance

- Thera-Band exercises begin in flexion, internal, external rotation and extension. Exercises are done 45 to 60 reps per day in sets of 15 (Figure 6-25 and 6-26).
- Keep all exercises below 90° plane.
- Attention to scapular stabilization by doing exercises in mirror if necessary.

TIMELINE 6-2: **Postoperative Rehabilitation After Subacromial Decompression**

PHASE I (days 0 to 14)	PHASE II (weeks 2 to 4)
• Sling as needed • Ice • Codman's pendulum exercises • Stationary bike	• Sling discontinued • Pulley and wand exercises • Modalities if needed

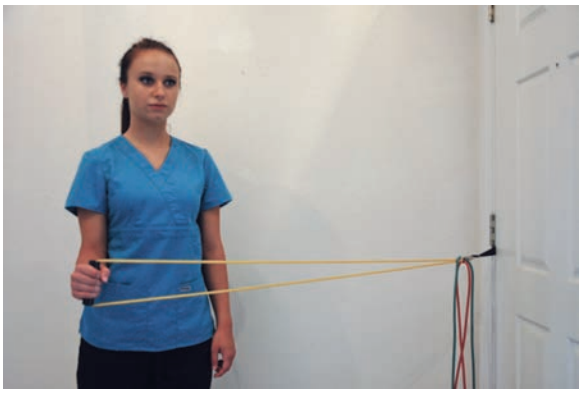

FIGURE 6-25. Band exercises for external rotational exercises.

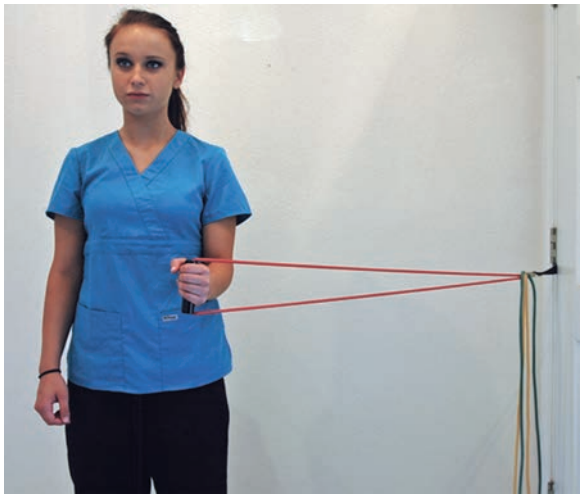

FIGURE 6-26. Band exercises for internal rotation strengthening.

- Scapular stabilization exercises
- Band exercises only for first 6 weeks minimum; lasts 2 to 3 months

Phase IV (weeks 8 to 12)

Clinical Pearls

- If full passive ROM has not been achieved, passive stretching can be initiated at this time. Heat and modalities can be helpful, but are not required. Focus at this point on passive stretching can avoid later complications with stiffness requiring later manipulation or arthroscopic release.
- Studies have demonstrated that athletes who maintain appropriate scapulothoracic mechanics have significantly less injury. Avoiding loss of motion, especially internal rotation, can prevent development of glenohumeral internal rotation deficit (GIRD) and subsequent impingement.

Goals

- Normal scapulohumeral rhythm
- Full PROM in all planes
- AROM near full with minimal pain
- Strength MMT 4/5 in all planes

Management of Pain and Swelling

- Oral NSAIDs, Tylenol
- If pain continues to be a limiting factor, the patient should be returned to the surgeon for reassessment
- Soft tissue techniques can be useful, but vigorous release techniques are generally counterproductive
- Scar mobilization reasonable

Other Therapeutic Exercises

- Sport-specific exercises can be initiated for upper extremity work such as Jobe exercises using a gradual approach limiting resistance and increasing repetitions
- High intensity above shoulder resistance work should be avoided until 12 weeks

Phase V (weeks 12+)

Management of Pain and Swelling

- Ice application postexercise

Techniques for Progressive Increase in Range of Motion

- Patients should have achieved full AROM by this time

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Passive stretching to continue if indicated

Techniques to Increase Muscle Strength, Power, and Endurance

- Although impingement is not generally a diagnosis of young throwing athletes, throwing athletes may begin

TIMELINE 6-2: Postoperative Rehabilitation After Subacromial Decompression (Continued)

PHASE III (weeks 4 to 8)	PHASE IV (weeks 8 to 12)	PHASE V (weeks 12+)
• Continue pulley and wand exercises • Start Thera-Band exercises • Hold other upper extremity exercises	• Continue pulley and wand exercises • Continue Thera-Band exercises; initiate low resistance, high repetition exercise program below shoulder level • If full PROM not present, initiate gentle passive stretching exercises • Attention to scapular mechanics	• Continue Thera-band • Start sport-specific exercise programs, Jobe exercises • Monitor return to sports carefully

light tossing at shorter distances and are instructed to avoid full windup throws until 20 weeks postoperatively. Interval training programs can be useful. Limited overhead stroke work for swimmers, tennis, and volleyball players.
- Progression of throwing intensity may begin at 14 to 16 weeks as long as the patient demonstrates good mechanics. Throwing should be closely monitored and discontinued if the athlete exhibits any compensatory movement patterns or shoulder girdle discomfort. Resumption of other overhead sports can be managed similarly.
- Progression to formal strength and conditioning commences once athletes have 4+/5 rotator cuff strength, full AROM, and are pain-free with activity.

Criteria for Return to Sport

General

- Normal scapulothoracic and glenohumeral mechanics
- Full AROM
- Normal strength to manual muscle testing
- Athletes at risk can benefit from isokinetic testing, emphasizing a 90% or better side-to-side difference in internal and external rotation.

Sport-Specific

- Coaches and trainers can be helpful in assessing specific sport rehab issues
- Although no hard and fast rules apply, most patients without appropriate supervision return too soon, and reinjure or inflame previously injured or operated structures

After Return to Sport

Continuing Fitness or Rehabilitation Exercises

- Total upper extremity and total body strengthening exercises

Exercises and Other Techniques for Prevention of Recurrent Injury

- Prevention of injury is best accomplished by maintaining the shoulder rehabilitation program throughout athletic participation, with specific emphasis on rotator cuff strengthening.

Evidence

Andersen NH, Søjbjerg JO, Johannsen HV, et al: Self-training versus physiotherapist-supervised rehabilitation of the shoulder in patients treated with arthroscopic subacromial decompression: A clinical randomized study. *J Shoulder Elbow Surg* 8:99–101, 1999.

Small level 1 study with no significant difference between two groups in regards to outcome. (Level I evidence)

Bang M, Deyle G: Comparison of supervised exercise with and without manual physical therapy for patients with impingement syndrome. *J Ortho Sports Phys Ther* 30:126–137, 2000.

Although applied to nonoperative patients, this small, nonrandomized study showed a significant improvement with supervised physical therapy over exercises alone for impingement syndrome in some but not all areas. (Level I evidence)

Burkhart SS, Morgan CD, Kibler WB: The disabled throwing shoulder: spectrum of pathology part III: the SICK scapula, scapular dyskinesis, the kinetic chain, and rehabilitation. *Arthroscopy* 19:641–661, 2003.

Classic review article on the importance of scapular mechanics to overhead throwing disability. (Review article of level IV article with level V commentary)

Ellman H: Arthroscopic subacromial decompression: Analysis of 1- to 3-year results. *Arthroscopy* 3:173–181, 1987.

Original work on arthroscopic acromioplasty. (Level IV evidence)

Kirkley A, Litchfield RB, Jackowski DM, et al: The use of the impingement test as a predictor of outcome following subacromial decompression for rotator cuff tendinosis. *Arthroscopy* 18:8–15, 2002.

Prospective, randomized series representing the use of steroid injection in the diagnosis of impingement, showing poor predictability despite widespread clinical use. (Level IV evidence)

Kuhn J: Exercise in the treatment of rotator cuff impingement: A systematic review and a synthesized evidence-based rehabilitation protocol. *J Shoulder Elbow Surg* 18:138–160, 2009.

A systematic review of the literature was performed to evaluate the role of exercise in treating rotator cuff impingement and to synthesize a standard evidence-based rehabilitation protocol. Eleven randomized, controlled trials evaluating the effect of exercise in the treatment of impingement. Supervised exercise was not different than home exercise programs. (Level 1 and 2 evidence)

Laudner KG, Pasquale MR, Bradley JP, et al: Scapular dysfunction in throwers with pathologic internal impingement. *J Orthop Sports Phys Ther* 36:485–494, 2009.

Throwing athletes diagnosed with pathologic internal impingement present with statistically significant increases in sternoclavicular elevation and scapular posterior tilt position during humeral elevation in the scapular plane. (Level IV evidence)

Mulieri PJ, Holcomb JO, MD, et al: Is a formal physical therapy program necessary after total shoulder arthroplasty for osteoarthritis? *J Shoulder Elbow Surg* 19:570–579, 2010.

Study showing no difference in supervised versus home program for shoulder arthroplasty rehabilitation. (Level III case controlled series evidence)

Neer CS: Anterior acromioplasty for the chronic impingement syndrome in the shoulder. *J Bone Joint Surg Am* 54:41–50, 1972.

This represents the original description and treatment guidelines for this clinical condition. (Level IV evidence)

Tate AR, Kareha S, Irwin D, et al: Effect of the scapula reposition test on shoulder impingement symptoms and elevation

strength in overhead athletes. *J Orthop Sports Phys Ther* 38:4–11, 2008.

A study to determine whether manually repositioning the scapula using the Scapula Reposition Test (SRT) reduces pain and increases shoulder elevation strength in athletes with and without positive signs of shoulder. (Level IV evidence)

Tate AR, McClure PW, Young IA, et al: Comprehensive impairment-based exercise and manual therapy intervention for patients with subacromial impingement syndrome: A case series. *J Orthop Sports Phys Ther* 40:474–493, 2010.

A program aimed at strengthening rotator cuff and scapular muscles, with stretching and manual therapy aimed at thoracic spine and the posterior and inferior soft-tissue structures of the glenohumeral joint appeared to be successful in the majority of patients. (Level IV evidence)

Multiple-Choice Questions

QUESTION 1. The diagnosis of impingement is made by:

A. Normal passive range of motion
B. Imaging studies negative for other causes of pain
C. Pain relief with subacromial lidocaine injection
D. All of the above

QUESTION 2. Correct surgical technique for acromioplasty:

A. Can only be done beach chair
B. Always involves resection of the distal clavicle
C. Use of "cutting block" technique
D. Can be done blindly if visualization is poor

QUESTION 3. Postoperative pain and swelling can be managed by:

A. Immediate use of nonsteroidals
B. Pain pumps
C. Cryotherapy pumps
D. Oral pain meds or tylenol

QUESTION 4. Scapulothoracic function _____:

A. Is not important
B. If dysfunctional usually represents a nerve injury
C. Can be related to glenohumeral internal rotation deficits (GIRD)
D. Requires manual therapy

QUESTION 5. Return to sport varies, but must involve:

A. Full ROM
B. Normal strength
C. No pain
D. All of the above

Answer Key

QUESTION 1. Correct answer: **D** (see Indications for Surgical Treatment)

QUESTION 2. Correct answer: **C** (see Surgical Technique)

QUESTION 3. Correct answer: **D** (see Phase I: Management of Pain and Swelling)

QUESTION 4. Correct answer: **C** (see Phase IV)

QUESTION 5. Correct answer: **D** (see Criteria for Return to Sport)

BEYOND BASIC REHABILITATION: RETURN TO PITCHING AFTER SUBACROMIAL DECOMPRESSION

Michael G. Ciccotti, MD, and Scott P. Sheridan, PT, ATC, CSCS

Introduction

- The overhead or throwing athlete is exposed to a tremendous variety of forces during the act of throwing. This complex baseball throwing motion has been thoroughly evaluated by multiple authors.[1–3]
- The precise shoulder muscle activity in each of the five phases of pitching (Figure 6-27) has been defined by several electromyographic studies.[2,4]
- Other authors have identified the importance of the scapula, core, hips, and legs in this activity[5–8] Kibler[9] has described this Kinetic Chain Theory wherein the force imparted on a ball begins at the ground, is amplified through the legs, hips and core, and transmitted to the upper extremity via the shoulder.
- Most often there is a precise balance in the musculoskeletal system that allows these athletes to perform this throwing maneuver painlessly and effectively. Not infrequently, though, that balance may be lost and injury may occur.
- This injury takes a wide spectrum of form that often involves the rotator cuff and presents with impingement-like symptoms.
- The etiologic factors vary from primary rotator cuff tendon failure, altered scapular mechanics, posterior capsular and posterior rotator cuff contracture, anterior

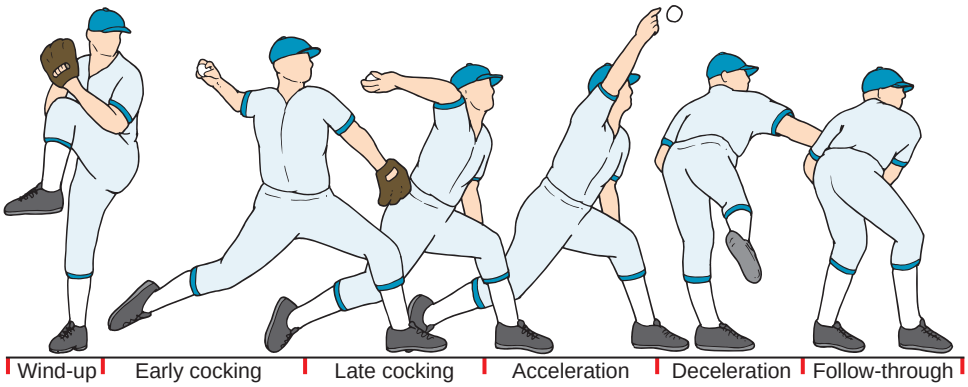

FIGURE 6-27. The phases of throwing. *(Redrawn from Ciccotti MG, Jobe FW. Medial collateral ligament instability and ulnar neuritis in the athlete's elbow. American Academy of Orthopedic Surgery Instructional Course Lectures 48:384, 1999, figure 1.)*

capsular strain or laxity, labral fraying and tearing, to even infrequently primary subacromial impingement.

- Primary subacromial impingement is defined as a repetitive injury to the anterolateral aspect of the rotator cuff (especially the supraspinatus portion) caused by supraspinatus outlet narrowing.
- Kibler has proposed that the subacromial space is a dynamic region whose borders are affected by numerous intrinsic and extrinsic factors.[10]
- Intrinsic factors occur within the subacromial space and include acromial bone spurs, coracoacromial ligament hypertrophy, bursitis, calcific enthesopathy, and os acromiale.
- Extrinsic factors occur beyond the subacromial space and include superior humeral head translation or altered scapulothoracic rhythm. Superior humeral head translation may result from rotator cuff tear or tendonopathy or labral injury. Altered scapulothoracic rhythm may be a result of glenohumeral instability, perishoulder contracture or inflexibility, scapular dyskinesis, acromioclavicular arthrosis or instability, biceps tendonopathy, or neurologic injury.
- Rotator cuff impingement in the throwing athlete may be the result of any number of these etiologic factors occurring concomitantly. The thrower may be exposed to a cascade of events that result in some combination of several or all of these pathologies.[11] With repetitive throwing, rotator cuff and periscapular muscle weakness can develop. With this a posterior capsular and/or rotator cuff contracture or inflexibility ensues. In throwing athletes with these two events, a posterior superior humeral instability occurs when the arm is abducted and externally rotated in the throwing mechanism. This creates an extrinsic subacromial impingement and glenohumeral peel back mechanism. This peel back force can lead to superior labral and posterior superior rotator cuff fraying or tearing. Although several pathologies may be present in these athletes, the main presentation may be that of subacromial impingement.
- Previous sections in this chapter have outlined nonsurgical rehabilitation of rotator cuff impingement syndrome. If this structured nonsurgical protocol does not allow the athlete to return to preinjury performance, then surgical treatment may be necessary.
- Surgical treatment focuses on the specific pathologies present. For those overhead or throwing athletes with primary, intrinsic subacromial impingement, subacromial decompression has been proposed.[12–15]
- Initial reports on subacromial decompression in the overhead athletic population have noted inconsistent outcomes.[12–15] These authors suggest this may be a reflection of the complex nature of this injury in the throwing athlete, which most often involves several of the previously described, inter-related pathologies. All of these factors require focused attention for a truly successful postoperative outcome.
- In throwers, primary impingement is most likely to be an incomplete diagnosis, with varying degrees of rotator cuff injury, labral fraying or tearing, posterior capsular or rotator cuff contracture, and even anterior capsular laxity present. These shoulder-specific, concomitant pathologies may require focused surgical attention as well, including rotator cuff debridement or repair, labral debridement or repair, posterior capsular release, or infrequently even anterior capsular plication.[16–22]
- Furthermore, nonshoulder sources of disability such as core, hip, and leg weakness or inflexibility may be present in the throwing athlete. These nonshoulder abnormalities mandate focused attention in the postsurgical rehabilitation program after subacromial decompression. And, in fact, failure to correct these issues may be just as likely as the specific surgical technique to prevent a throwing athlete from returning to preinjury level of sport.

Postsurgical Rehabilitation Program

- The postsurgical rehabilitation after subacromial decompression depends on the specific surgical treatment performed.
- For those throwers with primary, intrinsic subacromial impingement having undergone isolated subacromial decompression with, at most, debridement of the rotator cuff or labrum, the postsurgical rehabilitation follows principles similar to nonsurgical rehabilitation.

- For those throwers undergoing concomitant rotator cuff or labral repair, special attention is focused on allowing biologic healing while preventing capsular contracture and muscular weakness. In addition, postsurgical rehabilitation after subacromial decompression in the throwing athlete necessitates attention to the extrinsic and nonshoulder factors described previously. Therefore, the rationale for the phased, progressive postsurgical rehabilitation after subacromial decompression in the throwing athlete is predicated on the specific contributing pathologies, the individual demands of throwing, and known biomechanical and kinesiologic principles.
- The purpose of this chapter is to discuss the end stages of rehabilitation after subacromial decompression in the throwing athlete. The acute and intermediate phases of rehabilitation have been discussed in the previous chapter. (see Chapter 6: Post Surgical Rehabilitation after Subacromial Decompression). However, it will be important to complete a thorough review of what has been accomplished in those phases and what should be evaluated to determine the readiness of an athlete to progress to the functional phase of rehabilitation after this surgical procedure.
- The basic goals that should have been accomplished in the initial phases of rehabilitation are full, pain-free arc of motion, ability to complete basic rotator cuff and scapular stability exercises without symptoms, and total body conditioning that is expected for baseball.
- Range of motion is particularly important in throwers. Of concern is placing the shoulder at risk by not properly identifying glenohumeral internal rotation deficit (GIRD) or changes in total rotational motion (TRM). GIRD, as defined by Burkhart et al.[7], is a greater than 20° loss of internal rotation on the throwing shoulder in comparison to the nonthrowing shoulder. Burkhart indicates the traction forces placed on the shoulder with throwing cause GIRD, and over time a thickening of the posterior inferior capsule occurs.[7]
- Wilk proposed the TRM concept, where the amount of external rotation (ER) and internal rotation (IR) at 90° of abduction are added and a TRM arc is determined.[23]
- Both concepts are appropriate ways to determine the shoulder at risk for injury, although pitchers with GIRD and TRM differences outside the 5° window are at the greatest risk of injury.[24]
- In addition to range of motion, the scapula plays a significant role in the rehabilitation of the throwing athlete. The scapula serves as a base for muscle attachment, positions the glenoid to encourage osseous stability of the glenohumeral joint, and acts as a link in proximal-to-distal sequencing for the function of the shoulder.[6] The goal is to make sure that scapular asymmetry or scapular dyskinesis has been relatively eliminated.
- Lastly, with the understanding of the kinetic chain as noted earlier in this chapter, the previous phases should evaluate several other aspects as they relate to return to throwing. These items are posture, spinal movement/mobility, lower extremity range of motion/flexibility, and conditioning of the athlete.
- Once all the above factors have been completed, evaluated, and are satisfactory, the progression to the functional phase of rehabilitation can be initiated.
- As indicated above, this chapter is dedicated to beyond basic rehabilitation and return to pitching after subacromial decompression. For the purpose of this chapter, a throwing program for a starting pitcher is discussed as opposed to a relief pitcher. The overall program in regards to exercise, conditioning, and techniques is similar, however, the total time dedicated to throwing and mound progressions for return to pitching would differ.
- Periodization is the planned manipulation of training variables (load, set, and repetitions) to maximize training adaptations and prevent the onset of overtraining syndrome.[25] Periodization of the exercises in this phase would be nonlinear or undulating.
- In general, some modification of the exercise variables would be made on a weekly or biweekly basis. Exercises in this particular phase would be initiated at one set of 10 to 15 repetitions. The long-term goal would be to progress to 2 to 3 sets of exercises with repetitions of 25 to 30 per set.
- Starting pitchers will need to prepare for a significant number of repetitions over the course of pitching in games, but also long tossing on a daily basis.
- In the off-season, the program may be completed on a 3 to 4 times per week basis; as spring training and the season begins, however, the program in place will be accomplished 7 days per week.
- In some cases the speed of exercises will be increased, however, with the realization that no particular exercise can mimic the significant velocity involved in actually throwing or pitching a baseball.
- Shoulder internal rotation during a pitch is the fastest human movement recorded, and it occurs in excess of 7250° per second.[26]
- Most programs are performed with minimal rest periods and exercise order may be the most important factor to modify.
- When a throwing program is just being initiated, the order may be less important (other than the necessity to accomplish a dynamic warmup before throwing).
- As the number of throws, distance, and mound progressions are accomplished, limited strength work is completed before throwing.
- Once the pitcher is back to games, the program should be reevaluated to accommodate the typical 5-day rotation that is set up for a starting pitcher.
- Overall this phase of rehabilitation will be broken down into three programs: Advanced strength and conditioning, Performance enhancement techniques, and Sport-specific training. This is done to better define each area; however it should be understood that these programs are all occurring and overlapping during the functional phase of rehabilitation after subacromial decompression. These programs are initiated at approximately 8 to 10 weeks after isolated subacromial decompression and 16 weeks after decompression with either labral or rotator cuff repair. In addition and more importantly, during these programs it will be necessary to continually reevaluate each of the areas discussed above.

ASPECTS OF PITCHING THAT REQUIRE SPECIAL ATTENTION IN REHABILITATION

- Pitching exposes an athlete to a variety of forces during the act of throwing. With repetitive throwing, rotator cuff and periscapular muscle weakness can develop after which posterior capsular and/or rotator cuff contracture or inflexibility ensues.
  - In throwing athletes with posterior capsular and rotator cuff contracture, a posterior superior humeral instability occurs when the arm is abducted and externally rotated in the throwing mechanism creating an extrinsic subacromial impingement and glenohumeral peel back mechanism.
  - Peel back force can lead to superior labral and posterior rotator cuff fraying or tearing.
  - The main presentation may be subacromial impingement, although several pathologies may present.
- In throwers, primary impingement is most likely to be an incomplete diagnosis, with varying degrees of rotator cuff injury, labral fraying or tearing, posterior capsular or rotator cuff contracture, and even anterior capsular laxity present.
- Failure to correct nonshoulder abnormalities, such as core, hip, and leg weakness or inflexibility, may be just as likely as a specific surgical technique to prevent a throwing athlete from returning to preinjury level of sport.

Phase I: Advanced Strength and Conditioning Programs

Program Design/Performance Training Program

- Includes exercises and activities relative to spinal movements, core exercises, and the lower extremity, all of which are key in returning the throwing athlete after subacromial decompression.

Sport-Specific Concepts of Integrated Training

- The initial sport-specific concepts to be addressed in this program are to make sure lower extremity flexibility and spinal mobility are maintained or improved. The exercises and manual therapy skills to be initiated are determined through the evaluation process described above.
- Specific techniques used to address the posterior chain restrictions include:
  - Hamstring progressions in a True Stretch device [27] (Figure 6-28).
  - In addition to the athlete performing these motions in the True Stretch, the therapist can assist in providing additional stability or manual contacts to address specific limitations (Figure 6-29).
  - Furthermore, as part of the regular shoulder stretch routine, a general spinal stretch can be included (Figure 6-30).

Training Principles Used in the Design of the Program

- Typical limitations seen in the overhead athlete include, but are not limited to, posterior chain myofascia, hip

TIMELINE 6-3: **Beyond Basic Rehabilitation: Return To Pitching After Subacromial Decompression***

PHASE I	PHASE II
Advanced Strength and Conditioning: Begins at 8 to10 weeks after isolated SAD or 16 weeks after SAD with labral or rotator cuff repair	***Performance Enhancement Training:*** Begins at 8 to 10 weeks after isolated SAD or 16 weeks after SAD with labral or rotator cuff repair
• Lower extremity flexibility • Hip internal and external rotation • Posterior myofascial work (True Stretch Device) • Spinal mobility • Core stabilization (multiplanar lunges) • Interval running and agilities	• Shoulder and scapular exercises • Basic tubing exercises progress from split stance, to single leg, and finally split stance, narrow base on a balance pad • Impulse machine • Manual resistive exercises (PNF) • Rhythmic stabilization • Passive stretching for upper body and spine



FIGURE 6-28. Hamstring progressions in a True Stretch device during Phase I.



FIGURE 6-29. Therapist providing additional stability and manual contact for athlete while in True Stretch device during Phase I.

internal and external rotation, and spinal motion in positions of side bending and rotation.

- It is important to maximize functional range of motion for baseball. However with the progression of mobility that is created from these activities, it will be important to perform strengthening within the newly gained motions. As stated by Gary Gray, "do not create mobility without sufficient stability".[27]
- With the mobility program in place, exercises to include multiplanar actions and core stability need to be initiated. There are several options for exercises in this area with many modifications that can be made, limited only by the imagination of the therapist. Some particular concepts that are beneficial are multiplanar lunges with progressions of upper body and spinal movements. Even within these simple exercises, there are endless options of progressions. It is important that the lunges are performed in each plane and that one progression is the addition of either bilateral overhead flexion (Figure 6-31) or opposite lunge side rotations

TIMELINE 6-3: **Beyond Basic Rehabilitation: Return To Pitching After Subacromial Decompression*** (Continued)

PHASE III	PHASE IV	PHASE V
Sport Specific Training: Begins at 12 to14 weeks after isolated SAD or 20 weeks after SAD with labral or rotator cuff repair • Tossing/throwing program • Fielding • Hitting • Base running	***Throwing Progressions—Tossing:*** Begins at 12 to 14 weeks after isolated SAD or 20 weeks after SAD with labral or rotator cuff repair • Initiated 3 ×/week • Progress to 2 days on and 1 day off • Continue daily tossing with recovery day built in • Begin with 20–30 throws; increase to 100 throws, splitting into 2 sets • Initial throwing distance is 35–40 ft; increase to 120 ft/more (increase beyond 120 ft is debatable) • Beyond 90 ft, a drop step is used with each throw	***Throwing Progressions—Mound Pitching:*** Begins after completion of the Tossing Program • Athlete must demonstrate quality mechanics, arm strength with throwing, and good response to throwing on consecutive days • Begin with 15 throws from mound • Begin with 2–3 days between sessions progressing to every other day • # of throws gradually progresses up to 70–80 if starting pitcher • The number of throws will be split into groups of ~20 with brief rest periods to simulate "up and down" in a game • All throwing begins with fastballs, followed by change-ups • Breaking pitches are only added when athlete comfortable with velocity and control of fastballs and change-ups • Progress to throwing to batters (BP) • Simulated game • Initial return to play involves careful monitoring of innings pitched, types of pitches, and time of game

*The acute and intermediate phases of rehabilitation have been discussed in the previous section Postsurgical Rehabilitation after Subacromial Decompression.



FIGURE 6-30. General spinal stretch during Phase I.

(Figure 6-32). These types of exercises involve multiple, coordinated movements, and special attention should be paid to activation of the core/transverse abdominis muscles during their completion by the athlete.



FIGURE 6-32. Opposite lunge side rotation while lunging during Phase I.

Phase II: Performance Enhancement Training Techniques

Program Design/Performance Training Program

- The performance enhancement training techniques program includes concepts that are specific to the upper body and essential in returning the throwing athlete after subacromial decompression.
- Initially shoulder and scapular exercises are performed to address individual muscles and are performed in isolation.
- The goal of this program is to perform those same exercises, but add other components to increase the functionality of the exercise. One particular way this is accomplished is by adding balance components, lower extremity movements, or changing the surface upon which the exercise is performed to advance the quality of the exercise.

Training Principles Used in the Design of the Program

- One exercise progression can be taken from basic tubing exercises that are performed for scapular muscles in which they are progressed from split stance, to single leg, and finally split stance narrow base on a balance pad (Figures 6-33 to 6-35).



FIGURE 6-31. Bilateral overhead flexion while lunging during Phase I.

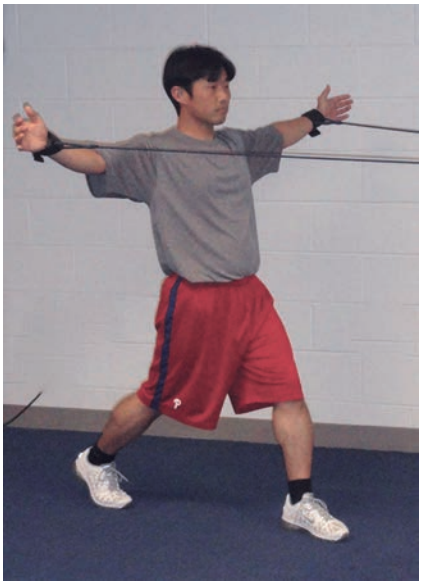

FIGURE 6-33. Bilateral middle trapezius exercise in split stance during Phase II.



FIGURE 6-34. Exercises on single leg for stance side during Phase II.



FIGURE 6-36. Lower trapezius exercise in split stance during Phase II.



FIGURE 6-35. Exercises in split stance on pad during Phase II.



FIGURE 6-37. Lower trapezius exercise on stance side during Phase II.

- Understanding the importance of balance on the stance side leg for pitching and incorporating that activity into the shoulder program is an important progression.
- Also, exercises with an Impulse Machine can both increase the velocity at which exercises are performed and also involve balance progressions (Figures 6-36 and 6-37).
- In addition to exercises performed by the athlete alone, manual resistive exercises become a significant part of the shoulder program. Manual resistive exercises are often termed PNF exercises, however, they frequently do not follow the exact principles defined by proprioceptive neuromuscular facilitation. For the purpose of this chapter, these exercises will be referred to as manual resistive exercises. These techniques can mimic DI and D2 PNF patterns (Figures 6-38 and 6-39) or simple isolated internal and external shoulder rotation.
- Other variables within these exercises are rhythmic stabilization, emphasis on eccentric loading, or isometric holds. The benefit of these types of exercises being performed on a regular basis is that the therapist can gain valuable knowledge on how the quality of movement and strength are progressing.
- Furthermore, passive stretching routine is incorporated into the program at this time. This passive upper body and spinal mobility program should include scapular mobility in multiple positions, passive range of motion in multiple planes, joint mobilizations, contract-relax techniques, pectoralis stretching, and spinal mobility or joint mobilizations (Figures 6-40 to 6-42).



FIGURE 6-38. Manual resistive exercises in a D1 pattern during Phase II.



FIGURE 6-39. Manual resistive exercises in a D2 pattern during Phase II.



FIGURE 6-40. Side-lying scapular mobility exercises during Phase II.

- Lastly, within this program, any soft tissue techniques can be used to assist in the rehabilitation process. Moving out from anatomical and osteopathic circles, the concept that fascia connects the whole body in an 'endless web' has steadily gained support.[28,29]

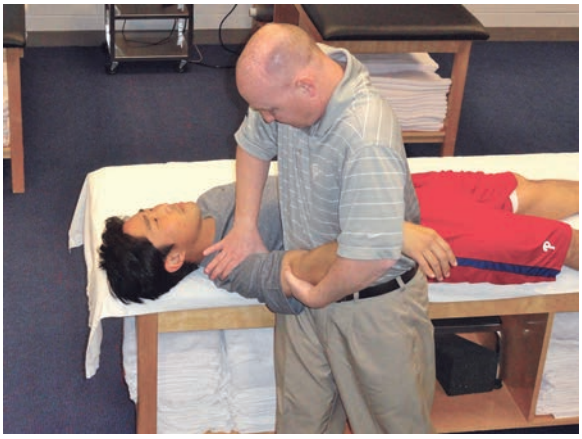

FIGURE 6-41. Posterior glide joint mobilization during Phase II.



FIGURE 6-42. Pectoralis minor stretch in supine position with bolster during Phase II.

Phase III: Sport-Specific Training

Program Design/Performance Training Program

- The sport-specific training program includes the throwing program, functional activities, and baseball conditioning to allow for return to pitching after subacromial decompression. To return to pitching in a game, several baseball specific activities must be accomplished. The obvious activities are long toss and throwing off the mound. However, other activities to be included at this time are hitting, base running, and fielding practice for pitchers.
- Of those, the ability of the pitcher to field his position is paramount and is accomplished with the baseball coaching staff. It consists of what is termed pitcher's fielding practice (PFPs). These activities involve fielding bunts, covering first base, and making the appropriate decisions to back up bases when indicated.
- In preparation for these activities, the conditioning program will include interval running and agilities.

Sport-Specific Concepts of Integrated Training

- Often pitching is considered to be an endurance activity that has inspired many to advise their athletes to complete long distance running. However, the activity of a starting pitcher is an interval activity. It is composed of an average of 15 to 17 pitches in an inning followed by a rest period of approximately 5 to 10 minutes.
- Therefore, it appears to be more appropriate to progress toward interval training as the athlete approaches return to game situations.
- Lastly within this program is the most functional activity of long toss and pitching. The progression from long tossing to pitching on the mound is the paramount exercise of the entire rehabilitation program.

Training Principles Used in the Design of the Program

- It is crucial that the athlete is reevaluated prior to initiating a throwing program to ensure that the athlete is ready for this phase. Once it has been determined that a throwing program can be initiated, the trainer or therapist will need to consider the number of throws, distance, intensity, and frequency of the program.
- There are many well-documented throwing programs[30–32] and there is no research indicating one program is better than another. Therefore, the following program is a guideline, identifying important considerations as the athlete progresses in the throwing program.

Sports Performance Testing

Recommendations for Throwing Progressions

- Initially begin with throwing 3 times per week. Increase the frequency after the athlete is satisfied with the symptom response to throwing. Typically progress to 2 days on and 1 off and then to daily tossing with recovery days built in. A recovery day is not an off day, but a day where the athlete may throw less total throws or a shorter distance. In our experience, complete days off from throwing are not always beneficial. Most athletes report feeling that they "took a step back or felt more stiff" after true off days.
- The initials days of throwing may include 20 to 30 throws. As the number of throws increases, splitting the total number of throws into two sets is important. The challenge for many players is how they respond to throwing after cooling off. The goal for us has been to complete a total of approximately 100 throws with at least 25 at the maximum distance for that day.
- The initial distance at which a player will throw should be 30 to 45 feet. The big question is what distance they should progress to. This should be based on previous long-toss programs, age of the player, and quality of throwing. If a player has never long tossed beyond 120 feet, they will need to be monitored with any progress beyond that distance. Some pitching coaches believe that no long tossing should occur beyond 120 feet for pitchers. Our experience is that overall mechanics of throwing should not be altered to reach a certain distance. In addition, beyond the distance of 90 feet, a drop step should be incorporated with the throw. Lastly, quality of throwing would be defined as throwing the ball with a good release point and keeping the ball on a line (not a high arc) to achieve the distance to be thrown.
- The next decision is when to progress the athlete to the mound. There is no exact formula for this decision. The athlete must demonstrate quality mechanics, arm strength with throwing, and a good response to throwing on consecutive days. Additionally, all the areas reevaluated before initiating the throwing program must be at a satisfactory level. The initial time on the mound may involve as few as 15 throws and may be thrown at less than the full distance (either in front of the rubber or with the catcher in front of the plate). Often we will have 2 or 3 days between these sessions and then progress over time to every other day or back-to-back days. Much of this will be determined based on the type of pitcher and the overall response to throwing off the mound. The number of pitches on the mound will progress from 15 to as many as 70 or 80 for a starting pitcher. In addition, progressions from one set of throws on the mound to multiple sets must be accomplished for starters. This will be referred to as "up and downs" by many pitching coaches. As mentioned earlier, the ability to return to throwing after cooling off (simulating between innings) is often a challenge in the rehabilitation process. Furthermore, with respect to pitch types, typically fastball and change ups are initiated first; and when the athlete is comfortable and confident with his velocity and control of those two pitch types, then breaking pitches are added.
- Finally the athlete will progress back to game situations. This may initially be accomplished with throwing live batting practice to his teammates and then creating game simulated activities. The final decision to make is when to return the player to a game. This decision will be made based on performance in simulated games and when the quality of pitching is acceptable to the player, athletic trainer/physical therapist, and coaches. The initial game situations may involve limitations in innings, pitches, and even time of the game in which the athlete is used.
- The goal is for the player to return to his previous level of competition after subacromial decompression. It will be important to continue to monitor and reevaluate the player throughout the entire rehabilitation process and beyond.
- The player should be reminded of the need to continue with his rehabilitation program even after he has returned to pitching. The athlete must understand the need to address the entire kinetic chain as he continues to throw.
- It is the responsibility of the medical staff to constantly reevaluate the athlete and ensure that he is consistent with the program.

Evidence

Burkhart SS, Morgan CD, Kibler WB: The disabled throwing shoulder: spectrum of pathology: Part III: the SICK scapula, scapular dyskinesis, the kinetic chain, and rehabilitation. *Arthroscopy* 19:641–661, 2003.

The authors review all the available literature on the disabled athlete's throwing shoulder. The SICK scapula is precisely defined; scapular dyskinesis is described in terms of diagnosis and evaluation; the concept of the kinetic chain of throwing is elucidated with respect to the precise biomechanical cascade of events that occur from the ground up to the ball release. (Expert Opinion; Level V evidence)

Fleisig GS, Bolt B, Fortenbaugh D, et al: Biomechanical comparison of baseball pitching and long-toss: implications for training and rehabilitation. *J Ortho Sports Phys Ther* 41:296–303, 2011.

A controlled laboratory study was performed on 17 healthy, collegiate baseball pitchers throwing fastballs from varying distances (18.4 meters from a mound, 37 meters, 55 meters, and maximum distance). Kinematics and kinetics were evaluated with a three-dimensional motion analysis system. It was noted that hard effort, horizontal, flat-ground throwing was biomechanically similar to pitching from a mound. Maximum distance throwing produced higher shoulder internal rotation and elbow varus torques as well as kinematic changes, and so should be used cautiously for rehabilitation and training. (Controlled laboratory study)

Reinold MM, Wilk KE, Reed J, et al: Interval sport programs; guidelines for baseball, tennis, and golf. *J Ortho Sports Phys Ther* 32:293–298, 2002.

The authors present an interval sports program in conjunction with a structured rehabilitation for baseball, tennis, and golf based on the available literature. The specific components of strengthening, flexibility, plyometrics, dynamic stabilization and neuromuscular control are reviewed. Sport-specific warm-up procedures and technique of sports are also presented. (Expert Opinion; Level V evidence)

Wilk KE, Marcina LC, Fleisig GS: Correlation of glenohumeral internal rotation deficit and total rotation motion to shoulder injuries in professional baseball pitchers. *Am J Sports Med* 39:329–335, 2011.

One hundred and twenty-two professional pitchers were evaluated over a three-season period to determine if glenohumeral internal rotation deficit (GIRD; >20° loss of internal rotation) and any deficit in total rotational motion (external rotation and internal rotation) compared with the nonthrowing shoulder correlated with shoulder injury and need for surgery. Those pitchers with GIRD and with a total rotational motion deficit of >5° appeared to be at higher risk for injury and shoulder surgery. (Case series; Level IV evidence)

Wilk KE, Meister K, Andrew JR: Current concepts in the rehabilitation of the overhead athlete. *Am J Sports Med* 30:136–151, 2002.

The authors provide an evidence-based current concepts review of rehabilitation for the overhead throwing athlete. They highlight the challenges of the "thrower's paradox" as it relates to the delicate balance between mobility and functional stability in this unique athletic population. They provide a structured, multiphase rehabilitation approach, which emphasizes inflammation control, muscle balance, soft tissue flexibility, enhanced proprioception, and neuromuscular control. (Expert Opinion; Level V evidence)

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32. Reinold MM, Wilk KE, Reed J, et al: Interval sport programs; guidelines for baseball, tennis, and golf. *J Ortho Sports Phys Ther* 32:293–298, 2002.

Multiple-Choice Questions

QUESTION 1. Primary subacromial impingement is defined as:

A. Abrasion of the subscapularis tendon on the coracoid process with repetitive crossbody maneuvers.
B. Instability of the acromioclavicular joint in multiple planes with overhead lifting.
C. Repetitive injury to the anterolateral aspect of the rotator cuff caused by supraspinatus outlet narrowing.
D. Anterior laxity of the glenohumeral joint with the arm in an abducted, externally rotated position.

QUESTION 2. Subacromial impingement symptoms in the throwing athlete may be a result of intrinsic and extrinsic factors, which include:

A. Acromial bone spurs and subacromial bursitis.
B. Superior humeral head migration caused by rotator cuff tear.
C. Altered scapulothoracic rhythm caused by glenohumeral instability.
D. All of the above.

QUESTION 3. Nonshoulder sources of disability in the throwing athlete include all of the following except:

A. Core muscular weakness.
B. Hip rotational deficits.
C. Coracoid impingement.
D. Leg muscular weakness.

QUESTION 4. The initial phases of rehabilitation of the throwing athlete after subacromial decompression include:

A. Full pain free arc of motion.
B. Ability to complete basic rotator cuff and scapular exercises.
C. Overall body conditioning.
D. All of the above.

QUESTION 5. All of the following are true concerning the recommended, beyond basic rehabilitation after subacromial decompression in the throwing athlete except:

A. There are three overlapping programs including Advanced strength and conditioning, Performance enhancement, and Sport-specific training.
B. The sport-specific training program for the pitcher includes only throwing.
C. These programs may begin at approximately 8 to 10 weeks after isolated subacromial decompression.
D. These programs may begin at approximately 16 weeks after subacromial decompression with either labral/rotator cuff repair.

QUESTION 6. The ultimate distance to which a player long tosses is determined by all of the following except:

A. Age of the player.
B. Presurgical velocity of throwing.
C. Quality of throwing.
D. Previous long tossing program.

Answer Key

QUESTION 1. Correct answer: **C** (see Introduction)

QUESTION 2. Correct answer: **D** (see Introduction)

QUESTION 3. Correct answer: **C** (see Introduction)

QUESTION 4. Correct answer: **D** (see Postoperative Rehabilitation Program)

QUESTION 5. Correct answer: **B** (see Postoperative Rehabilitation Program)

QUESTION 6. Correct answer: **B** (see Recommendations for Throwing Program)

NONOPERATIVE REHABILITATION OF INTERNAL IMPINGEMENT

Mark Rogow, ATC, CSCS, and Charles E. Rainey, PT, DSc, DPT, OCS, SCS, CSCS, FAAOMPT

GUIDING PRINCIPLES OF NONOPERATIVE REHABILITATION

- Establish diagnosis: Identify if there is GIRD (Greater Internal Rotation Deficit), posterior capsular hypomobility, a lack of rotator cuff and/or scapular strength and endurance, acquired glenohumeral anterior instability, labral and/or rotator cuff injury, or a combination of a number of these dysfunctions/pathologies
- Establish a plan to address each of these conditions
- Optimize postural alignment
- Address SICK (Scapular malposition, Inferior medial border prominence, Coracoid pain and malposition and dysKynesis of scapular motion) scapula and/or scapular dyskinesis
- Restore glenohumeral and scapulothoracic joint mobility
- Address any and all mobility issues and fascial restrictions from nose to toes
- Reestablish and enhance dynamic stability/muscle synergy (balance)/neuromuscular control of both glenohumeral and scapula-thoracic joints
- Improve shoulder, trunk, lumbopelvic, and ankle stability
- Monitor progress closely and advance forward in the program as milestones are achieved
- Moving forward in a program is less determined by time than it is by goals attained; however, it is possible to be working in multiple phases given we are rehabilitating and improving the performance of the entire kinetic chain, rather than just a single body part
- Return to ADLs (Activities of Daily Living) without pain
- Increase strength, power, endurance, and myokinematics of entire kinetic chain
- Return to sport

Phase I: Movement-Mobility (weeks 2 to 4)

Goals

- Protect healing tissue and discontinue mechanism of injury
- Do not sleep on shoulder, do not sleep with arm/shoulder in overhead position (prone, supine or side-lying)
- Reduce pain, inflammation, point tenderness
- Improve pliability of inferior and posterior capsule, posterior rotator cuff, upper trap, pectoralis minor
- Restore pain-free range of motion of glenohumeral, scapulothoracic, acromioclavicular and sternoclavicular joints
- Restore scapular equilibrium, scapular mechanics, upper extremity proprioception, dynamic stability, and neuromuscular control of the scapula
- Evaluate and correct cervical, thoracic, lumbopelvic, hip, and ankle mobility dysfunctions
- Once spine, pelvis and ankle motions are sufficient, begin trunk, hip, and ankle stability exercises
- Emphasize correct posture 24/7 through Home Exercise Program and education
- Minimize muscle atrophy
- Be active/productive while healing
- Address cardiovascular fitness

Protection

- To optimize healing, for nonoperative care, minimize hyperangulation (no hyperabduction, no external rotation at 90/90 or ER above 90 abduction).
- Do not sleep on the injured shoulder or with the arm in an overhead position.

TIMELINE 6-4: **Nonoperative Rehabilitation of Internal Impingement**

PHASE I (weeks 2 to 4)	PHASE II (weeks 4 to 8)
• Protect healing tissue • Avoid sleeping on shoulder or sleeping in overhead position • Decreased pain, inflammation, point tenderness • Increase mobility of inferior/posterior capsule, posterior rotator cuff, upper traps, and pectoralis minor • Restore pain-free ROM of all scapulothoracic joints • Restore scapular equilibrium, scapular mechanics, upper extremity proprioception, dynamic stability, and neuromuscular control of the scapula • Correct cervical, thoracic, lumbopelvic, hip, and ankle mobility dysfunctions • Start trunk, hip, and ankle stability exercises • Postural education and HEP • Minimize muscle atrophy • Address cardiovascular fitness	• Continue protecting healing tissue • Continue shoulder stretching, emphasize horizontal adduction and sleeper position • Begin rotator cuff strengthening (isometrics, concentric, eccentric) at a low intensity using proper scapular mechanics/alignment • Maintain cervical, thoracic, lumbopelvic, and ankle mobility • Advance scapular, cervical, thoracic, lumbopelvic/hip/lower extremity stability training • Continue neuromuscular stability training • Advance and challenge cardiovascular fitness

- Establish or maintain good posture and good scapulothoracic position throughout the day. Kinesiological taping may help reinforce and/or reeducate critical postural and suprascapular muscles.

Management of Pain and Swelling

- Electrotherapy (INF/TENS/high voltage galvanic) may be used if there is pain, inflammation, spasm, or muscle guarding
- Oral NSAIDs and pain medications as prescribed by physician
- Iontophoresis may be indicated
- Cryotherapy as needed for pain and swelling
- Compression/sports wrap if swelling

Techniques for Progressive Increase in Range of Motion

Physical therapy begins immediately after evaluation by a physician and rehabilitation specialist. This phase should include an evaluation, discussion, and plan. Active physical therapy care should begin as soon as possible.

Manual Therapy Techniques

- Manual therapy in Phase I is indicated if there is palpable muscle spasm, tightness, and point tenderness to anterior, posterior, superior, and inferior structures of the glenohumeral joint.
- Manual therapy techniques to include contract/relax PNF and muscle energy. The authors have found better results with using contract-relax techniques during both self-stretching and therapist-assisted stretching versus passive stretching alone.
- Begin gentle mobilization of posterior and inferior capsule if patient has tight posterior capsule and/or restrictive inferior glenohumeral ligament complex. Use manual therapy for the scapulothoracic joint, lumbar, thoracic, cervical spine, and pelvis if range of motion is limited and lacks necessary mobility.

Soft Tissue Techniques

- Soft tissue massage/mobilizations, IASTM (instrumental assisted soft tissue mobilization), and trigger point dry needling are all indicated to reduce spasm, tightness, reset muscle tendon units, and improve joint restrictions. Cross friction massage is indicated for biceps tendon and teres minor tenderness/tendonitis which are common secondary side effects of internal impingement.
- Other soft tissue therapy techniques include using foam rolls, myofascial/lacrosse balls, and massage sticks. These are all also effective objective measurements of effectiveness and produce increased ROM and decreased pain level.
- This does not need to be a "passive" treatment. Be sure to include active movement while using these tools. Moving the joint or contracting the muscle while applying the pressure of the modality will educate the patient as to where there are soft tissue restrictions, muscle spasm/tightness, as well as trigger points. This "active" approach is effective while working on the pec minor, rhomboids, and posterior cuff (taking the shoulder through flexion, IR/ER, and abduct), as well as deep soft tissue structures in the hip (taking it through IR/ER and flexion).
- The common muscle tendon units/soft tissue that tend to be hypomobile lack pliability and/or are joints that lack mobility with internal impingement, such as pectoralis minor, levator scapulae, scalenes, upper trap, teres minor/infraspinatus, posterior capsule, scapula-thoracic joint, thoracic spine, and contralateral hip.
- Be sure to evaluate horizontal adduction, internal rotation, and the sleeper stretch position (Figure 6-43) bilaterally. While looking at horizontal adduction be sure the scapula is immobilized and in a neutral position (not retracted or protracted). The scapula needs to be fixed against the thorax before horizontally adducting the humerus.
- The intent of treatment during this phase is to address any and all soft tissue restrictions surrounding the shoulder and throughout the kinetic chain.
- Muscles that when tight affect, or can contribute to, scapular dyskinesis:
  - Pectoralis minor
  - Levator scapulae
  - Upper trapezius
  - Infraspinatus/teres minor
  - Latissimus dorsi

TIMELINE 6-4: **Nonoperative Rehabilitation of Internal Impingement** (Continued)

PHASE III (weeks 8 to 12)	PHASE IV (weeks 12+)
• Advance upper quarter strength and power • Maximize use of kinetic chain • No signs or symptoms of impingement returning • Improve dynamic neuromuscular control of scapula/trunk • Begin reintroducing mechanism of injury	• Return to sport with no symptoms, full function • Normal kinematics, including no scapular dyskinesis or SICK scapula • Improved neuromuscular control and muscle firing patterns throughout kinetic chain • Improve cardio and anaerobic function • Patient has knowledge/understanding of shoulder function, mechanical awareness, injury predispositions, and recovery needs • Continue maintenance drills, exercises, movement patterns, correctives, stretching, and sport-specific training

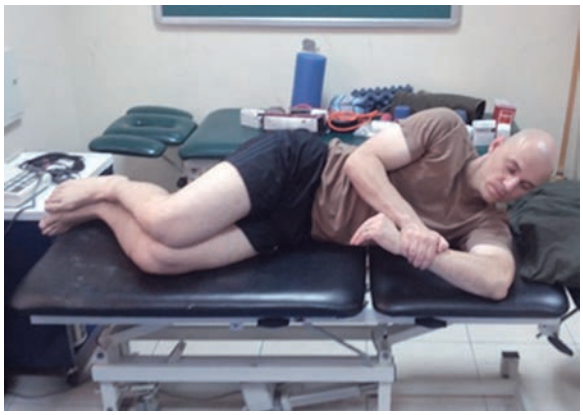

FIGURE 6-43. Sleep stretch at 90°.

- Techniques include, but are not limited to, if indicated:
  - Inferior and posterior glides during horizontal adduction and internal rotation of the humerus on the glenoid (low grade end range mobilization glides; performed by therapist)
  - Side-lying horizontal adduction stretch (self-stretch)
  - Standing with scapula pinned against wall; horizontally adduct humerus (self-stretch)
  - Standing with scapula pinned against wall; internally rotate humerus with shoulder abducted at 70° and at 90° (self-stretch)
  - Supine horizontal adduction stretch (therapist assisted)
  - Sleeper stretch/modified sleeper stretch at 70°, 90° and 110° (self and therapist assisted)
- If there is any anterior or subacromial pain while performing the sleeper stretch, modify the position by performing 1), 2) and/or 3), as the stretch should only be felt in the posterior and posteriolateral shoulder:
  1) Rotate torso away from elbow 10° to 20° then reattempt stretch.
  2) Increase the angle of the elbow from 90° out to 120° to 135°.
  3) Lower position of humerus from 90° abducted to 50° to 70°.
  - Corner stretch (self-stretch) (Figure 6-44)
  - Doorway pectoralis major/pectoralis minor stretch (self-stretch)
  - Pectoralis minor on foam roll stretch (self and assisted technique)
  - Side-lying, supine, and prone flexion stretch (therapist-assisted)
  - Side-lying on foam roll and actively flexing and extending shoulder (Figure 6-45)
  - Standing shoulder extension (self-stretch)
  - Supine shoulder extension (therapist assisted)
  - Backscratch/Apley's stretch (self-stretch with Thera-Band or towel)
  - Subscapularis release (therapist assisted)
  - Standing latissimus/thoracolumbar fascia stretch
  - Supine angular (diagonal) with rotation stretches (therapist assisted)



FIGURE 6-44. Corner stretch.



FIGURE 6-45. Side-lying on foam roller.

Clinical Pearls

- The authors have found better results with using contract-relax techniques during both self-stretching and therapist-assisted stretching versus passive stretching alone.
- The key is initiating the low intensity contraction at the "first barrier," the first feeling of tissue tension, not taking it to its end range, then giving a contraction. After contracting the muscle or muscle group the patient is trying to stretch, take the stretch to the next barrier, and then repeat. This technique also keeps the patient engaged and on task by making them an active participant in the stretch.
- It forces the patient to pay attention and be in tune with where their extremity is and the direction it is going in, what angles are the most effective, and tissue tension differences at different angles; in the long run it forces them to become less dependent upon the therapist.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Aerobic/cardiovascular conditioning to begin right away, however running should not begin until full pain-free range of motion in the shoulder is achieved
- Improve postural awareness
- Address SICK scapula and scapula dyskinesis if present
  - Initiate activity of the serratus anterior, rhomboids, and mid-lower trapezius
  - Low row
  - Active assistive shoulder flexion and in scaption with cane, pulley, UE Ranger, tubing, or cable
  - Sternal lift: While seated or standing, on exhalation, force sternum toward ceiling while performing scapular retraction and depression. Hold 5 seconds and return to normal resting position.
  - Shoulder dump: While standing in split stance (normal stride length distance), slowly perform a throwing motion (without a ball or other object) emphasizing depression and retraction of scapula when torso is upright, and performing elevation and protraction of scapula when torso is flexed and rotated over forward stride leg; then reverse the exercise slowly. (Arm can remain at side or can begin in abducted/externally rotated position depending on symptoms of patient.)
- Functional core stabilization exercises
  - Pelvic tilts
  - Partial crunches
  - Bridging (Figures 6-46 and 6-47)/single leg bridge (Figure 6-48)/bridge marching
  - Quadruped (alternate arms, alternate legs, alternate arms and legs) (Figure 6-49)
  - Dead bugs (alternate arms, alternate legs, alternate arms and legs)
  - Supermans
  - Physio ball wall squats
- Evaluate for and treat deep neck flexor inhibition (may need tissue work on suboccipitals, cervical extensors, and scalenes)
  - Supine active chin tuck
  - Supine cervical flexion
- Teach diaphragmatic/belly breathing
- Dynamic lower extremity exercises
  - Body weight squats
  - Lunges (in the sagittal, frontal, and transverse planes)
  - Step-ups
  - Lateral step-ups



FIGURE 6-46. Double leg bridge.



FIGURE 6-47. Double leg bridge with leg extension.



FIGURE 6-48. Single leg bridge.

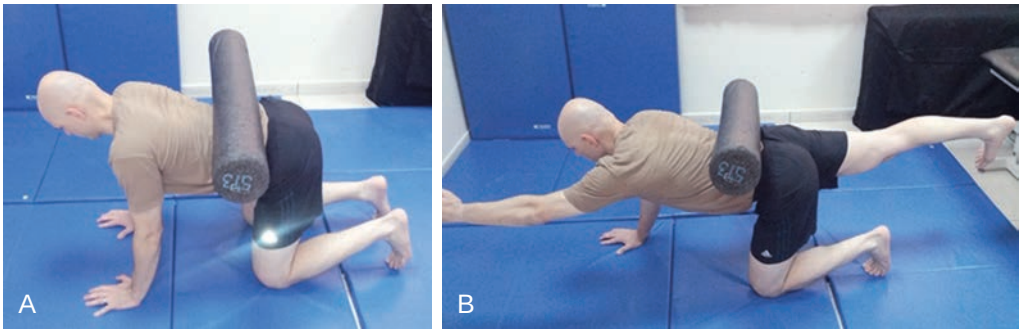

FIGURE 6-49. Quadruped diagonals. **A,** Start. **B,** Finish.

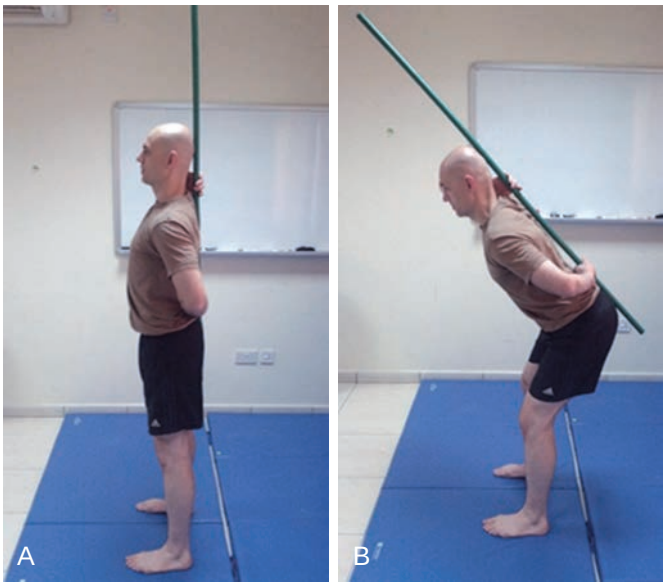

FIGURE 6-50. Deadlift. **A,** Start. **B,** Finish.

- Step-downs
- Trendelenburg exercise
- Thera-Band walking (forward, backward, side-step)
- Romanian deadlift (RDL) (body weight only) (Figure 6-50)
- Single leg RDL
- Good morning exercise (body weight only)
- Single-leg excursions (in the sagittal, frontal, and transverse planes)
- Calf exercises
- Hiking/incline on treadmill

- All exercises and stretches should be done pain free. If the patient experiences soreness and/or stiffness in the injured shoulder, these side effects from exercise should resolve within 24 to 48 hours.
- If they do not, then the clinician needs to reevaluate the exercise, treatment, and recovery programs of the patient as well as the quality of the reinforcement, movement, and mechanics when working on posture and scapular control.
- It is critical to achieve good scapular control by minimizing scapular dyskinesis during overhead ROM before increasing volume and intensity of strength training, or the underlying issue of scapular dyskinesis and poor scapular control will either slow the athlete's return to play or will significantly increase the athlete's predisposition to reinjury.

Activation of Primary Muscles Involved

- As part of the muscle reeducation process, the patient needs to learn to recruit proximal musculature (trunk/core/pelvis/hip) before recruiting distally (extremities). The purpose is to improve motor control.
- Avoid hyper-horizontal abduction, ER at 90/90 and ER above 90 ABD, and avoid any reproduction of symptoms.
- Using proprioceptive neuromuscular facilitation (PNF) for the scapula, manually cue the scapula to elevate/depress, upwardly rotate/downwardly rotate, retract/protract.



FIGURE 6-51. Packing the shoulder (supine).

Sensorimotor Exercises

- These activities are advisable and critical as soon as an axial load or perturbations can be performed without pain.
- Performing upper and lower extremity proprioception and balance exercises will activate, improve, and control muscle patterns which in turn will improve postural and neuromuscular control.
- They include, but are not limited to, single-leg stance on contralateral leg and single-leg stance on ipsilateral leg (eyes open and progress to eyes closed).
- If more challenge is needed, add upper extremity row and scapular retraction with tubing during SL stance.
- Kneeling, half-kneeling or standing with hand of injured arm on physio ball on floor or against wall doing up-and-down, left-and-right movement patterns, circles, rhythmic stabilization, and perturbations.
- Quadruped weight shifts, quadruped with hand of injured arm on ball or wobble board (all exercises must not elicit, reproduce pain, or compromise good scapular/postural position).
- Upper extremity sensorimotor exercises also include lying supine and balancing an object such as a kettlebell or dumbbell in the hand of injured arm. Be sure to "pack the shoulder," consciously contracting all periscapular musculature as if to squeeze tight one's armpit. The latissimus must be tonic. Each repetition is to be done for 15 to 30 seconds in length.
- Then move to side-lying with the arm extended toward the ceiling or sky and again "pack the shoulder." (Discontinue if painful.) This can also be executed with the arm outstretched while kneeling, half-kneeling, or standing, depending upon the patient's ability to maintain good core/trunk stability while performing the exercise (Figures 6-51 and 6-52).

Clinical Pearl

The rehabilitation program should move along a continuum. Its difficulty should increase over time with respect to the sport or desired activity[1] and evolve from bilateral to unilateral, supported to unsupported,[2] using active and passive movement, with and without load.[3]



FIGURE 6-52. Packing the shoulder (side-lying).

Open and Closed Kinetic Chain Exercises

- Closed kinetic chain (CKC) activities should take precedent over open kinetic chain (OKC) activities early on in the program, caused by their functionability and avoidance of unwanted stresses. CKC exercises improve sensorimotor function, joint proprioception and centralization, and stability.
- Perform multiplanar, frontal, sagittal, and transverse planes exercises and focus on the weakest, the most easily fatigued and poorest performing planes of motion.
- In Phase I all humeral movements should be kept below 90° of shoulder flexion and below 90° abduction.
  - CKC exercises include, but are not limited to:
    - Weight shifts left and right, up and down, forward and back, as well as diagonal and circular patterns with elbows at 90° or with elbows extended against wall, table, or floor
    - Pushup plus (slow and controlled concentric and eccentric components) on forearms or with elbows extended
    - Scapular clocks with arm extended against fixed surface, controlling movement of scapula/glenohumeral joint clockwise and counterclockwise
    - Ball/physio ball oscillations with arm outstretched
    - Seated towel slides protracting and retracting scapula
    - Seated towel slides upwardly rotate and downwardly rotate scapula (putting contralateral hand behind neck and actively cocontracting the contralateral scapula usually yields better dynamic scapular results)
    - Thumbtacks: Imagine gripping a thumbtack on the wall with each hand, then upwardly and downwardly rotate humerus/scapula and getting a scapular pinch end range external rotation)
    - Pulley exercise: This is an active exercise, not a passive one. Be sure the patient is firing their humeral and scapular depressors during both flexion/extension, scaption and abduction/adduction movement patterns. If pain free above 90°, you can take shoulder through full available pain-free ROM.

Clinical Pearl

The act of gripping has been shown to activate reflex contraction of the rotator cuff muscles which will stimulate glenohumeral mechanoreceptors.[4] This in turn increases joint compression and dynamic muscular cocontraction improving joint congruity, reducing shear forces, and stimulating joint proprioceptors while enhancing dynamic stabilization.[5]

Techniques to Increase Muscle Strength, Power, and Endurance

- In Phase I, work begins on lower extremity muscle strength, power and endurance.

Neuromuscular Dynamic

- Kneeling and half-kneeling (with narrow base) modified lifts and chops with or without resistance depending upon ability to stabilize hips and trunk (Figures 6-53 and 6-54)
- Quadruped (on all fours): Alternate arms, alternate legs, alternate opposite arms and legs
- Bridging/single-leg bridge/bridge marching
- Dead bugs: Alternate arms, alternate legs, alternate opposite arms and legs

Clinical Pearls

"*A key premise of the dynamic neuromuscular stability approach is that every joint position depends on stabilizing muscle function and coordination of both the local and distant muscles to ensure neutral or centered position of joints in the kinetic chain. The quality of this coordination is critical for joint function and influences not only local, but also regional and global anatomical and biomechanical parameters in the kinetic chain.*"[6]

The goals of neuromuscular rehabilitation according to Lephart et al.[7] are:

- To improve cognitive appreciation of the shoulder relative to position and motion
- To enhance muscular stabilization of the joint in the absence of passive restraints
- Restore synergistic muscular firing and coordinated movement patterns

Plyometrics

- Low-level lower extremity plyometrics can begin in the final 1 to 2 weeks of Phase I
  - Low-intensity dot drills, box drills, cone/footwork drills, jump rope, one- and two-legged hops, skipping, low-level bounding

Functional Exercises

- Ground-based exercises for the lower extremities (that do not load, compromise, or force the shoulder into flexion or abduction above 90°). Many are listed above, however the athlete should add additional exercises that incorporate movement patterns specific to the athlete's sport.



FIGURE 6-53. Half-kneeling chop. **A,** Start **B,** Finish.



FIGURE 6-54. Half-kneeling lift **A,** Start **B,** Finish.

Sport-Specific Exercises

- Review all sport-specific exercises related to the athlete's sport. Consider each exercise, movement pattern, or sport-related activity that does not invoke stress on the injured shoulder. Examples of this might include taking groundballs without throwing, foot work, and body positioning drills that do not involve the affected shoulder.
- Maintain indoor and outdoor cardiovascular/aerobic fitness.

Milestones for Progression to the Next Phase

- No pain at rest
- Very little to no pain with increased activity
- Good scapulothoracic mobility and control
- Full glenohumeral motion
- If present, eliminate GIRD if patient is not an overhead athlete
- Core/trunk/pelvic stability, posture, and scapular kinesis need to have improved if the need was there
- Improved hip motion and symmetry

Phase II: Stability-Strengthening (weeks 4 to 8)

Volume/duration: Perform 10 to 15 reps, 1 to 3 sets per exercise, depending on quality of movement and

Note: Mobility/ROM are measured and assessed via goniometry measurement, so that right versus left extremities are within 10° of one another to achieve symmetry. Stability/postural control are measured via administrator's observation, so that movement quality is high and no compensatory/unwanted motion are observed during these movement patterns.

minimizing the presence of compensatory movement patterns. Exercise will be terminated when there is a decrease in movement quality and/or movement compensations noted.

Goals

- Continue to protect healing tissue; not ready to resume mechanics of the causation of injury
- Shoulder stretching needs to continue, most importantly the horizontal adduction and sleeper position stretching
- Begin to address rotator cuff strength deficits (isometrically, concentrically, and eccentrically) using low intensity, high-volume work, while simultaneously using correct scapular mechanics and good postural alignment
- Increase strength training (volume and intensity) throughout this phase but be sure adequate recovery between sets and between workouts is accomplished
- Maintain cervical, thoracic, lumbopelvic, and ankle mobility acquired in Phase I
- Advance scapular, cervical, thoracic, lumbopelvic/hip/lower extremity stability training
- Reinforce muscle memory of correct neuromuscular firing, going from conscious to unconscious control
- Advance and challenge cardiovascular fitness

Protection

- Do not sleep on shoulder; do not sleep with arm/shoulder in overhead position (prone, supine or side-lying). "Crimping the garden hose" affects the rate of flow of the water down the hose much like sleeping on the shoulder and squeezing the neurovascular structures and vessels that feed the arm and shoulder. One bad night can negatively affect the patient for a day or more.

Management of Pain and Swelling

- Electrotherapy (TENS, IFC, Russian) may be used if there is pain, spasm, and muscle guarding
- Oral NSAIDs and analgesics should be able to be discontinued in this phase
- Cryotherapy as needed

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Manual therapy techniques used in Phase I are also indicated in Phase II to not just maintain what has been accomplished, but to address any new issues that may arise or be uncovered.
- Take advantage of this time to periodically evaluate the patient's strength and range of motion, as well as the firing patterns of motor recruitment.

Soft Tissue Techniques

- The same soft tissue techniques listed in Phase I certainly can apply in Phase II to not only maintain what's been achieved soft-tissue wise, but also to evaluate the tissue as new issues and changes in tissue tension, capsular, and muscular tightness emerge.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Although the patient has moved on to Phase II, it is critical that both the therapist and patient remain aware and on top of the patients kinetic chain mobility.
- Many flexibility goals have been met up to this point, however the patient's body type, posture, sport, and genetics are still programmed to return that athlete to the state of flexibility the athlete was in before the injury occurring. That being said, working on stretching and being "routine" with it needs to continue well beyond this program, much less beyond Phase I.
- At this point identifying the few stretches to help maintain the patient's flexibility would be beneficial because it is probably a bit of overkill to perform all of the stretches every day.
- Commonly the horizontal adduction stretch and modified sleeper stretch need to be continued 3 to 5 times per week. More aggressive techniques (such as active assistive and active isolated stretching with the use of a band, tubing or towel) can be used.

Clinical Pearls

- As the athlete increases their function and gets closer to returning to their sport, it is important to get them on their feet and doing ground-based mobility and dynamic warmup activity geared specifically toward their sport as well as their own mobility needs.
- This also plays a significant role in keeping the athlete on task and keeps their head in the sport. Although a particular body part may be on the mend and out of commission, the rest of their body is not.

Other Therapeutic Exercises

- Aerobic/cardiovascular conditioning needs to continue. This is a good time to start cross-training, mixing in some anaerobic work and building opportunities into the program to increase the athlete's level of fitness using other types of conditioning equipment and surfaces (i.e., treadmill, StairMaster, Versaclimber, Jacob's Ladder, upper body ergometer, viper rope climb [machine], rowing ergometer, ski ergometer, elliptical, arc trainer, conditioning on artificial grass, the beach, playing field, hard court and more).
- Continue to improve and reinforce postural awareness
  - Be sure patient is aware of their "neutral spine" and the optimal position of the pelvis
  - Correct shoulder protraction, forward head posture, and thoracic hypomobility and kyphosis
  - Most exercises in this phase should be performed standing or while in upright posture (can be done in kneeling, half-kneeling or standing)
    - Low rows
    - Tubing two-arm diagonals

  - Straight arm shoulder extension from 90° flexion to 0° with scapular pinch throughout the exercise
  - Chin tucks
- "No Money": Standing with arms at side, palms up and elbows bent at 90°. Externally rotate, pinching shoulder blades together, and pulling them inferior (toward tailbone), hold for 5 to 10 seconds, then slowly return to starting position. Can be done with or without tubing.

- Begin Rotator Cuff Exercises
  - Isometrics: Abduction/adduction, flexion/extension, internal/external rotation
  - Prone I (flexion), Ts (horizontal extension), Ys (scaption), and Ws (90/90 external rotation exercises) (with palms down or thumbs up)
    - Have a 5-second hold at the top of the arm lift and slowly lower the arm to complete each repetition. As soon as the arm touches the table or bench begin the next rep, with no rest until the set is complete.
  - Side-lying
    - External rotation
    - Dynamic "4": Externally rotate, extend elbow pressing hand toward the sky. With a straight arm slowly lower the arm in a diagonal pattern toward contralateral hip, return elbow to starting position at side with elbow bent at 90°, and repeat
  - Standing: Internal/external rotation at 30° and 45° abducted
    - External rotation needs to be done slowly and under control with good cocontraction of the scapula stabilizers and moving slowly during the eccentric phase of the exercise.
  - Diagonal patterns can begin 1 to 2 weeks into Phase II
  - Standing "3"
    - Front raises
    - Lateral raises (with GH-ER to prevent iatrogenically impinging the shoulder)
    - Scaption/full can (thumb up position) raises
- Have a 1 to 2 second hold at the top and slowly lower the weight. Do not allow the patient to "rest" and relax at the end of each repetition; maintain an "active" shoulder and correctly positioned scapula and posture throughout the set
  - Bodyblade/perturbations can be done in many planes and with many of the exercises listed above in the rotator cuff exercise list
- Increase work on active scapular control, increasing strength and endurance
  - Back to corner external rotation isometrics
  - Back to corner wall slides
  - Wall angels (Figure 6-55)
  - Wax on/wax off (one arm and two arm: against wall, on slideboard, or on floor with sliding discs)
  - Robbery (begin with arms at side, with elbow bent at 90° and internally rotated with hands on abdomen. Finish with both arms externally rotated with humerus at side and elbow bent 60° to 90°)
  - Lawnmower (beginning from contralateral side, end with elbow flexed at side and scapula retracted)
  - Thumbtacks



FIGURE 6-55. Wall angels.

  - Lunge and punch (at 135° shoulder flexion, 120° shoulder abduction, bring arm overhead in a half circle pattern)
  - Kettlebell holds: "Pack the shoulder" and do 15 to 30 second holds
    - Supine punch position
    - Supine punch position with kettlebell bottom up
    - Side-lying 90° abduction
    - Side-lying 90° abduction with kettlebell bottom up
    - Move from supine to side-lying and back to supine
  - Dynamic hug
  - Supine punch: Retract and protract scapula
  - Prone row
  - Pushup plus
  - Pushups/wall pushups with various hand positions on wall
  - Plank to side plank (start in plank position, then rotate torso to left or right so unloaded forearm is pointing to sky, then rotate trunk back to prone plank position, then rotate in the opposite direction and repeat) (Figures 6-56 to 6-58)
  - Kneeling forearm physio ball slides
  - Standing forearm wall slides with Thera-Band around elbows and wrists
  - Lat pulldowns (never behind head)
  - Assisted pullups (do not hang at end of each rep, maintain active shoulders throughout set)



FIGURE 6-56. Prone plank on elbows.



FIGURE 6-57. Prone plank.



FIGURE 6-58. Side plank on elbows.

- Functional core stabilization exercises
  - Continue core stabilization exercises in Phase I
  - Upper extremity work (rotator cuff ex—IR/ER, D1/D2) while sitting on a physio ball
  - Stability "prone plank"
    - As the plank gets easier, then lift each elbow off the ground (1 to 5 seconds)
    - As the plank gets easier, then lift each foot off the ground (1 to 5 seconds)
  - Stability "side plank"
- Continue diaphragmatic/belly breathing
- Dynamic lower extremity exercises
  - Increase resistance and volume with all of the dynamic lower extremity exercises done in Phase I
  - Begin running/sprinting progression

Clinical Pearls

- It is critical that to have success strengthening a muscle or a group of muscles, their antagonist counterparts cannot be chronically tight and shortened.
- Using a foam roll, massage stick, and the other modalities listed in the soft tissue technique section will improve recovery, reduce muscle soreness, and help maintain joint ROM and mobility.

Sensorimotor Exercises

- Increase difficulty of sensorimotor exercises presented in Phase I
- Ideas to increase difficulty: Close eyes/add resistance/increase distance of excursions/add wobble board, DynaDisc or Airex pad/if performing a lower extremity exercise then add an upper extremity movement or exercise and vice versa

Neuromuscular Dynamic Stability Exercises

- Kneeling and half-kneeling (with narrow base) modified lifts and chops with or without resistance depending upon ability to stabilize hips and trunk while maintaining a narrow base
- Bodyblade/perturbations are done dynamically in this phase working to stabilize the glenohumeral, scapulothoracic, sternoclavicular, as well as postural muscles of the spine and pelvis while the arm is moving at different angles and at different speeds (IR/ER, abduction/adduction, flexion/extension, diagonal patterns, scaption)
- Lower extremity balance activities such as single leg stance, BOSU ball squats, star excursion, Y-balance
- Segmental upper and lower body rolling patterns[8]
  - The upper body rolling pattern from supine to prone is initiated by lifting and turning the head, and reaching with the opposite arm. The roll needs to occur in segmental fashion. (The movement begins by rotating the head, the shoulders rotate in the same direction, followed by the trunk, hips, and then the legs. If the patient is log rolling, corrections, either verbal and/or tactile, cues needs to be used.)
  - The upper body rolling pattern from prone to supine is initiated by turning the head and retracting the lead scapula to bring the arm around. Keep reaching and rotating, and again this need to happen in a segmental fashion from the head all the way down the spine to the lower extremities.
  - The lower body rolling pattern from supine to prone is initiated by flexing, adducting, and internally rotating the opposite hip. Reach the leg across the body and extend the knee as the hips, pelvis, and lumbar spine begin rotating over toward the prone position. The roll must be segmental in nature.
  - The lower body rolling from prone to supine is initiated by extending, adducting, and externally rotating the opposite hip. While rotating over to supine be sure the rotation occurs segmentally and not as a log roll.

Sport-Specific Exercises

- The patient should be able to increase the level of intensity and volume of the sport-related activity as long as the activity does not put the rehabilitating shoulder at risk. Other activities that do involve the affected shoulder can be considered (i.e., hitting, tossing underhand, swimming the breaststroke, or modified sidestroke).

Milestones for Progression to the Next Phase

- Glenohumeral range of motion is within normal limits with a firm end feel with joint mobility testing.
- Rotator cuff strength (MMT) has improved to within 1 to ½ grade right versus left.
- Maintained or improved spinal, hip/pelvis, and ankle mobility

Phase III: Power and Acceleration (weeks 8 to 12)

Volume/duration: Perform 10 to 15 reps, 1 to 3 sets per exercise, depending on quality of movement and minimizing the presence of compensatory movement patterns. Exercise will be terminated when there is a decrease in movement quality and/or movement compensations noted.

Goals

- Improve strength and power
- Maximize use of kinetic chain
- No signs or symptoms of impingement returning
- Improve dynamic neuromuscular control of scapula/trunk
- Begin mechanical work of the mechanism of injury

Management of Pain and Swelling

- Ice application postexercise as needed.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Manual therapy techniques as previously stated in Phase II as needed to achieve full mobility in upper quarter.
- Joint mobilization grade III to IV as indicated for the glenohumeral joint, scapulothoracic joint, and thoracic spine.

Soft Tissue Techniques

- Continue soft tissue techniques in Phase II as indicated.

Stretching and Flexibility Techniques for the Musculotendinous Unit

Other Therapeutic Exercises

- Patients should be instructed in glenohumeral, scapulothoracic, and cervicothoracic stretching/flexibility techniques.
- Progress Phase II exercises with increased intensity, volume, and frequency as tolerated.

Activation of Primary Muscles Involved

- Progress Phase II exercises with progressive resistance as tolerated.

Open and Closed Kinetic Chain Exercises

- Advance exercises from Phase II
- Front planks and side planks, with and without weight shifts on stable surfaces and progress to unstable surfaces
- Slide board exercises in plank or quadruped position

Techniques to Increase Muscle Strength, Power, and Endurance

- Progress strength exercises in Phase II per tolerance
- Begin periodization program for strength training, which entails cycling or manipulating training variables to provide variation in volume and intensity to avoid overtraining.

Neuromuscular Dynamic Stability Exercises

- Advance exercises from Phase II
- Continue chops and lifts in half and tall kneeling and split squat positions
- The pushup progression leads to dynamic wall pushups to dynamic pushups to floor pushups

Clinical Pearl

> Stability exercises should be progressed from static to dynamic movements, bilateral to unilateral activities, and from a stable to unstable base of support.

Plyometrics

- Bilateral throwing patterns using chest pass movements into the rebounder progressing to single arm activities
- Overhead bilateral medicine ball slams

Functional Exercises

- Overhead strengthening is incorporated, such as kettlebell presses, pullups, etc.
- Lower extremity agility drills are added, such as higher speed cone/footwork, bounding, hurdles, and box jumping.

Sport-Specific Exercises

- Progression to a formal strength and conditioning program once athletes have full mobility/ROM, strength, and are pain free with upper quarter activity/movements.

Milestones for Progression to Advanced Sport-Specific Training and Conditioning

- Improve function, strength, endurance, and stability as well as improved neuromuscular control and coordination of the kinetic chain.
- Power tests may include overhead medicine ball throw and standing rotational medicine ball throw.

Note: Mobility/ROM are measured and assessed via goniometry measurement, so that right versus left extremities are within 10° of one another to achieve symmetry. Strength comparisons are measured via manual muscle testing (MMT) to assess symmetry right versus left. Stability, endurance, and power tests are measured by assessing symmetry right versus left with the absence of compensatory motion during observed movement patterns.

Phase IV: Return to Sport/ Competition (weeks 12+)

Note: Volume/duration: Perform 10 to 15 reps, 1 to 3 sets per exercise, depending on quality of movement and minimizing the presence of compensatory movement patterns. Exercise will be terminated when there is a decrease in movement quality and/or movement compensations noted.

Goals

- Return to sport symptom-free
- Normal kinematics: no scapular dyskinesis, no SICK scapula, improved neuromuscular control, and muscle firing patterns throughout kinetic chain
- Improved cardio and anaerobic function
- Patient has increased knowledge and understanding of their body, function, predispositions to injury, mechanical awareness, the need to build in recovery into their program, and have a "plan"
- Continue maintenance drills, exercises, movement patterns, correctives, stretching, and sport-specific training

Management of Pain and Swelling

- Ice application postexercise as needed

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Manual therapy techniques as previously stated in Phase III as needed.
- Additional joint mobilizations can be targeted toward hypomobile joints, including the glenohumeral joint (grade III to IV), scapulothoracic joint, and thoracic spine as needed.

Soft Tissue Techniques

- Patient instruction self-management techniques including the use of a foam roller, tennis ball, or lacrosse ball which can provide long-term treatment options.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Use of sustained end range stretching to achieve desired mobility goals.
- Pre- and postexercise stretching should focus on functional movement patterns.

Other Therapeutic Exercises

- Multijoint movements should be included in this phase including front squats, deadlifts, overhead press, pull-ups, and rows.

Activation of Primary Muscles Involved

- Focus should be establishing on returning to a level of preinjury function.

Sensorimotor Exercises

- D1/D2 movements with cables or bands
- Ball toss exercises in standing or split squat
- Medicine ball rotations

Open and Closed Kinetic Chain Exercises

- Advancing the previous exercises from Phase III in accordance with sport-specific demands
- Examples of progression may include kettlebell swings, push presses, snatch, and power cleans

Techniques to Increase Muscle Strength, Power, and Endurance

- Continue periodization to optimize recovery and return to sport.

Neuromuscular Dynamic Stability Exercises

- Resistance exercises in standing progress from symmetrical stance to asymmetrical stance to unstable surfaces as necessary. Exercises may include PNF movements, such as resisted chops and lifts.
- Kettlebell Turkish get-ups with added neck and shoulder rotations in each phase (Figure 6-59)

Clinical Pearl

> Dynamic stability exercises and strength training should duplicate the endurance, strength, and power demands that will be encountered closest to an athlete's chosen sport.

Plyometrics

- Advance level of dynamic pushups, plank walking up and down over a step, and overhead tossing activities/ movements

Sport-Specific Exercises

- Light sport-specific training including light throwing for pitchers and light overhead stroke movements for swimmers

Specific Criteria for Return to Sports Participation: Tests and Measurements

- Pain scale (VAS): 0/10, full shoulder ROM/mobility in all planes, strength/MMT 4+ to 5/5 in all planes, HHD: less than 5% to 10% right versus left.
- Upper extremity Y-balance test: less than 4 cm difference right versus left in all test directions.
- Closed kinetic chain upper extremity stability test.
- Functional movement screen (FMS): >14 total score with a ≥2–2 right to left symmetry on the shoulder mobility test component.



FIGURE 6-59. Turkish get-up. **A,** Phase 1. **B,** Phase 2. **C,** Phase 3. **D,** Phase 4. **E,** Phase 5. **F,** Phase 6. **G,** Phase 7.

Evidence

Cook G, Burton L, Kiesel K, et al: Movement: Functional Movement Systems: Screening, Assessment and Corrective Strategies, Optos, CA, 2010, On Target Publications.

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Rubin BD: Principles of shoulder rehabilitation. In Johnson DH, Pedowitz RA, editors: Practical orthopaedic sports medicine & arthroscopy, ed 4, Philadelphia, PA, 2007, Lippincott Williams & Wilkins, pp 323–335.

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Multiple-Choice Questions

QUESTION 1. The goals of Phase I rehabilitation include all but:

A. Protect healing segment
B. Minimize effect of spinal immobilization
C. No signs or symptoms of instability
D. Return to sports

QUESTION 2. What are appropriate interventions for Phase III rehabilitation?

A. Manual therapy
B. Stretching exercises
C. Begin return to sport activity
D. All the above

QUESTION 3. The act of _____ has been shown to activate reflex contraction of the rotator cuff muscles?

A. Neck rotation
B. Gripping
C. Jaw clenching
D. Eye tracking

QUESTION 4. During which time frame does "return to sport" start?

A. Week 6
B. Week 8
C. Week 10
D. Week 12

QUESTION 5. What is not a criteria for progression of the patient to the next phase?

A. Increased AROM without pain
B. Able to perform sport-specific motion without pain
C. Able to tolerate improved activity without pain
D. Contact sports without physician clearance

Answer Key

QUESTION 1. Correct answer: **D** (see Phase I)

QUESTION 2. Correct answer: **D** (see Phase III)

QUESTION 3. Correct answer: **B** (see Phase I: third Clinical Pearl)

QUESTION 4. Correct answer: **D** (see Phase IV)

QUESTION 5. Correct answer: **D** (see Phase I-IV)

POSTOPERATIVE REHABILITATION AFTER TREATMENT OF INTERNAL IMPINGEMENT

Mark Rogow, ATC, CSCS, and Charles E. Rainey, PT, DSc, DPT, OCS, SCS, CSCS, FAAOMPT

Indications for Surgical Treatment

- Persistent activity-related pain and/or pain with instability with desire to continue in these sports/activities.
- This is typically experienced by throwing athletes, caused by the articular side of the insertion of the supraspinatus tendon impinging against the posterosuperior glenoid rim in the combined movement of abduction and extreme external rotation (overhead throwing position) (Figure 6-60).
- Prehabilitation failed: The preoperative rehabilitation protocol offered in this text is a quality example of the needs and goals of what should be accomplished. If this fails, then surgical treatment should be considered if the athlete has a strong desire to return to their sport at the level at which they were competing before their injury.
- In the nonathletic population, conservative treatment is recommended for a minimum of 3 to 6 months. Be sure to determine their level of symptoms and activities in which they are limited before deciding upon surgery.
- When pain and a positive relocation test persist after rehabilitation.
- Surgery may be recommended earlier in the athlete.

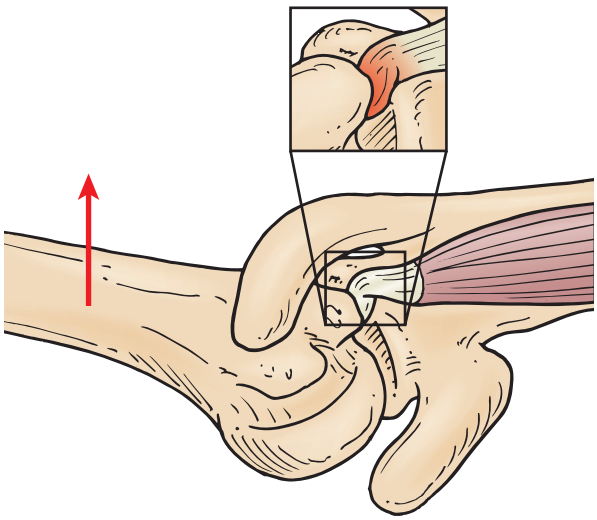

FIGURE 6-60. Articular side of the insertion of the supraspinatus tendon impinging against the posterosuperior glenoid rim in the combined movement of abduction and extreme external rotation.

Brief Summary of Surgical Treatment

Major Surgical Steps (Debridement Only)

- General anesthesia and shoulder arthroscopy, patient in lateral decubitus position
- Diagnostic arthroscopy to document all pathology (Figure 6-61)
- Glenohumeral joint explored through posterior portal to examine partial tears in the supraspinatus and infraspinatus tendon insertion and posterior labrum
- An anterior-superior instrument portal is used, just anterior to the acromioclavicular joint.
- Arm is positioned in abduction-extension-external rotation (the critical position) to ensure all pathology is detected and confirm diagnosis (demonstrating the tendon lesion impinged on the glenoid rim).
- Extensive debridement of the posterior labrum is performed with a motorized shaver, starting superiorly 15 to 20 mm posterior to the biceps insertion, removing all the pathologic tissue and precluding any labral reinsertion.
- Soft tissue debridement is often continued into the posteroinferior glenoid rim (seven o'clock position) to obtain a smooth posterior angle.
- Glenoidplasty performed with a motorized burr, removing all spurs present from the posterior glenoid rim.
- An additional instrumental portal is required many times to reach the posteroinferior glenoid rim more easily
- The arm is positioned in the critical position to ensure absence of internal (posterior) impingement

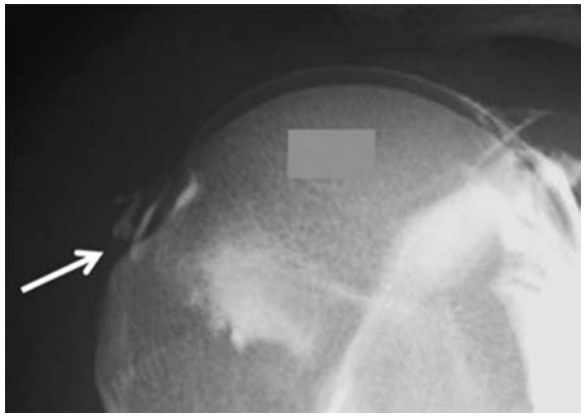

FIGURE 6-61. Partial tear of the articular side of the supraspinatus tendon (*arrow*) shown on arthrogram.

- Padded abduction sling postoperatively for patient comfort

Factors That May Affect Rehabilitation

Surgical

- If arthroscopic labral repair, rotator cuff repair or bicep tendon tendinosis are performed, the repaired structures will need to be protected for 6 weeks.
- This includes limited passive glenohumeral abduction and external rotation ROM, active shoulder ROM, and resistive bicep work.
- The sling may be discontinued at 4 to 5 weeks postoperatively depending on surgeon preference and patient compliance with ROM restrictions.

Before Surgery: Overview of Goals, Milestones, and Guidelines[1]

The prehabilitation outline is included in the nonoperative rehabilitation section of this chapter. We strongly recommend executing the program or at least a majority of it before choosing surgical intervention.

Goals to be Met Before Surgery

- Establish diagnosis: Identify if there is GIRD, posterior capsular hypomobility, a lack of rotator cuff and/or scapular strength and endurance, acquired glenohumeral anterior instability, labral and/or rotator cuff injury, or a combination of a number of these dysfunctions/pathologies. Establish a plan to address each of these conditions
- Optimize postural alignment
- Address SICK scapula and/or scapular dyskinesis
- Restore glenohumeral and scapulothoracic joint mobility
- Address any and all mobility issues and fascial restrictions from nose to toes
- Reestablish and enhance dynamic stability/muscle synergy (balance)/neuromuscular control of both glenohumeral and scapulothoracic joints
- Improve shoulder, trunk, lumbopelvic, and ankle stability
- Monitor progress closely and advance forward in the program as milestones are achieved. Moving forward in a program is less determined by time, rather than by goals attained. However, it is possible to be working in multiple phases given the performance of the entire kinetic chain is being rehabilitated and improved, not a single body part.
- Return to ADLs without pain.
- Increase strength, power, endurance, and myokinematics of entire kinetic chain.
- Failure to return to sport after goals above had been met.

[1]*Prehabilitation, if appropriate, is described in the Nonoperative Rehabilitation section of this chapter.*

Clinical Pearls

Jobe's clinical classification of internal impingement:
- Stage III (Advanced): Surgery is likely indicated for patients who have not responded to nonoperative treatment when pain localized to the posterior shoulder in the late-cocking and early acceleration phases of throwing, and/or have pain with activities of daily living.
- When pain and a positive relocation test persist after rehabilitation, Jobe feels that such patients require surgical repair of their rotator cuff and/or labral pathology as well as a modified anterior capsulolabral shift.

GUIDING PRINCIPLES OF INTERNAL IMPINGEMENT REHABILITATION

- Understand type(s) of surgical repair performed is critical
- Understand the anatomic structures and their rate of healing
- Understand positions and activities that stress the healing structures
- Proper selection of manual therapy intervention applied at the appropriate phase of healing
- Respect rate of ROM progression
- Because every surgical repair is different, respect that the rehabilitation progression needs to be customized to the individual, taking into account their sport, size of repair, age, type of repair, as well as their willingness and ability to comply with the protocol.

After Surgery—Postoperative Rehabilitation: Overview of Goals, Important Milestones and Guidelines

Factors Contributing to and Pathologies Resulting from Internal Impingement

- Poor scapular mechanics and movement patterns (dyskinesis)
- Weak scapular stabilizers and/or rotator cuff
- Lack of endurance of scapular stabilizers and/or rotator cuff
- Partial tear or complete tear of rotator cuff: Surgeons have identified undersurface tears of the anterior aspect of the infraspinatus tendon as well as undersurface tears on the posterior aspect of the supraspinatus
- Laxity of the anterior capsule: Acquired glenohumeral anterior instability
- Labral pathology: Most commonly superior-posterior labral tears
- GIRD: Significant loss of glenohumeral internal rotation
- Less than optimal posture
- Bony changes: Bennett's lesion (extra-articular ossification of the posterior capsule)
- Glenoid chondral erosion

- Chondromalacia of posteriosuperior humeral head
- Biceps tendon pathology

GUIDING PRINCIPLES OF INTERNAL IMPINGEMENT REHABILITATION

- Establish diagnosis: Identify if there is GIRD, posterior capsular hypomobility, a lack of rotator cuff and/or scapular strength and endurance, acquired glenohumeral anterior instability, labral and/or rotator cuff injury or a combination of a number of these dysfunctions/pathologies before surgery. Establish a plan to address each of these conditions following surgery in congruence with the patient's surgeon.
- Once the postoperative restrictions have been established, the rehabilitation protocol needs to be customized based on the patient's age, tissue quality, size of tear, security of repair, and additional procedures performed.
- Optimize postural alignment
- Address SICK scapula and/or scapular dyskinesis
- Restore glenohumeral and scapulothoracic joint mobility
- Address any and all mobility issues and fascial restrictions from nose to toes
- Reestablish and enhance dynamic stability/muscle synergy (balance)/neuromuscular control of both glenohumeral and scapula-thoracic joints
- Improve shoulder, trunk, lumbopelvic, and ankle stability
- Monitor progress closely and advance forward in the program as milestones are achieved. Moving forward in a program is less determined by time, rather than by goals attained. However, it is possible to be working in multiple phases given the performance of the entire kinetic chain is being rehabilitated and improved, not a single body part.
- Return to ADLs without pain
- Increase strength, power, endurance and myokinematics of entire kinetic chain
- Return to sport!

Phase I: Immediate Postoperative Period (days 0 to 14)

Volume/duration: Perform 10 to 15 reps, 1 to 3 sets per exercise, depending on quality of movement and minimizing the presence of compensatory movement patterns. Exercise will be terminated when there is a decrease in movement quality and/or movement compensations noted.

Clinical Pearl

- The rehabilitation program should move along a continuum. Its difficulty should increase over time with respect to the sport or desired activity[1] and evolve from bilateral to unilateral, supported to unsupported,[2] using active and passive movement, with and without load.[3]

Goals

- Protect the repaired structures
- Minimize the effects of immobilization
- Decrease pain and inflammation
- Retard muscle atrophy
- Restoring good posture
- Facilitating scapular mobility and control
- Initiate core stabilization exercise

If the athlete/patient is progressing without complications (with no signs of infection, no signs and symptoms of instability, or damage to the repair) progress to the next phase.

Protection

- Postoperative immobilization is achieved via sling use with the arm in slight abduction and neutral rotation.
- A sling with an abduction pillow is preferred due to patient comfort and proper glenohumeral positioning to prevent stress to the healing superior and posterior structures.
- Sling is to be used at all times, including sleep, unless directed by physician or therapist.
- Discuss proper sleep hygiene: Do not sleep on shoulder, do not sleep with arm/shoulder in overhead position (prone, supine or side-lying)
- If patient maintains kyphosis, forward head, forward shoulder posture, consider postural correction shirt or proprioceptive scapula taping.

Management of Pain and Swelling

- Oral pain medications as prescribed by surgeon
- Therapeutic modalities for pain and inflammation to include TENS, Hi-Volt and IFC e-stimulation
- TENS to control pain as well as inhibit muscular guarding and spasm
- Cryotherapy for pain and inflammation reduction
- Poly-mem/sports wrap and Kinesio taping (fan/weave technique) if postoperative swelling visible
- Patient education: Using pillows or bolsters to find a position of comfort to reduce stress on contractile structures of the shoulder as well as repaired structures while resting and sleeping

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- ROM Precautions: IR 0°, humeral elevation in scapular plane 90° (precautions adjusted for other concurrent surgical repairs such as SLAP, Bankart repair, posterior capsule release, anterior capsule plication)
- PROM: Manual range of glenohumeral joint via oscillatory passive range of motion (per precautions) as well as affected elbow/wrist (flexion, extension), and scapula. Muscular guarding should be considered and manual therapy adjusted as necessary to facilitate relaxation to avoid undue stresses on the posterior capsulolabral complex. Additionally, stretching into

the end ranges should be avoided to prevent stressing the repair and limit any unnecessary increase in inflammation.[4]

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Shoulder stretching not performed during this stage with the exception of the cervical musculature (i.e., levator scapula, upper trapezius) as needed.
- Grade I to II glenohumeral/scapulothoracic joint mobs

Clinical Pearl

- If SLAP repair or biceps tenodesis has been performed, NO biceps muscle activation should be performed for first 8 weeks.

Other Therapeutic Exercises

- Athletes/patients are encouraged to participate in low intensity cardiovascular conditioning activities such as stationary biking or treadmill walking. The sling must be worn during these activities and if there is increased pain or muscle guarding, the activity should be modified or ceased.
- Core stabilization exercises: Supine
  - Establish neutral pelvis
  - Draw-in maneuver
  - Partial crunch
  - Pelvic tilts
  - Bridging/single-leg bridge/bridge marching
  - Dead bugs (moving legs only)
  - Physio ball wall squats
- Evaluate for and treat deep neck flexor inhibition (may need tissue work on suboccipitals, cervical extensors, and scalenes)
  - Supine active chin tuck
  - Supine cervical flexion
- Properly instruct diaphragmatic breathing
  - The importance of breathing and the quality of each breath needs to be emphasized to the patient throughout their exercise program, so the volume dosage parallels their therapeutic exercise dosage. They should inhale and exhale fully on every repetition.
- Dynamic lower extremity exercises
  - Body weight squats
  - Lunges (in the sagittal, frontal and transverse planes)
  - Step-ups
  - Lateral step-ups
  - Step-downs
  - Trendelenburg exercise
  - Thera-Band walking (forward, backward, side-step)
  - Romanian dead lift (can use light weight with uninjured arm)
  - Good morning exercise (body weight only)
  - Single-leg stance/single leg excursions (in the sagittal, frontal and transverse planes)
  - Calf exercises

Clinical Pearls

- All exercises and stretches in this phase should be done pain free, slowly and under control.
- Reinforcement of quality movement and mechanics while working on posture and scapular control needs to be regular and routine.
- It is critical to achieve good scapular control before increasing volume and intensity of strength training or the underlying issue of scapular dyskinesis and poor scapular control will either slow the athlete's return to play or will significantly increase the athlete's predisposition to reinjury.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Postural Exercises
  - Reinforce proper scapular position
  - Sternal lifts
  - Scapular pinches (supine, side-lying)
- Codman's Pendulum exercises to maintain passive motion at the glenohumeral joint. Due to improper technique, which is often observed clinically, the use of assisted Codman's with the sound side support of the affected arm until the patient understands and regularly executes proper technique is recommended.
- UE ranger exercises (Figure 6-62)
  - Flexion/extension
  - Abduction/adduction from 0° to 45° abduction
  - Circumduction
- Hand gripping and active wrist flexion and extension range of motion activities initiated.

Clinical Pearl

- Establish or maintain good posture and good scapulothoracic position throughout the day. Using postural correction shirts, clavicle collars, as well as Kinesio-type tape, can help reinforce and/or reeducate critical postural and suprascapular muscles.

Sensorimotor Exercises

- Finger and wrist kinesthetic and strengthening exercises can be performed; however, no pronation or supination should be done, while the biceps is not to be exercised if a biceps tendinosis was performed.
- Active assistive ROM; cane/wand exercises after 7 to 14 days postoperatively

Open and Closed Kinetic Chain (CKC) Exercises

- Depending upon healing parameters and type of repair performed, patient may begin upper extremity CKC exercises versus the therapist.
- The hand of the patient needs to be gripping an object, either the therapist's hand or another object, to initiate the coupling and co-contraction of the scapulothoracic and glenohumeral musculature to prevent shear, increase joint stability, reproduce, or provide proprioceptive stimulation to joint mechanoreceptors (GTO,



FIGURE 6-62. UE Ranger. **A,B**, Shoulder flexion/extension with contralateral scapular retraction. **C,D,** Shoulder abduction/adduction with contralateral scapular retraction. **E,F,G,H,** Perform shoulder circumduction or write 'alphabet' with hand while contralateral scapula maintains retracted position.

muscle spindle, etc.) which helps to reorganize and reestablish normal muscle firing patterns.
- Submaximal isometrics can also begin after first week of healing.

Clinical Pearls

- The act of gripping has been shown to activate reflex contraction of the rotator cuff muscles which will stimulate glenohumeral mechanoreceptors.[5]
- This in turn increases joint compression and dynamic muscular cocontraction improving joint congruity, reduce shear forces, stimulates joint proprioceptors while enhancing dynamic stabilization.[6]

Techniques to Increase Muscle Strength, Power, and Endurance

- Resistance to lower body and core strengthening exercises should be light in resistance and in intensity throughout this phase. Begin to increase endurance (increase repetitions/volume) in the second half of this phase.

Neuromuscular Dynamic Stability Exercises

- Begin core/trunk stability exercises listed above.

Functional Exercises

- Discuss with patient shoulder/spine posture. Give home exercise program
- Initiate diaphragmatic breathing

Milestones for Progression to the Next Phase

- Minimal pain with PROM
- Decreased tenderness and swelling on and around incision
- Isometrics performed pain free
- Ready to move forward with active assistive range of motion (AAROM)
- Ready to begin active range of motion (AROM)

Phase II: Mobility (weeks 2 to 6)

Volume/duration: Perform 10 to 15 reps, 1 to 3 sets per exercise, depending on quality of movement and minimizing the presence of compensatory movement patterns. Exercise will be terminated when there is a decrease in movement quality and/or movement compensations noted.

Goals

- Protect repaired structure(s)
- Minimize effect of immobilization
- Retard muscle atrophy
- PROM glenohumeral elevation in scapular plane of 140°, ER 30°
- No marked pain globally about the glenohumeral joint
- No signs or symptoms of instability
- Restoring good posture
- Facilitating scapular mobility and control
- Continue core stabilization exercise

Protection

- Use of the sling is continued. If arthroscopic labral repair was performed without involvement of the rotator cuff musculature or bicep tendon, the sling may be discontinued at 4 to 5 weeks postoperatively depending on surgeon preference and patient compliance with ROM restrictions.
- Continue to use proper sleep hygiene, especially after the sling has been discontinued.

Management of Pain and Swelling

- Electrotherapy (TENS and IFC) is continued for pain and muscle guarding
- Hi-Volt E-stimulation/Russian helps muscle reeducation
- Oral pain medications are usually continued (per physician/surgeon)
- Cryotherapy with compression postexercise/treatment and at home if needed

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- ROM precautions: IR 0°, ER 30°, horizontal adduction 0°, scapular plane elevation to 120° week 4, scapular plane elevation to 140° week 6, sagittal plane flexion 90° week 4, sagittal plan flexion 120° week 6.
- PROM: Manual ROM of the humerus (per above precautions) while ensuring quality of glenohumeral and scapulothoracic motion and avoidance of excessive/compensatory scapular mobility to impingement. Scapular elevation, depression, and abduction.
- Grade I and III glenohumeral joint mobilizations, with light traction, may improve available PROM and also contribute to pain management.

Soft Tissue Techniques

- Scar mobilization to postsurgical incisions once closed.
- Soft tissue massage/mobilizations, IASTM (instrumental assisted soft tissue mobilization), and trigger point dry needling are all indicated to reduce spasm, tightness, reset muscle tendon units, and improve joint restrictions.
- Be sure to look outside the glenohumeral joint to cervical, thoracic, scapulothoracic, acromio- and sternoclavicular restrictions all affect position and function of the glenohumeral joint

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Patients may begin table slides or physio ball rolling for passive techniques within the ROM precautions.

- AROM: Scapular clocks are continued and scapular dumps are initiated to emphasize thoracic and lumbar mobility.
  - Scapular clocks: with elbow extended, hand is placed in either abducted position (at 90°), in scapular plane or with shoulder flexed to 90° at 0° abducted. Always with hand against fixed object, like a wall. Actively retract and protract scapula (9 to 3 o'clock), then elevate and depress scapula (12 to 6 o'clock). Note: Scapular dumps are equivalent to lawnmowers.
- Elbow and wrist ROM is encouraged and can be done as part of the Home Exercise Program.
- Pulleys for AAROM may begin after the second postoperative week (depending upon the type of repairs performed in surgery) as long as correct technique is demonstrated. As patients gain PROM to 120° in the scapular plane without guarding or pain, AAROM techniques are continued to include flexion and abduction via wands, wall walks and the UE ranger with cues to avoid compensatory shoulder shrugs.

TIMELINE 6-5: **Postsurgical Rehabilitation After Treatment of Internal Impingement**

PHASE I (weeks 1 to 2)	PHASE II (weeks 2 to 6)	PHASE III (weeks 6 to 10)
• Postop immobilization: wear sling at all times (including sleep) • Pain control: oral pain meds as prescribed • E-stimulation and cryotherapy for pain/inflammation • Patient education: proper sleep hygiene and positioning • PROM to glenohumeral, scapula, elbow, and wrist • Glenohumeral ROM precautions: IR 0°, scapular plane elevation 90° • Grade I/II mobs to glenohumeral and scapulothoracic joints • AAROM with can/wand exercises after 7–14 days postop • Sub-maximal isometrics can begin at 7 days postop • Cervical musculature (upper traps, levator scapulae) stretching as needed. • Low intensity cardiovascular activities (treadmill, stationary bike) • Core stabilization exercises in supine • Codman Pendulum exercises • UE ranger exercises • Hand gripping, active wrist flex/ext activities, finger strengthening • Diaphragmatic breathing in all exercise postures • Postural stabilization exercises (scapular pinches) • Dynamic lower extremity CKC exercises (squats, lunges, step-ups, lateral step-ups, etc.)	• Continue to wear sling. If repair performing without rotator cuff or bicep tendon repair, sling may be D/C at 4–5 per surgeon • Continue proper sleep hygiene and positioning • Oral pain medications continued per surgeon • E-stimulation and cryotherapy for pain/inflammation • Continue ROM to glenohumeral, scapula, elbow, and wrist • Wk 4: IR 0°, ER 30°, horizontal adduction 0°, scapular plane elevation to 120°, sagittal plane flexion 90° • Wk 6: scapular plane elevation to 140°, sagittal plan flexion 120° week 6 • Avoid horizontal adduction and shoulder extension beyond neutral/beyond the frontal plane with ALL exercises • Grade II/III to glenohumeral joint for ROM and pain management • Scar mobilizations to incisions once closed • Soft tissue mobilizations to upper quarter in include cervical, thoracic, scapulothoracic, acromio- and sternoclavicular restrictions • Pulleys for AAROM can begin at Week 2, progress to AROM per pt tolerance • Began light AROM movements (wall walks, seated towel slides behind back) • Continue scapular stability exercises (Is, Ys Ts, Ws) • Scapular AROM (scapular clocks) and PNF patterns in all planes • Moderate intensity cardiovascular exercise (treadmill. stationary bike, elliptical, StairMaster, etc.) • Kettle bell holds with shoulder packing (supine/side-lying) • Core stabilization in supine/prone (dead bugs, SL/DL bridges, etc.) • Continue dynamic lower extremity CKC exercises • Lower extremity balance activities (SL stance eyes open/closed, BOSU ball, Airex pad, balance beam) • Begin motor control exercises, such as PNF rhythmic stabilization and perturbations (physio ball oscillations with arm outstretched) • Begin quadruped upper extremity weight shifting if healing parameters and repair type is suitable • Pushup holds leaning into wall • Seated towel slides • Thumbtacks	• D/C sling • Oral analgesics prn per surgeon • E-stimulation and cryotherapy use as needed or use postexercise soreness • AAROM and AROM for glenohumeral and scapulothoracic joints performed in all planes (no ROM restrictions, per pt tolerance only) • Joint mobilizations (Gr I-IV) per capsule restrictions • Rotator cuff strengthening/stability exercises • Sleeper stretch/modified sleeper stretch • Side-lying horizontal adduction stretch • Bicep/triceps strengthening • Body blade/perturbations • Continue to advance scapular stability exercises (Is, Ys, Ts, Ws) • Continue scar mobilization, including cross-friction • Soft tissue mobilizations and self-stretching to upper quarter musculature (pectoralis major/minor, levator scapulae, upper trapezius, lats, rhomboids, rotator cuff muscles) • Pulleys or cable pulls • Viper (rope climbing machine) • Standing forearm wall slides • Wax on/wax off exercises • Dynamic 4 exercises • Quadruped weight shifts and pushups on knees • Seated press-ups at Week 10 • Cardiovascular endurance activities (light jogging, swimming, UBE) • Advanced core stabilization exercises (Supermans, quadruped diagonals/bird dogs, dead bugs) • Lower extremity balance activities • Low level lower extremity plyometrics (dot drills, jump rope, hops, skipping, low level bounding/box jumps)

- Careful observation for compensation and emphasis on restoring scapulohumeral mechanics is important while increasing ROM during this phase to avoid subacromial impingement.

Other Therapeutic Exercises

- Athletes/Patients should continue low to moderate intensity cardiovascular conditioning activities such as:
  - Stationary biking
  - Treadmill walking
  - Treadmill incline
  - Elliptical
  - Arc trainer
  - Stairmaster
  - Outdoor walking and/or up to moderate level hiking

Be sure that the potential need for upper body support and loading during the use of stairclimbers, elliptical and arc trainer activities restricts safe implementation of these conditioning options until 8 weeks postoperatively in most postsurgical cases. In this phase the sling may be

TIMELINE 6-5: Postsurgical Rehabilitation After Treatment of Internal Impingement (Continued)

PHASE IV (weeks 10 to 14)	PHASE V (weeks 14 to 24)	PHASE VI (weeks 24 to 52)
• Oral analgesics prn per surgeon • E-stim and cryotherapy use as needed or use postexercise soreness • PROM to full ROM • Glenohumeral joint mobilizations (Gr III-IV) as needed • Continue scar mobilization as needed • Continue soft tissue mobilizations to pec major/minor, subscapularis. Lats • End-range stretching of upper quarter musculature • IR stretching can begin at Week 12 postop (cross chest stretch, sleeper stretch) • Rotator cuff strengthening/stability exercises • Bent over rows • Jacob's ladder • TRX serratus hug exercise • Half/tall kneeling chops and lifts with narrow base (with and without resistance) • Glenohumeral PNF D1/D2 patterns • Pushups (wall pushups to standard floor pushups) • Lower extremity SL balance exercises progressed • Medicine ball front squats • Dynamic CKC activities with manual perturbation, tilt boards • Lower extremity plyometrics progressed • Upper extremity rebounder exercises (chest pass, ER/IR ball toss/catch) • Begin walk-jog progress at 12 weeks • Lower extremity sport-specific drills (hops, jumping, change in direction/agility drills)	• Continue joint mobilizations (Gr III-IV) and soft tissue mobilizations as needed • Continue scar mobilization as necessary • End-range stretching of upper quarter musculature • Progress lower extremity, gluteal, and hip stretch exercises • OKC: Upright rows, seated rows, lateral raises, front raises • OKC: ER/IR at 0° and 90° abduction, isotonic/resistance bands, PNFs, diagonal lift and chop exercises, pool resisted motions • CKC: side planks, front planks and weight shifts on stable and progress to unstable surfaces • CKC: BOSU ball for progression of pushups to uneven surfaces • Advance upper body strengthening • Pushup progression from single arm wall pushup to floor pushups • Upper body plyometrics using bilateral arm throwing patterns • Overhead bilateral medicine ball slams and catching drills • Rebounder IR/ER at 90° abduction • Overhead strengthening • TRX Exercises (SL squat, mountain climbers, split squat, prone runners, etc.) • Lower extremity agility program (ladder and hurdle drills) • Progress lower extremity balance activities • Running progression • Turkish get-up progression • Bear crawling • Inchworms/crabs • SFMA Rolling patterns (upper body/lower body) • Dynamic stability exercises (jumping jacks, walking lunges, skipping, hops, etc.) • Throwing athletes begin light tossing at short distances (avoid full wind-up until 20 wk postop)	• Cryotherapy postexercise • Joint mobilizations to glenohumeral, scapulothoracic, thoracic spine as needed • Self soft tissue mobilizations using tennis/racquet ball as needed • Home stretching for posterior capsule progression (supine horizontal stretch with IR, sleeper stretch) • Continue end range stretching for upper body musculature • Multijoint movements (front squats, power/hang cleans, clean and press) • Ball toss exercises in standing • D1/D1 exercises with cables • Medicine ball throwing activities (diagonals, woodchops, slams, Russian twists) • Advance upper body plyometrics (overhead toss, dynamic pushups, etc.) • Single arm dumbbell walks • Rock climbing wall • Tire flipping • Battle rope exercises • Wk 24: Throwing athletes begin short tossing (increase throwing intensity/volume) • Wk 24: Swimming athletes begin limited overhead stroke work • Return to sport: continue fitness/rehab exercises including total body strengthening program

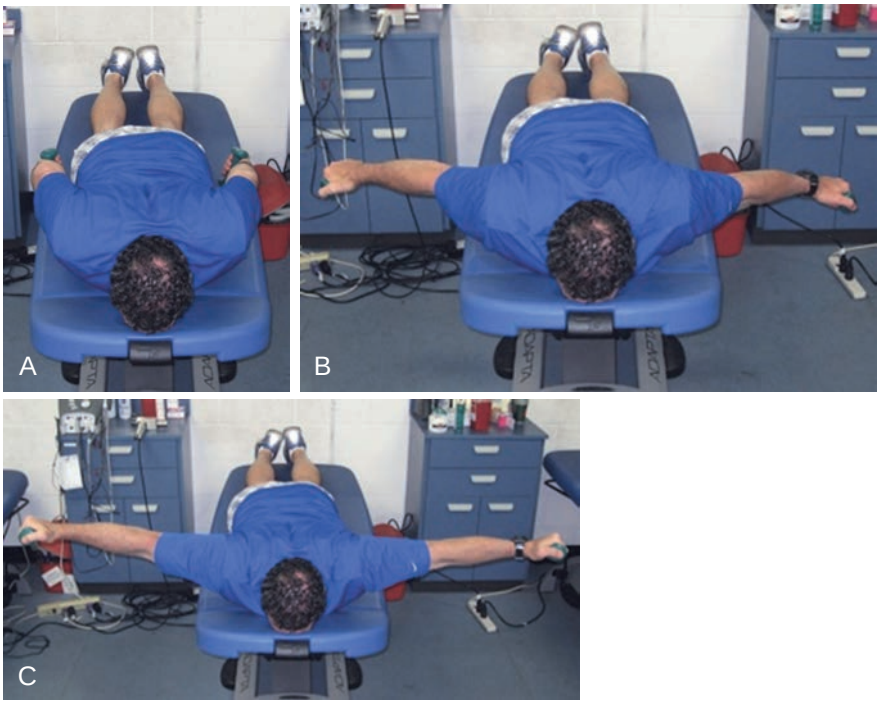

FIGURE 6-63. Prone I (**A**), V (**B**), T (**C**) light dumbbell or cuff weight exercise.

worn during these activities initially, however, will not be worn by the end of this phase.

- Core stabilization exercises (supine/prone)
  - Establish neutral pelvis
  - Draw-in maneuver
  - Partial crunch
  - Pelvic tilts
  - Bridging
    - Bridging in supine position, with knees bent, extend hips toward ceiling by pushing through heels and mid-foot.
  - Single-leg bridge
    - Single-leg bridge is performing this with only one leg while the other leg is extended.
  - Bridge marching
    - Bridge marching is maintaining hips in extended position and alternating each foot on and off the table (or floor).
  - Butterflies
    - Butterflies are the same as clamshells: Side-lying with hips and knees bent at 90° with Thera-Band around knees, keep bottom leg on table or floor while the top leg externally rotates and abducts.
  - Modified dead bugs (arms may begin to flex above 90° if pain free and allowable per the protocol/arms may also press against the ground or versus tubing (concentric or isometric shoulder extension)
  - Wall/table prone plank (on elbows against wall or table)
- Lower extremity exercises during this phase may include all those listed in Phase I. The volume of those exercises should be increased in this phase. Intensity/resistance should increase in the next phase. Can add:
  - Single leg Romanian Deadlifts (RDLs)
  - Machines: Leg extension, leg curl, abduction/adduction, multihip

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Sub-maximal isometrics are begun in neutral rotation and less than 30° abduction with the elbow flexed to 90° with submaximal force (modified neutral):
  - Flexion/extension
  - Abduction/adduction
  - IR/ER
- Continue scapular squeezes/pinches and sternal lifts
- Modified prone (bilateral 5 second holds with slow and control eccentric lowering of arms) (Figure 6-63)
  - I
  - V/Y
  - T
- Unsupported Codman's are continued
- UE ranger exercises with ranger on floor and with ranger on wall
  - Flexion/extension
  - Abduction/adduction within protocol rom
  - Circumduction
- AROM may be initiated as to include:
  - Wall walks
  - Standing shoulder raises (shoulder flexion and scaption in the open can position)
- May begin low rows toward end of this phase
- Hydrotherapy
  - Front raises/scaption, lateral raises with foam bells (AAROM)
  - Scapular protraction/retraction with foam bells (Punches)
    - Foam bells are dumbbells made out of foam material.
  - IR/ER in modified neutral position
  - Rhythmic stabilization in any of these planes/exercises (sub maximal effort)
  - Bicep curls



FIGURE 6-64. Kettle bell holds. **A,B,** Supine (kettle bell bottom down and bottom up). **C,D,** Side-lying (kettle bell bottom down and bottom up).

- Triceps pressdowns
- Shrugs/reverse shrugs

- Patients are reminded to avoid horizontal adduction and shoulder extension beyond neutral/beyond the frontal plane with all exercises

If possible, use mirror for immediate visual feedback so patient can see compensations, uneven shoulder height, posture, and more!

Sensorimotor Exercises

- Begin active angular replication exercises, for motor control, in the range of 0° to 90° scaption
- Saluting exercise
  - Begin with arm at side, then move hand out in front of body, lightly placing the radial side of the index finger just above same ipsilateral eyebrow. Perform this while maintaining good upright posture and scapular retraction.
- Point, reach, and touch various points against the wall
- Using PNF (proprioceptive neuromuscular facilitation) for the scapula. Manually cue and resist the scapula to elevate/depress, upwardly rotate/downwardly rotate, retract/protract in seated, supine and prone positions
- Kneeling, half-kneeling or standing with hand of injured arm on physio ball on floor or against wall doing up-and-down, left-and-right movement patterns, circles, rhythmic stabilization, and perturbations.
- Kettle bell holds (Figure 6-64)
  - Supine
    - With shoulder at 90°, and extending arm toward ceiling, hold kettle bell with the bottom down. As the patient gets stronger, turn the kettle bell with its bottom up. Be sure to pack the shoulder consciously contracting all periscapular musculature as if to squeeze tight one's armpit. The latissimus must be tonic. Each repetition is to be done for 15 to 30 seconds. (Discontinue if painful and do not perform if surgical repair performed)
- Packing the shoulder: Performed by synergistically and simultaneously cocontracting all muscles about the shoulder complex, making sure that the posterior, suprascapular muscles are firing. They will often times either fatigue sooner or be overshadowed by the more dominant anterior musculature.
  - Side-lying
    - Move to side-lying with the arm extended toward the ceiling or sky and again pack the shoulder.
- Using devices like the Wii and MR Cube which should use little to no resistance in this phase will help increase kinesthetic awareness, sensorimotor function, and

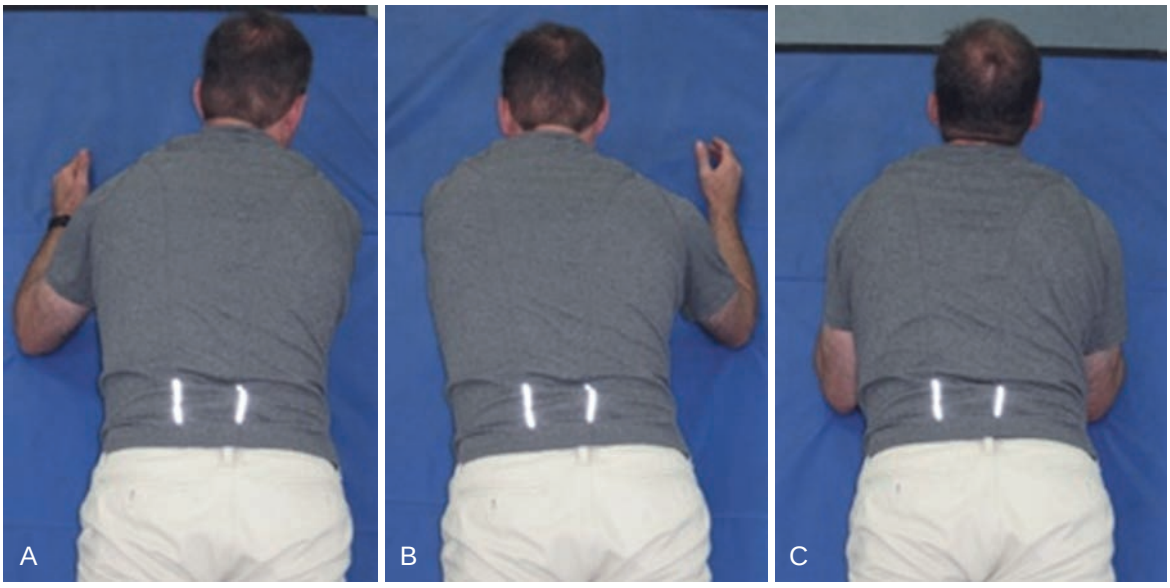

FIGURE 6-65. Quadruped weight shifts. Right (**A**), Left (**B**), Superiorly (**C**).

hand eye coordination. Parameters, which may include ROM limitations and speed of movement, need to be set by therapist.

Open and Closed Kinetic Chain Exercises

- Depending upon healing parameters and type of repair performed, patient may begin upper extremity weight shifting exercise. Begin in modified quadruped position (on elbows and on knees) control minor weight shift to left, right, up, down, and circular movements.
- Pushup position leaning into wall can also be performed if patient is able to have shoulder flexed slightly above 90° without pain or without scapular-thoracic compensation (Figure 6-65).
- Scapular clocks with arm extended against fixed surface with controlling movement of scapulo/glenohumeral joint clockwise and counterclockwise.
- Ball/physio ball oscillations with arm outstretched
- Seated towel slides protracting and retracting scapula while pressing down into table with sub-maximal effort
- Seated towel slides upwardly rotate and downwardly rotate scapula (putting contralateral hand behind neck and actively cocontracting the contralateral scapula usually yields improved dynamic scapular control) (Figure 6-66)
- Thumbtacks: In scapular plane only (Figure 6-67)
  - Imagine gripping a thumbtack on the wall with each hand, then upwardly and downwardly rotate humerus/scapulas and getting a scapular pinch at end range external rotation and repeat
- Pulley exercise: This is an active exercise, not a passive one. Be sure the patient is firing their humeral and scapular depressors throughout the entire exercise. If pain free above 90° can take shoulder through full available pain-free ROM.
  - Flexion/extension
  - Scaption
  - Abduction/adduction
- Total Gym exercises with bench angled from 5° to 30°
  - Low rows; 1 and 2 arm
  - Shoulder extension; seated and supine
  - Shoulder extension with back extension
  - Bicep curls
  - Triceps extensions
  - Seated torso twist with elbows flexed/with elbows extended

Clinical Pearl

- These closed chain exercises should be performed with sub-maximal effort. These exercises are geared more to achieve increased proprioceptive and kinesthetic awareness versus increasing strength.

Techniques to Increase Muscle Strength, Power, and Endurance

- Resistance to lower body and core strengthening exercises can and should increase in this phase; however, resistance shall not be applied on top of, around, or held by the surgical shoulder.
- Weighted vests may be considered depending upon type of surgery and postoperative week.

Neuromuscular Dynamic Stability Exercises

- Lower extremity balance activities may include but are not limited to:
  - Single-leg balance (eyes open and eyes closed 10 to 30 seconds)
  - BOSU ball
  - Star excursions
  - Airex pad/DynaDiscs/Thera-Band foam pad
  - Airex balance beam
- Manual rhythmic stabilization of trunk and core.



FIGURE 6-66. Seated towel slides. **A,** Scapular protraction. **B,** Retraction with contralateral scapula retracted. **C,** Scapular abduction. **D,** Adduction with contralateral scapula retracted.



FIGURE 6-67. A,B, Scapular thumbtacks.

Clinical Pearl

- A key premise of the Dynamic Neuromuscular Stability approach is that every joint position depends on stabilizing muscle function and coordination of both the local and distant muscles to ensure neutral or centered position of joints in the kinetic chain. The quality of this coordination is critical for joint function and influences not only local, but also regional and global anatomical and biomechanical parameters in the kinetic chain. (From Frank C, Kobesova A, Kolar P: Dynamic Neuromuscular Stabilization and Sports Rehabilitation. *Int J Sports Phys Ther* 8:62–73, 2013.)

Functional Exercises

- Seated and standing trunk rotation and trunk diagonals combined with flexion and extension while wearing sling may be performed to maintain thoracolumbar mobility
  - Shoulder dumps
  - Lawnmowers (beginning from contralateral side, end with elbow flexed at side and scapula retracted)
    - Begin the exercise with trunk flexed and rotated to the contralateral side with their hand at the level of their contralateral patella. Rotate the trunk toward the ipsilateral side as the arm that was reaching toward the patella, and extend the hip and trunk to a vertical orientation while simultaneously placing their arm at waist level and retracting their scapula so that the patient tries to place an elbow into their back pocket position.

Milestones for Progression to the Next Phase

- Minimal tenderness to palpation on and around incision
- PROM, AROM, and AAROM performed pain free
- Patient should have or nearly have full active range of motion via goniometer. ROM goals are based on surgeon's protocol.
- Good scapulothoracic joint mechanics/kinematics without compensation or substitution patterns measured qualitatively.

Phase III: Stability (weeks 6 to 10)

Volume/Duration: Perform 10 to 15 reps, 1 to 3 sets per exercise, depending on quality of movement and minimizing the presence of compensatory movement patterns. Exercise will be terminated when there is a decrease in movement quality and/or movement compensations noted.

Goals

- Achieve full pain-free AROM
- Attain normal glenohumeral and scapulothoracic mechanics and rhythm
- Initiate rotator cuff strengthening exercises
- Progress scapular stabilization exercises
- Achieve (if not yet acquired) and maintain cervical, thoracic, lumbopelvic, and ankle mobility
- Advance scapular, cervical, thoracic, lumbopelvic/hip/lower extremity stability training
- Reinforce muscle memory of correct neuromuscular firing going from conscious to unconscious control
- Advance and challenge cardiovascular fitness

Protection

- Sling use is discontinued
- Good sleep best practices continues
- Reinforce patient education as patient will be feeling more and more confident yet rotator cuff exercises are about to begin so it is easy to do too much too soon, especially if there was a rotator cuff repair involved

Management of Pain and Swelling

- Oral analgesic use is continued as needed (per the physician/surgeon)
- NSAIDs should be discontinued by this phase
- IFC E-stimulation for pain control PRN
- Hi-Volt E-stimulation/Russian: muscle re-education/may use with exercise
- Cryotherapy can continue to be used to mitigate postexercise inflammation and soreness if the shoulder does not recover within 24 to 48 hours from exercises

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- AAROM and AROM should be able to be performed for scaption, ER in scaption, and forward flexion. Progress IR, ER, horizontal adduction, scapular plane elevation, sagittal plane flexion, and abduction.
- PROM: techniques continue in the scapular plane. Sagittal flexion and IR/ER at 45° of abduction are introduced while respecting pain complaints.
- Joint mobilizations: If adhesions are noted, capsular joint mobilizations may begin in reduced ranges such as oscillatory techniques grade I-III for inferior and posterior capsule if indicated per the procedure. Care must be taken when assessing posterior capsular structures. Scapular mobilizations in all planes continue including scapular lifts.

Clinical Pearl

- If multiple procedures were performed (i.e., rotator cuff repair, labral repair, capsular plication, Bankart repair, or others, which is often the case with internal impingement type of procedures), please refer to the more conservative ROM goals for each procedure which is available in this text.



FIGURE 6-68. A,B, Side-lying horizontal adduction self-stretch.

Soft Tissue Techniques

- Scar mobilization techniques including cross-friction are performed to assist with full tissue mobility around the shoulder region. This can also be performed by the patient at home with a little patient education.
- Soft tissue massage/mobilizations, IASTM (instrumental assisted soft tissue mobilization), and trigger point dry needling are all indicated to reduce spasm, tightness, reset muscle tendon units, and improve joint restrictions if needed.
- Low intensity friction massage is indicated for biceps tendon and teres minor tenderness/tendonitis, which are common secondary side effects of internal impingement and can be found postoperatively in some patients.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Patients should continue table slides and/or physio ball rolling for passive techniques within the ROM precautions.
- AROM: scapular clocks and scapular dumps are continued to emphasize thoracic and lumbar mobility.
- If limited, elbow and wrist ROM should be continued.
- Pulleys or cable pulls (on functional trainer, cable machines or with tubing) for AAROM should continue depending upon the type of repairs performed in surgery) as long as correct technique is demonstrated.
- The common muscle tendon units/soft tissue that tend to be hypomobile, lack pliability and/or joints that lack mobility following internal impingement surgery tend to be: pectoralis minor, levator scapulae, scalenes, upper trapezius, teres minor/infraspinatus, posterior capsule, scapulothroacic joint, and thoracic spine. Be sure to evaluate horizontal adduction, internal rotation, and the sleeper stretch position bilaterally within 6 weeks following surgery. While looking at horizontal adduction be sure the scapula is immobilized and in a neutral position (not retracted or protracted). The scapula needs to be fixed against the thorax before horizontally adducting the humerus. The 6- to 10-week postoperative phase is a critical time to address any and all soft tissue restrictions surrounding the shoulder as well as throughout the kinetic chain.
- Muscles that when tight affect can contribute to scapular dyskinesis:
  - Pectoralis minor
  - Levator scapulae
  - Upper/mid/lower trapezius
  - Rhomboids
  - Infraspinatus/teres minor
  - Latissimus dorsi
- Techniques to improve mobility/flexibility of the scapulothoracic and glenohumeral musculature include:
  - Inferior and posterior glides during horizontal adduction and internal rotation of the humerus on the glenoid (low grade end range mobilization glides to be performed by therapist)
  - Side-lying horizontal adduction stretch (self-stretch) (Figure 6-68)
  - Standing with scapula pinned against wall, horizontally adduct humerus (self-stretch)
  - Standing with scapula pinned against wall, internally rotate humerus with shoulder abducted at 70° and at 90° (self-stretch)
  - Supine horizontal adduction stretch (therapist assisted)
  - Corner stretch (self-stretch)
  - Doorway pectoralis major/pectoralis minor stretch (self-stretch)
  - Pectoralis minor on foam roll stretch (self and assisted technique)
  - Side-lying, supine and prone flexion stretch (therapist assisted)
  - Side-lying on foam roll and actively flexing and extending shoulder
  - Standing shoulder extension (self-stretch)
  - Supine shoulder extension (therapist assisted)
  - Backscratch/Apley's stretch (self-stretch with TheraBand or towel)
  - Subscapularis release (therapist assisted)
  - Standing latissimus/thoracolumbar fascia stretch

- Supine angular (diagonal) with rotation stretches (therapist assisted)
- Sleeper stretch/modified sleeper stretch at 70°, 90° and 110° (self and therapist assisted) (Figure 6-69)

If there is any anterior or subacromial pain while performing the sleeper stretch, modify the position by performing 1), 2) and/or 3) as the stretch should only be felt in the posterior and posterior-lateral shoulder:

1) Rotating torso away from elbow 10° to 20° then reattempt stretch.
2) Increase the angle of the elbow from 90° out to 120° to 135°.
3) Lower position of humerus from 90° abducted to 50° to 70°.

Clinical Pearls

- We have found better results using contract-relax techniques during both self-stretching and therapist assisted stretching alongside passive stretches versus passive stretching alone.
- The key is initiating the low intensity contraction at the first barrier, the first feeling of tissue tension, not taking it to its end range then giving a contraction.
- After contracting the muscle or muscle group the patient is trying to stretch, take the stretch to the next barrier and then repeat. This technique also keeps the patient engaged and on task by making them an active participant in the stretch.
- It forces them to pay attention and be in tune with where their extremity is and the direction it is going in, what angles are the most effective, tissue tension differences at different angles, and in the long run it forces them to become less dependent upon the therapist.
- Patients should be given a home exercise/stretch program and are told of its critical nature. Without executing the Home Exercise Program, the chances of them having a successful outcome are significantly decreased.



FIGURE 6-69. Sleeper and modified sleeper stretch. **A,B,** Sleeper stretch: humerus at 90°/elbow at 90° and 135°. **C,D,** Sleeper stretch: humerus at 45°/elbow at 90° and 135°. **E,F,** Sleeper stretch: humerus at 105°/elbow at 90° and 135°.

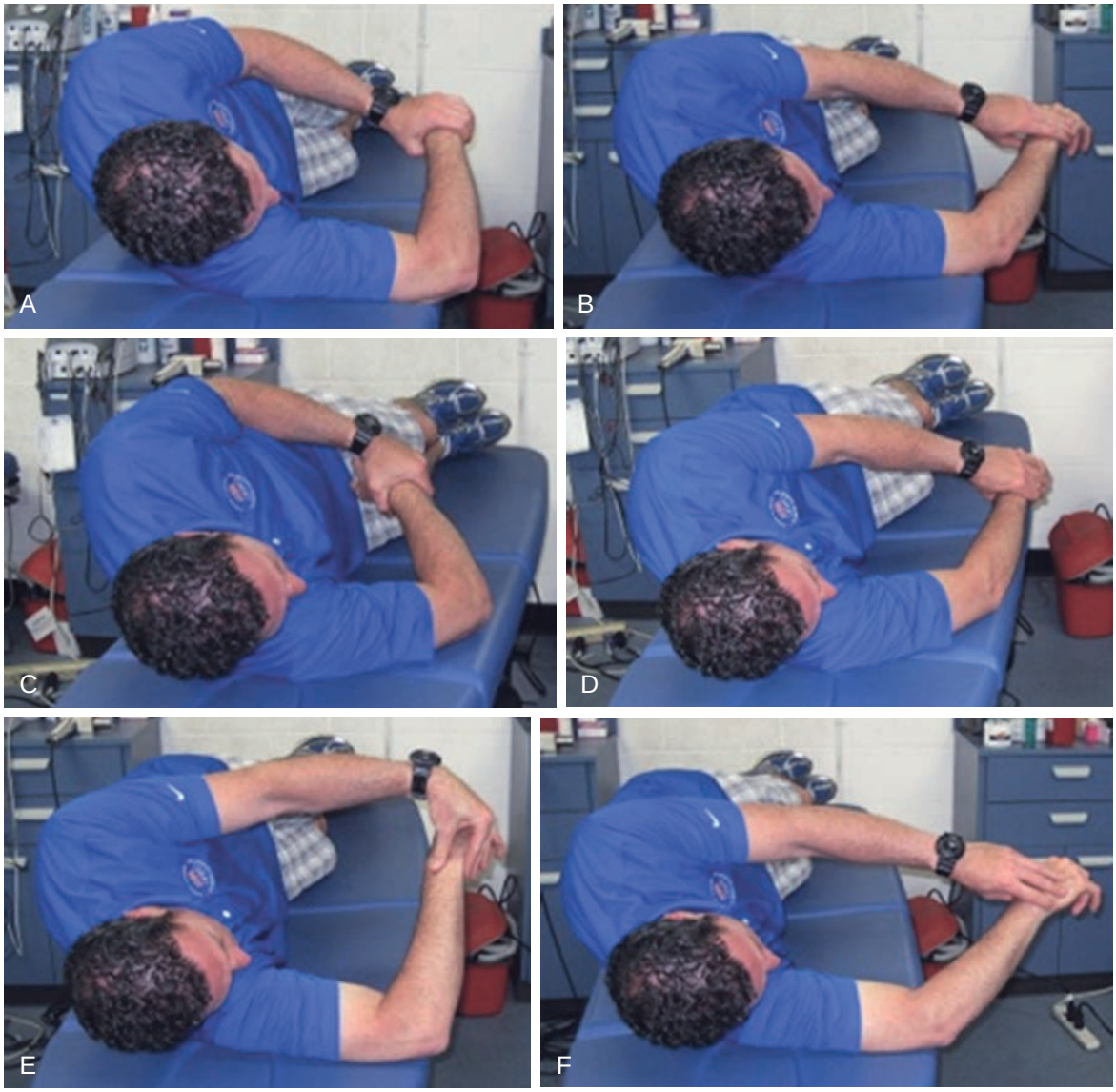

FIGURE 6-69 (cont'd). G,H, Modified sleeper torso lying on scapula: humerus at 90°/elbow at 90° and 135°. **I,J,** Modified sleeper torso lying on scapula: humerus at 60°/elbow at 90° and 135°. **K,L,** Modified sleeper torso lying on scapula: humerus at 105°/elbow at 90° and 135°

Other Therapeutic Exercises

- Patients should increase their intensity and duration times of cardiovascular conditioning. A variety of exercises are listed in Phase II. (Ensure the safe implementation of upper body support and loading during the use of stairclimbers, ellipticals, arc trainers and other conditioning activities until 8 weeks postoperatively for most cases.) Activities that can be added in this phase include:
  - Light jogging
  - Swimming (if indicated based upon having achieved full ROM, having adequate strength and per the parameters of the surgeon's protocol)
- Upper body ergometer (UBE) within pain-free ranges without resistance
  - Patient needs to maintain neutral scapular posture (scapula is not to be protracted or elevated)
  - Perform interval programs
  - Work in both directions (forward and backward/30 seconds: 1 minute in each direction is a good place to start).
  - Performing the UBE in standing position provides an integrated conditioning exercise involving upper body strengthening and endurance, torso, pelvis, and lower extremity stability work.
  - Within 1 to 2 weeks should be able to add resistance
- Viper (rope climb machine) (Figure 6-70)
  - Patient needs to maintain neutral scapular posture (scapula is not to be protracted or elevated)
  - Work by pulling down on rope, either two hands together or alternating
  - Usually start with humerus flexed no greater than 90° flexion and over next 1 to 2 weeks increase shoulder ROM



FIGURE 6-70. Viper machine (rope climb) with split stride (**A**) and contract core and trunk (**B**) to stabilize. Patient should focus on scapular involvement.

- Core stabilization exercises (Supine: establish neutral pelvis, partial crunch, pelvic tilts, bridging, modified dead bugs: arms may begin to flex above 90° if pain free and allowable per the protocol)
- Core stabilization exercises (supine/prone)
  - Continue exercises in Phase II
  - Superman (if pain free at end range shoulder flexion while prone)
  - Quadruped
    - Alternate arms
    - Alternate legs
    - Alternate arms and legs
  - Dead bugs (arms may begin to flex above 90° if pain free and allowable per the protocol. Arms may also press against the ground or vs. tubing; concentric or isometric shoulder extension)
    - Alternate arms
    - Alternate legs
    - Alternate arms and legs
  - Wall, table, floor prone plank
- Lower extremity exercises during this phase should increase in intensity/resistance. Dumbbells, kettle bells and weighted vests can be used to add resistance if the shoulder and shoulder girdle are ready and able to stabilize itself throughout the entire exercise. Exercises to add to those listed in Phase I and II include:
  - Single leg Romanian deadlift
  - Single-leg excursions (in the sagittal, frontal and transverse planes)

Clinical Pearl

- Although these stretching/flexibility exercises focus on ROM and mobility, cueing the depressors of the humeral head before initiating the movement pattern, as well as maintaining the depressed humeral head during the exercise can be critical for the patient.
- If unable to do this, there is often a premature and subconscious elevation of the humeral head and scapula when initiating forward flexion, abduction and scaption either during AROM and/or AAROM work.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Increase work on active scapular control: increasing strength and endurance
- Back to corner external rotation isometrics
- Back to corner wall slides
- Wall angels
- Wax on/wax off (1 arm and 2 arm, against wall, on slideboard, or on floor with sliding discs) (Figure 6-71)
- No money or robbery (begin with arms at side, with elbow bent at 90° and internally rotated with hands on abdomen, finishes with both arms externally rotated with humerus' at side and elbows bent 60° to 90°)
- Lawnmower (beginning from contralateral side,-end with elbow flexed at side and scapula retracted)
- Thumbtacks (in sagittal and scapular plane)
  - With hand simulating as though the hand is closed and the thumb is pushing a thumbtack into the wall, with elbow extended, hand is placed in either abducted position (at 90°), in scapular plane or with shoulder flexed to 90°at 0° abducted. Always with hand against fixed object, like a wall. Actively retract and protract scapula (9 to 3 o'clock), then elevate and depress scapula (12 to 6 o'clock),very similar to scapular clocks.
- Kettle bell holds, pack the shoulder for 15- to 30-second holds
  - Supine punch position
  - Supine punch position with kettle bell bottom up
  - Side-lying 90° abduction



FIGURE 6-71. Wax on/wax off. Scapular upward (**A**), downward (**B**) rotation with contralateral scapular retraction. Shoulder flexion (**C**), extension (**D**) movement pattern with contralateral scapular retraction.

  - Side-lying 90° abduction with kettle bell bottom up
  - Move from supine to side-lying and back to supine
- Dynamic hug
- Supine punch: Retract and protract scapula (with dumbbell, cuff weights, or tubing)
- Prone row
- Wall pushup plus
- Wall push-ups with various hand positions on wall
- Kneeling forearm physio ball slides
- Standing forearm wall slides with Thera-Band around elbows and wrists (Figure 6-72)
- Lat pulldowns (never behind head/begin with light weight)

The scapulohumeral muscles become the primary focus during this phase.

- In the previous phase we focused on middle and lower trapezius, rhomboids, and serratus anterior to create stability and foundational strength and stamina for the scapulothoracic joint and we added exercises before this section to advance their development.
- The rotator cuff musculature is the next critical element for successful rehabilitation as full ROM is established and a significant amount of healing has taken place.
- Most exercises in this phase should be performed standing or while in upright posture (can be done in kneeling, half-kneeling or standing) with tubing, cables, Keiser equipment, or with just the weight of the arm:
  - Low rows
  - No money exercise
  - Tubing two-arm diagonals
  - Straight arm shoulder extension from 90° flexion to 0° with scapular pinch throughout the exercise



FIGURE 6-72. A,B, Standing forearm wall slides with Thera-Band.



FIGURE 6-73. A-E, Dynamic 4 (side-lying diagonal eccentric exercise) with dumbbell, cuff weight, or tubing

- Rotator cuff exercises include:
  - Side-lying (with weight of arm, cuff weights, or light dumbbells)
    - External rotation
    - Dynamic 4: Externally rotate, extend elbow pressing hand toward the sky. With a straight arm slowly lower the arm in a diagonal pattern toward contralateral hip. Return elbow to starting position at side with elbow bent at 90°, then repeat. (Figure 6-73)
  - Standing: Internal/external rotation at 30° and 45° abducted
    - External rotation needs to be done slowly and under control with good cocontraction of the scapula stabilizers and move slowly during the eccentric phase of the exercise.
  - Diagonal patterns can begin 1 to 2 weeks into Phase III
  - Standing 3 (with weight of arm, cuff weights, or light dumbbells)
    - Front raises
    - Lateral raises
    - Scaption/full can (thumb up position) raises
- Have a 1- to 2-second hold at the top and slowly lower the weight. Do not allow the patient to rest and relax at the end of each repetition. Maintain an active shoulder and active and correctly positioned scapula and posture throughout the set.
  - Bodyblade/perturbations can be done in many planes and with many of the exercises listed above in the rotator cuff exercise list once some foundational rotator cuff strength has been established
- Continue scapular squeezes/pinches and sternal lifts. However, add resistance by leaning into wall, using manual resistance, or tubing.
- Continue Prone I, V and T began in Phase II (Figure 6-74)
  - Add prone Y and W (with palms down and/or thumbs up)
  - Continue bilateral 5-second holds with slow and controlled eccentric lowering of arms
- Discontinue Codman's
- Biceps and triceps strengthening with light resistance may begin (beginning 8 weeks postoperatively)

Sensorimotor Exercises

- Rhythmic stabilization and manual strengthening of the upper extremity while patient is supine, seated, or standing

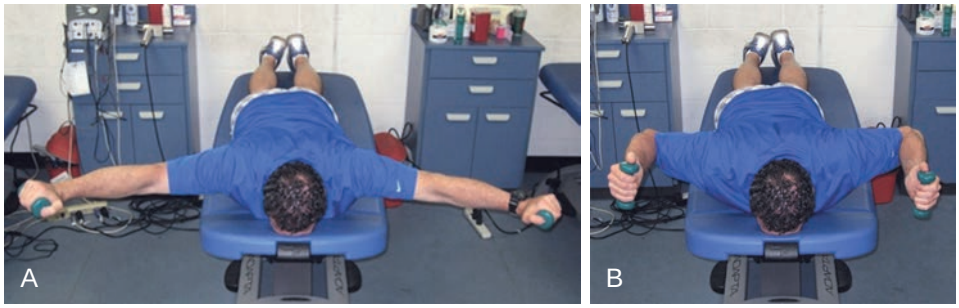

FIGURE 6-74. Prone Y (**A**) and W (**B**) light dumbbell or cuff weight exercise

- Isometric
- Concentric
- Eccentric

- The Bodyblade is an effective tool to incorporate (beginning at 8 weeks postoperatively) at 0° abduction as well as 90° scapular elevation.
- Upper extremity physio ball exercises. These can also be executed with the arm outstretched while kneeling, half-kneeling or standing depending upon the patient's ability to maintain good core/trunk stability while performing the exercise.
- UE ranger exercises with ranger on floor and on wall
  - Flexion/extension
  - Abduction/adduction
  - Circumduction
  - Write the alphabet with hand

Clinical Pearl

- A key component to successful PNF inclusion is patient education for proper positioning throughout; cue to stabilize the scapula before generating upper extremity motion or before accepting resistance.
- In addition, PNF is used to restore movement patterns common to athletes; this includes tracking the upper extremity movement with the eyes, as well as cervical and trunk rotation.
- This will also prepare the patient for more functional PNF patterns to be performed with tubing or cable resistance later in the treatment progression.
- PNF patterns are also performed on the nonaffected arm for crossover effect.
- Scapular PNF patters are continued throughout this phase progressing from side-lying to seated, and standing.

Open and Closed Kinetic Chain Exercises

- Closed chain proprioception activities: lightweight medicine ball rotations at 90° scapular plane elevation progressing to 90° forward flexion against a wall, and standing upper extremity weight bearing with weight shifting on a table with the hands at least 1.5 times the shoulder width to minimize direct posterior shear stresses through the GHJ.
- Quadruped weight shifts when able to load shoulder without discomfort or compensations per the surgeons protocol
- Quadruped with hand of injured arm on ball or wobble board (all exercises must not reproduce pain or compromise good scapular/postural position)
- Beginning at week 10: Seated press-ups for the latissimus dorsi as well as increased weight bearing/loading through the joint is added.
- Hydrotherapy
  - Similar volume dosage for hydrotherapy as other therapeutic exercises; however, caused by the decreased stress and benefit of movement, improving proprioception and muscle memory, there are times when reps and sets will be greater than normal volume dosage for therapeutic exercise.
    - Front raises/scaption, lateral raises with foam bells (AAROM)
    - Scapular protraction/retraction with foam bells (punches)
    - Horizontal abduction/adduction
    - IR/ER in modified neutral position
    - Rhythmic stabilization in any of these planes/exercises (sub max effort)
    - Bicep curls
    - Triceps press downs
    - Shrugs/reverse shrugs

Isokinetics

- Isokinetics can be initiated in this phase if patient can begin firing the rotator cuff
- IR/ER at modified neutral (in plane of scapula)
- Settings should be set for submaximal isometrics
- All exercises need to be supervised by the therapist

Techniques to Increase Muscle Strength, Power, and Endurance

- Progress biceps and triceps exercises in standing.
- Add light weights to shoulder flexion and scapular plane elevation in the open can position at 8 to10 weeks postop.
- Progress lower extremity strength training exercises.
- Progress to elliptical and stair stepper for cardiovascular conditioning at week 8.

Neuromuscular Dynamic Stability Exercises

- Progress manual rhythmic stabilization drills for upper extremity in neutral and advance in varying degrees of

abduction (0° to 90°) as ROM allows. Performing these exercises both sitting and standing will increase core recruitment and integrated work with the shoulder complex.

Clinical Pearl

The goals of neuromuscular rehabilitation according to Lephart et al.[7] are:
- To improve cognitive appreciation of the shoulder relative to position and motion.
- To enhance muscular stabilization of the joint in the absence of passive restraints.
- Restore synergistic muscular firing and coordinated movement patterns.

Plyometrics

- Low intensity lower extremity plyometrics may begin in the final 1 to 2 weeks of Phase III. Same volume dosage as therapeutic exercises.
  - Dot drills
  - Box drills
  - Cone/footwork drills
  - Jump rope
  - One- and two-legged hops
  - Skipping
  - Bounding
  - Box jumps

Functional Exercises

- Ground-based exercises for the lower extremities (that do not load, compromise or force the shoulder into flexion or abduction above 90°). Many are listed above; however, should add additional exercises that incorporate movement patterns specific to the athlete's sport but would not use the injured arm in the exercise.

Phase IV: Functional Strengthening (weeks 10 to 14)

Volume/Duration: Perform 10 to 15 reps, 1 to 3 sets per exercise, depending on quality of movement and minimizing the presence of compensatory movement patterns. Exercise will be terminated when there is a decrease in movement quality and/or movement compensations noted.

Goals

- Full pain-free ROM in all planes, both active and passive
- Improved scapular kinesis
- Normal scapulohumeral rhythm
- AROM WFL pain-free flexion and abduction
- Strength MMT 4/5 or better versus the scapulothoracic and scapulohumeral muscles
- Pain-free ADLs
- Normal soft tissue, T-spine and glenohumeral mobility
- Minimal to no pain with therapeutic exercise
- Progress rotator cuff strengthening

Management of Pain and Swelling

- Oral NSAIDs may be continued, however is likely unnecessary. If pain and/or inflammation continue to be a limiting factor to progress, the patient should return to the surgeon for reassessment.
- IFC E-stimulation may also be used to assist with pain and/or inflammation.
- Cryotherapy is used posttreatment sessions as needed to mitigate muscle soreness or reduce exercise-induced inflammation.
- Soft tissue massage can also be used to assist the reabsorption process of interstitial fluid, lactic acid, and other byproducts of exercise.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- AAROM, PROM, and AROM should be able to be performed through a full ROM.
- Joint mobilizations: If adhesions are noted, capsular joint mobilizations may continue along with oscillatory techniques grade I to IV for inferior and posterior capsule if indicated per the procedure as they may be incorporated to ensure full capsular mobility by the end of week 14.
- Care must be taken when assessing capsular structures that were compromised during surgery and those that were not within normal tissue pliability standards before surgery.
- Scapular mobilizations in all planes continue including scapular lifts.

Soft Tissue Techniques

- Assess the need for soft tissue mobilization to all muscles surrounding the scapulothoracic and glenohumeral joints, including but not limited to the pectoralis major/minor, subscapularis, and latissimus dorsi.
- Scar mobilizations are also indicated to minimize incisional adhesions.
- Monitor for development of biceps tendon inflammation and posterior rotator cuff tenderness and pain. Use direct soft tissue mobilization (many are listed in Phase III) to these tissues as indicated.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- PROM if needed with end-range stretching.
- Latissimus dorsi, pectoralis major/minor stretching should be routine at this point.
- Hot packs may be used before stretching to facilitate muscle relaxation.
- Patient education on restoration of mobility, avoidance of pain, and reporting any feelings of shoulder instability are critically important through the final 4 stages of this protocol.

Other Therapeutic Exercises

- Aerobic/cardiovascular conditioning needs to continue. This is a good time to start cross-training, mixing in



FIGURE 6-75. Jacob's ladder.

some anaerobic work and building into the program opportunities to increase the athlete's level of fitness from other types of conditioning equipment and surfaces (i.e., treadmill, StairMaster, Versaclimber, Jacob's ladder [Figure 6-75], upper body ergometer, viper rope climb [machine], rowing ergometer, ski-ergometer, elliptical, arc trainer, conditioning on artificial grass, the beach, playing field, hard court, and more.)

- Upper body support and loading during the use of stairclimbers, elliptical, and arc trainer activities should not be an issue by the end of this phase.
- Continue to improve and reinforce good posture and postural awareness throughout all upper extremity, lower extremity, and trunk exercises:
  - Be sure patient is aware of what a neutral spine is and what is the optimal position of the pelvis
  - Correct shoulder protraction, forward head posture, and thoracic hypomobility and kyphosis
- Increase volume and intensity with:
  - Jogging/running
  - Swimming
  - Upper body ergometer (UBE) with resistance, in both directions, using interval programs from 5 to 15 minutes
  - Viper (rope climb machine)
- Core stabilization exercises (all those listed in Phase III) in addition to:
  - Wall, table, floor prone plank
  - Wall, table, floor side plank
  - Plank to side plank (start in plank position, then rotate torso to left or right so unloaded forearm is pointing to sky, then rotate trunk back to prone plank position, then rotate in the opposite direction and repeat)
  - Supine upper extremity trunk twists
  - Supine lower extremity trunk twists
  - Progress to performing core stabilizing exercises on a physio ball
- Lower extremity exercises during this phase should increase in resistance and volume; however, move towards being more functional and more sport-specific. If dumbbells, kettle bells, and weighted vests were not able to be used in the previous phase they should be able to be used in this phase. Exercises to add to those listed in Phase I to III include, but are not limited to:
  - Hamstring curls
  - Deadlifts
  - Squats
  - Leg press

Clinical Pearls

- Resistance is increased within pain tolerance and the precautions of avoiding certain end ranges may be indicated caused by type of surgical procedure.
- As an example, forced horizontal adduction and sagittal plane axial loading with the arm past neutral horizontal adduction at this stage is avoided if the patient had a posterior stabilization procedure.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Humeral IR/ER rotator cuff strengthening exercises are progressed to 90° abduction.
- Rotator cuff exercises (IR/ER) at 30° and 45° abducted should increase volume (up to 3 sets of 20 reps) then increase resistance (beginning with 3 sets of 8 to 10 reps).
- Review list of exercises in this section in Phase III. There is a good chance the patient was unable to perform all of the exercises listed so switch out some of the exercises to add variety and complexity otherwise be sure to increase volume (reps) first, then increase level of resistance before moving to new exercises.

Sensorimotor Exercises

- Glenohumeral joint PNF D1 and D2 while seated, standing, or supine.
  - Can be performed versus therapist, with tubing, cable, or Keiser machine
- Continue the rhythmic stabilization exercises
  - To increase difficulty, increase speed and amount of resistance
  - Be sure to change arm angles and include changes in pronation/supination, gripping versus open hand, elbow partially flexed versus bent to 90°.
  - Be cognizant of what the rest of the body is doing. Is the patient employing good posture? Maintaining good trunk stability? Is the patient continuing to breathe? Are they in an athletic position if standing? Are they engaging the contralateral side to increase stability, joint proprioception, power, and strength?
- The Bodyblade can continue to be used in this phase. If the smaller blade was used in the previous phase,

perhaps the patient is ready to move up to a larger blade. Change arm angles and be aware that the exercises can be performed supine, side-lying, prone, and standing in this phase.
- While performing an upper extremity exercise, perform a lower extremity exercise and vice versa.

Open and Closed Kinetic Chain Exercises

- Both open and closed kinetic chain exercises are listed throughout Phases III and IV.
- Additional CKC exercises include, but not limited to prone physio,ball walking, prone physio ball weight shifting, prone physio ball single arm balance with contralateral arm raises at various angles.
- Pushups on wall can be performed with hands in various positions.
- Continue quadruped weight shifts and with one arm and knee on unstable surface if still challenging to athlete.
- Athletes are encouraged to avoid locking-out the elbows during this phase to avoid excessive loading of the posterior capsule. Hand width during CKC exercises should remain slightly wider than the shoulder distance.

Isokinetics

- IR/ER at modified neutral in plane of scapula
  - Reps performed at 180°/s to 300°/s
- IR/ER at 90°/90° in plane of scapula
  - Reps performed at 180°/s to 300°/s.
- Settings can be set for concentric/eccentrics
  - 60° to 120°/s for rhythmic stabilization

Techniques to Increase Muscle Strength, Power, and Endurance

- If athlete is not challenged with a particular exercise and they are up to 20 reps, then increase the resistance, if reps and resistance have been increased then work to increase the speed, while in control of the movement pattern, to increase power.
- Increase number of reps and intensity of exercises performed in pool
  - Add pushups against edge of pool for power and endurance

Neuromuscular Dynamic Stability Exercises

- Lunge with trunk twist (can add holding on to medicine ball)
- Lunge and unilateral punch (Kibler's exercises)
  - Punch with one arm at 135° shoulder flexion while the other elbow is bent with fist on chest and scapula retracted and return to starting position with both fists on chest
  - Punch with one arm at 120° shoulder abduction while the other elbow is bent with fist on chest and scapula retracted and return to starting position with both fists on chest
- Kneeling and half-kneeling with chops and lifts with or without resistance depending upon ability to stabilize hips and trunk while maintaining a narrow base (Figure 6-76)
- TRX serratus hug exercise (Figure 6-77)
  - Place forearms into the TRX handles, lean forward keeping your elbows tucked by your sides
  - Bring both arms into shoulder flexion, keeping elbows bent and protract the scapulas
  - Push out and up until the elbows are close to eye level
  - Pause at the top of the movement while the shoulders are rounded and slowly return to the start position
- Perform UE exercises:
  - While sitting on physio ball
  - While standing on Airex pad or on any unstable surface
  - While in quadruped position
  - While on one leg
  - With eyes closed
- Rhythmic stabilization is progressed to standing and in positions with decreased base of support, open chain, or unstable surface.
- Axial compression drills: closed chain on unstable surfaces (i.e., Airex pad, weighted ball, tilt boards)
- Manual perturbation to the trunk while in dynamic closed chain loaded position

Plyometrics

  - Increase level of lower extremity plyometric drills (i.e., box jumps, dot drills, hopping, broad jump, landing drills, single leg hops, jump rope) if begun in Phase III, if not, then begin those listed in Phase III and progress to those listed earlier in this paragraph.
  - Upper extremity wall dribble (begin with two-handed drills)
- Side toss (facing perpendicular to wall)
- Side to side toss with ball at waist level (facing wall)
- Side to side toss with ball at shoulder height (facing wall)
- Side to side mini-toss with arms overhead (facing wall)
- Plyoback/rebounder exercises to include:
  - Chest pass
  - Overhead throws
  - Side to side throws
  - ER/IR ball toss and catch (focus on eccentric component)
    - With elbow at side
    - With elbow at 90°/90°
    - D2 pattern
    - Catch the ball over the shoulder for eccentrics with elbow at side, at 90°/90° and in D2 pattern

Clinical Pearl

- We strongly recommend performing a minimum of 4 weeks of plyometrics before beginning the throwing program, a high velocity overhead exercise, or beginning whatever activity led to the athlete's surgery.

Functional Exercises

- Progress the walk-jog progression.



FIGURE 6-76. A-F, Half-kneeling chops and lifts.

Sport-Specific Exercises

- Lower extremity sport-specific drills in a controlled environment at 3 months postoperatively (i.e., hopping, jumping, changes in direction, agility drills)
- Begin sport-specific upper extremity defensive type drills (blocking, catching, fielding, etc.)

Phase V: Power and Acceleration (weeks 14 to 24)

Goals

- Full pain-free uncompensated functional AROM
- Normal kinematics of scapulohumeral and scapulathoracic joints (no dyskinesis)
- No episodes of instability
- Pain free with all exercises
- MMT 5/5 strength of rotator cuff, shoulder, and scapular stabilizers
- Functional strength, power and endurance of rotator cuff and scapular stabilizers should be >75% to 80% before the injury
  - All strength, endurance, stability, and power tests are measured by assessing symmetry right versus left with the absence of observed compensatory motion during movement patterns
  - Power tests may include overhead medicine ball throw and standing rotational medicine ball throw
- Thorough clinical examination produces negative findings
- No tender to palpation/no subjective symptoms
- No compensations seen while performing functional movement patterns or while under moderate resistance/load
- Good trunk, pelvis, and ankle stability
- Isokinetic testing: IR/ER ratio: 66% to 70%/ER 98% to 105%/IR 105% to 115%. Side to side ratios should be within 75% to 85% for abduction and adduction.



FIGURE 6-77. TRX unilateral serratus hug. (Also can be done with both arms at the same time).

- Progressing with sport-specific skill training (throwing, swimming, racquet sport, sport-related overhead activities)
- Compliance with Home Exercise Program
- May require clearance from physician/surgeon to begin throwing/overhead activity progression toward end of Phase V depending upon sport and complexity of surgery

Management of Pain and Swelling

- Oral NSAIDs may be continued; however, they are likely unnecessary. If pain and/or inflammation continue to be a limiting factor to progress, the patient should return to the surgeon for reassessment.
- IFC E-stimulation may also be used to assist with pain and/or inflammation.
- Cryotherapy is used posttreatment sessions as needed to mitigate muscle soreness or reduce exercise-induced inflammation.
- Soft tissue massage can also be used to milk and assist the reabsorption process of interstitial fluid, lactic acid, and other byproducts of exercise.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- AAROM, PROM and AROM should be able to be performed through a full ROM.
- Continue as above to increase or maintain full capsular mobility.
- Joint mobilizations: If adhesions and restrictions are noted, capsular joint mobilizations may continue along with oscillatory techniques grade III-IV for inferior and posterior capsule.
- Scapular mobility in all planes should be evaluated periodically to insure the capability to maintain ROM throughout sport-specific training.

Soft Tissue Techniques

- Assess the need for soft tissue mobilization to all muscles surrounding the scapulothoracic and glenohumeral joints, including but not limited to the pectoralis major/minor, subscapularis, and latissimus dorsi, especially since sport-specific work has been introduced.

- Scar mobilizations could be indicated.
- Continue to monitor for development of biceps tendon inflammation and posterior rotator cuff tenderness and pain. Use direct soft tissue mobilization (many are listed in Phase III) to these tissues as indicated.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- PROM if needed with end-range stretching.
- Athletes are instructed in full glenohumeral and scapulothoracic stretching techniques as well as how to maintain cervical, thoracic and lumbopelvic-hip mobility.

Other Therapeutic Exercises

- Progress with prone I, V, T, W and Y exercises, standing light dumbbell or cuff weight exercises and diagonal patterns with increased resistance and volume as tolerated.
- Progress lower extremity, gluteal and hip strength exercises.
- Progress walk, jog progression toward sprinting.
- TRX exercises
  - Single-leg squat
  - Mountain climbers
  - Split squat with single arm end range flexion resistance to TRX
  - Suspended knee tucks
  - Prone runners
  - Single-leg bridge + 2 arm row
- Advance core stability exercises
  - As the prone plank gets easier, lift each elbow off the ground (1 to 10 seconds)
  - As the prone plank gets easier, lift each foot off the ground (1 to 10 seconds)
  - As the side plank gets easier, lift the top leg up and lower leg slowly
  - As the side plank gets easier, lower hips toward ground and bring back up
- Can begin pullup program if have not done so. Begin with assistive pullups (on assistive pullup machine or use stretch bands to assist)
  - Do not hang at end of each repetition or at end of set; maintain active engaged shoulders throughout each set.

Clinical Pearls

- Remember it is critical that to have success strengthening a muscle or a group of muscles, their antagonist counterparts cannot be chronically tight and shortened.
- Using a foam roll, massage stick and other modalities listed in the soft tissue technique sections will improve recovery, reduce muscle soreness, and will help maintain joint ROM and mobility.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Refer to list in previous two phases and add progressive resistance.

Sensorimotor Exercises

- Glenohumeral joint PNF D1 and D2 while seated, standing, or supine.
  - Change speed and arm angles to increase difficulty.
  - Include eccentric exercises in the progression of the exercises.
- Continue rhythmic stabilization and Bodyblade exercises a minimum of 1 to 2 times a week.
- Vary the upper extremity exercises while performing lower extremity exercises and vice versa.

Open and Closed Kinetic Chain Exercises

- OKC: Continue progression of UE weight room exercises listed above.
- OKC: Pool resisted movement patterns should continue. Can use pool for recovery and flush.
- The BOSU ball can be used for progression of pushups to uneven surfaces for CKC activities.
- CKC may also include slide board exercises in quadruped or pushup position.

Isokinetics

- Isokinetics can be initiated in this phase.
- IR/ER at modified neutral in plane of scapula, reps performed at 180°/s to 300°/s.
- IR/ER at 90°/90° in plane of scapula, reps performed at 180°/s to 300°/s.
- Settings can be set for concentric/eccentrics 60° to 120° per second/rhythmic stabilization.
- Testing at 180°/s and 300°/s.
  - Following a minimum of 2 weeks of work on the isokinetic device
  - Expected Biodex results: ER/IR ratio at 180°/s: male 66; female 71
  - Peak T/BW range for IR at 180°/s: male 17 to 23; female 13 to 17
  - Peak T/BW range for ER at 180°/s: male 11 to 15; female 8 to 12

Techniques to Increase Muscle Strength, Power, and Endurance

- Advance endurance sets to strength exercises (repetitions of 6 to 10 per set).
- Implement an undulating periodization model for strength training

Neuromuscular Dynamic Stability Exercises

- The pushup progression leads to dynamic bilateral upper extremity wall pushups, then to single arm dynamic pushups on the wall; progression then leads to dynamic floor pushups.
- Bear crawling
  - In prone position with only feet and hands on the floor, butt should be raised higher than any other body part. Maintain hands and feet shoulder and hip wide respectively. Then move slowly and deliberately forward. (Can be performed crawling backwards as well as to left and right as patient progresses)
- Inchworms
  - With hands and feet on ground, walk each foot, one foot at a time, toward the hands while keeping

elbows and knees extended. As feet has gotten as close as they can to the hands, the hands begin to walk out away from the feet to a distance the patient feels comfortable supporting their own weight, then repeat.
- Renegade row (pushup position, then perform single arm row, alternate arms)
- Bow and arrows (standing with arms together out in front of body holding tubing or pulley handles in each hand, then rotate legs and torso 90° and get hands in a bow and arrow position then return to the starting point)
- Segmental upper and lower body rolling patterns[8]
  - The upper body rolling pattern from supine to prone is initiated by lifting and turning the head, and reaching with the opposite arm. The roll needs to occur in segmental fashion. (The movement begins by rotating the head, the shoulders rotate in the same direction, followed by the trunk, hips, and then the legs. If the patient is log rolling, corrections, either verbal and/or tactile cues, need to be used.)
  - The upper body rolling pattern from prone to supine is initiated by turning the head and retracting the lead scapula to bring the arm around. Keep reaching and rotating and again this needs to happen in a segmental fashion from the head all the way down the spine to the lower extremities.
  - The lower body rolling pattern from supine to prone is initiated by flexing, adducting, and internally rotating the opposite hip. Reach the leg across the body and extend the knee as the hips, pelvis, lumbar spine begin rotating over toward the prone position. The roll must be segmental in nature.
  - The lower body rolling from prone to supine is initiated by extending, adducting, and externally rotating the opposite hip. While rotating over to supine be sure the rotation occurs segmentally and not as a log roll.
- Turkish get-up progression: Work through all seven Turkish get-up stages with added neck and shoulder rotations in each phase to ensure adequate movement quality and overall stability in each phase.
- Dynamic stability warmups exercises that can be integrating into the daily routine are:
  - Jumping jacks
  - Jumping twists
  - Walking lunges
  - Walking side lunges
  - Walking lunge with twist and/or with upward reach
  - Walking quad stretch
  - Walking glut stretch
  - Leg swings: hip flexion/ext and hip abd/adduction
  - Skipping
  - Skip hops
  - High knees
  - Butt kicks
  - Side stepping
  - Carioca
  - Backpedals
  - Backpedal and rotate right/rotate left
  - Bounding
  - Spiderman crawls
  - Inchworms

Plyometrics

- Plyometrics were initiated in Phase IV using two-handed technique, then after two weeks of using two hands can progress to one hand if no compensations seen or pain experienced by patient.
  - Chest pass
  - Overhead throws
  - Side to side throws
  - ER/IR ball toss and catch (focus on eccentric component)
    - With elbow at side
    - With elbow at 90°/90°
    - D2 pattern
    - Catch the ball over the shoulder for eccentrics with elbow at side, at 90°/90° and in D2 pattern
- Overhead bilateral medicine ball slams and overhead medicine ball catching is also added.
- Pushup plyometrics can be initiated: begin against wall, then progress to counter, then to floor.

Clinical Pearls

- If anterior structures of the shoulder were repaired surgically, and/or anterior structures were injured before rehab, be conscious of volume, intensity and mechanics of anterior shoulder work (i.e., pressing movements).
- If anterior structures had been compromised, six to eight weeks or longer of pressing exercises should probably only be permitted to go to frontal plane only.
- It is the authors experience that allowing the humerus to horizontally abduct and go beyond the midline of the torso increases the likelihood of soft tissue irritation and inflammation.
- Be cognizant and educate your patients on the best exercise mechanics for them

Functional Exercises

- Overhead strengthening is incorporated as well as lower extremity agility drills including ladder and hurdle drills as well as running progression (intervals, sprints).
- Resistance exercises in standing progress from double-leg to single-leg stance, asymmetrical resistance and unstable surfaces continue.
- Continue lower extremity agility program.
- May add resistance sled, resistance bands or parachute to running/sprinting drills.

Sport-Specific Exercises

- Throwing athletes may begin light tossing at shorter distances (45 feet) after a minimum of four weeks of upper extremity plyometrics.
  - The patient needs to demonstrate relatively normal throwing mechanics.

  - Throwing should be closely monitored and discontinued if the athlete exhibits any compensatory movement patterns or shoulder girdle discomfort. Be conscious of what is going on with their lower extremity, length of stride, and position of landing leg and foot.
  - How does the follow-through look? Are they finishing the throw out in front of their body or does it look like they are cutting off the throw?
  - Throwing 3 times a week for the first 4 weeks is adequate and can progress to 4 times a week in week 8 to 12.
  - Begin with 10 tosses to warmup, then begin tossing at prescribed distance, initially 45 feet for 15 throws. Need to be at each distance a minimum of 3 to 6 sessions depending upon how the athlete is progressing and the complexity of surgery. The distances increase by 15 feet with of 60 feet and beyond including a step and throw. At 60 feet, 10 additional throws are added for a total of 25 throws at this distance. For athletes 18 years and over, a maximum distance of 150 feet is adequate and should only be performed if there are no compensations or poor mechanics exhibited.
  - Athlete needs to have been throwing for a minimum of 8 weeks and reached a distance of 120 feet before throwing off a mound. Mound work should be performed 2 times a week for the first 3 to 4 weeks, can then progress to 3 times a week.
  - Breaking pitches and off speed pitches do not begin until athlete has begun mound work.
- Other overhead activities such as swimming, racquet sports, serving in volleyball, shot putting, throwing a javelin, and others should have a warmup period before beginning the official count.
- Begin at a relatively low intensity and progress over the next month to increase volume and intensity with days of active rest/recovery in between.
- Be sure that the athlete is able to recover in between each training session before increasing volume or intensity.
- Four weeks of plyometrics should be performed before beginning the sport-specific overhead activity.

Milestones for Progression to the Next Phase

- Goal is for strength to be at least 80% of unaffected side before beginning sport-specific overhead activity

Phase VI: Return to Sport/ Competition (weeks 24 to 52)

Note: Volume/duration: Perform 10 to 15 reps, 1 to 3 sets per exercise, depending on quality of movement and minimizing the presence of compensatory movement patterns. Exercise will be terminated when there is a decrease in movement quality and/or movement compensations noted.

Goals

- Full pain-free uncompensated functional AROM.
- Normal upper extremity/scapular kinematics.
- Mobility and ROM geared to athlete's sport and position.
- Approximately 90% strength, power, and endurance required for sport.
- Pain free with all exercises and activities.
- MMT 5/5 strength of rotator cuff, shoulder, and scapular stabilizers.
- Maintain good trunk, pelvis, and ankle stability.
- Progressing with sport-specific skill training.
- To be in better physical condition, have increased athleticism, decreased likelihood to reinjure surgical shoulder or another body part, improved body control and sport-specific (i.e., throwing, serving, swimming) mechanics.
- Athlete's increased knowledge, understanding, and application of best practices to prepare to play, maintain good health, achieve a higher level of performance, and know how to build in recovery into their program.
- May need clearance from physician/surgeon to return to the playing field/arena at end of throwing or overhead activity program.
- Build in extended period of recovery following competitive season. Can continue to be active, however allowing 4 to 8 weeks of limited overhead activity after the season is over is recommended.

Management of Pain and Swelling

- Oral NSAIDs may be continued however is likely unnecessary. If pain and/or inflammation continue to be a limiting factor to progress, the patient should return to the surgeon for reassessment.
- IFC E-stimulation may also be used to assist with pain and/or inflammation.
- Cryotherapy is used posttreatment sessions to mitigate muscle soreness or reduce exercise-induced inflammation.
- Soft tissue massage can also be used to milk and assist the reabsorption process of interstitial fluid, lactic acid, and other byproducts of exercise.
- Do not sleep on shoulder ever! This will cause a reduction of blood flow and lymphatic drainage in both directions to the shoulder and upper extremity and will negatively affect the athlete's ability to recover from work and exercise.

Techniques for Progressive Increase in Range of Motion

- Should have full AROM by 6 months

Manual Therapy Techniques

- Continue as above to increase or maintain full capsular mobility if not yet achieved.
- Joint mobilizations: If adhesions and restrictions are still noted, capsular joint mobilizations may continue along with oscillatory techniques grade III to IV for inferior and posterior capsule.
- Scapular mobilizations in all planes should be evaluated periodically to be sure able to maintain throughout sport-specific training.

Soft Tissue Techniques

- Assess the need for soft tissue mobilization to all muscles surrounding the scapulothoracic and glenohumeral joints.
- Educating and reinforcing the patient to take ownership in self-management of monitoring and treating soft tissue tension issues, capsular and joint restrictions with the use of stretch bands, foam rolls, myofascial release balls and implements will provide a vehicle for long term self-treatment.
- Scar mobilizations could be indicated.
- Continue to monitor for development of biceps tendon inflammation and posterior rotator cuff tenderness and pain. Use direct soft tissue mobilization (many are listed in Phase III) to these tissues as indicated.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Athletes are instructed in full glenohumeral and scapulothoracic stretching techniques as well as how to maintain cervical, thoracic, and lumbopelvic-hip mobility.
- Home stretching for posterior capsule progression: supine horizontal stretch, supine horizontal stretch with IR, sleeper stretch, modified sleeper and sleeper stretch with rollover.
- Continued use of sustained end range stretching to achieve desired symmetrical or required mobility.
- Preperformance/exercise stretching should focus on functional movement patterns and dynamic warmup versus static stretching to prepare the athlete for sport.
- Postexercise and postcompetition cool down stretching should be incorporated into the program to address muscles, tendons, and joints that have a propensity to get tight following training or sport activity.

Other Therapeutic Exercises

- Integrated conditioning at this stage should include dynamic multijoint movements, predominately closed chained.
- Many of the total body, core stability, total arm, and total leg strengthening exercises can be continued; however, we recommend building in extended periods of active rest from many of these exercises following 6 months of rehabilitation. This ensures recovery, both physical as well as mental, a chance for the patient's body to regroup, and usually causes a reinvigoration of energy and enthusiasm by the athlete when it is time to resume strengthening exercises.

Clinical Pearls

- Where the athlete is on the competitive season calendar is very important in determining the plan from months 6 to 12. So following the sixth month of rehabilitation, consider the following:
  - If their season is getting ready to begin or has already begun, in most cases, surgeons and rehabilitation specialists do not expect pitchers to be game ready until at least month 8 or 9; however, it is often stated that 12 months is a more realistic timetable to expect a pitcher to return to live games.
  - It usually pays to lean toward the conservative side than the aggressive side of returning to game speed on the calendar; however, it is not uncommon for successful postoperative rehabs to take 15+ months to return.
  - Treat your athlete as an individual.
- Because position players typically do not throw as hard and as frequently with the volume of pitchers, they can typically return to games once they have completed the 120 to 150 feet in their throwing program and have spent 2 to 4 weeks throwing to bases, throwing on the infield if an infielder, and throwing to the bases from the outfield if they are an outfielder.
- If it is midseason following the sixth month of rehabilitation, rushing to get the pitcher in a game before the season is over is possible. However, be sure to listen to the athlete and pay close attention to how the pitcher's arm is feeling in between their mound work.
- If it is the end of the season and they have completed their throwing/overhead program, it's a good time to actively rest and not throw for the next 6 to 8 weeks. Take a break from formal conditioning for 4 to 6 weeks then resume by beginning with a cardio and mobility program. Work toward a strength building phase, then towards a power phase with 4 to 6 weeks of spring training/practice/preseason workouts.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- If preinjury levels of function, strength, stamina, power, and mobility have been achieved or exceeded then consider a maintenance phase for the primary muscles involved in the surgery.
- Those involve both the scapulothoracic and scapulohumeral muscles, so performing exercises that can incorporate this large group of muscles reducing the volume and intensity of the exercises need to be done.
- Selecting exercises that combine both groups 2 to 3 days/wk may be best to be able to maintain what the athlete has acquired to this point.

Sensorimotor Exercises

- Ball toss exercises in standing; to add difficulty, toss the ball on one leg
- D1/D2 movements with cables; to add difficulty, change angles of the pulley, change the athlete's base and foot position
- Medicine ball
  - Diagonals
  - Rotate left/rotate right
  - Woodchops
  - Slams
  - Wall ball drills
  - Russian twists
  - Supine upper extremity twists/supine lower extremity twists
  - Progression to slosh balls

- Slosh balls are different sized balls filled with water or other fluid. The movement of the fluid within the ball makes it more challenging to the patient while performing drills/exercises with the ball.
- Rapid repositioning drills and reaction movement drills
- Sport-specific balance/body control exercises

Open and Closed Kinetic Chain Exercises

- Advancing the previous exercises in accordance with sport-specific demands while also identifying exercises that will address the athlete's weaknesses

Techniques to Increase Muscle Strength, Power, and Endurance

- Isokinetic training is usually significantly reduced or eliminated at this point
- Refine and integrate the undulating periodization model to optimize recovery as the athlete prepares in the several months leading up to their playing season.

Neuromuscular Dynamic Stability Exercises

- Resistance exercises in standing progress from a double- to single-leg stance, asymmetrical resistance, and unstable surfaces as necessary to replicate anticipated performance demands.
- Single arm dumbbell walks
- Monster rope throws and drags
- Rope, pole, ladder, and rock wall climbing
- Obstacle courses
- Tire flipping
- Battle rope exercises

Clinical Pearl

- Reinjury is more likely to occur when the athlete is fatigued. To optimally prepare the athlete for full return to sport, dynamic stability exercises and strength training must be taken to a sufficient level of stress to closely replicate the strength, power, and endurance demands that will be encountered.

Plyometrics

- Advance the plyometric exercises in Phases IV and V to increasing level of difficulty with the use of the plyoback, wall, and ground.
- Medicine ball exercises need to include catching/receiving the ball to gain the physiological effect of eccentric and decelerating work.

Sport-Specific Exercises

- By 24 weeks postoperative athletes may have begun light sport-specific training to include short tossing for throwing athletes and limited overhead stroke work for swimmers, tennis, as well as other racquet sports, and volleyball players.
- A progression of throwing volume, distance and intensity continues during much of this phase.
- A progression of overhead swings, as well as freestyle and other overhead swimming strokes should increase in volume and intensity during much of this phase.
- Wrestlers and mixed martial arts athletes should progress toward more sport-specific drills (i.e., in quadruped and prone positions, grappling, boxing and striking objects).
- For football and rugby players introducing and increasing the volume and intensity of the position specific drills (i.e., punches, swim techniques, push off drills) should be done over 1 to 3 months depending upon the surgeon's expectations, type of procedure, and how well the rehab process is going to this point.
- Preparticipation CKC testing may include the CKC upper extremity stability test and/or the upper extremity Y-balance test (as well as isokinetic testing). Goniometric measurements, isometric dynamometers, MMT can also be used.
- Preparticipation power tests may include the vertical jump, broad jump, standing backward overhead medicine ball throw, and standing rotational medicine ball throw. Preinjury test values would provide the best measure of functional recovery as sport/position specific normative data is limited.

Clinical Pearl

- Do not learn the hard way; you may not be a subject matter expert on being able to identify and teach the best throwing mechanics, sport and position specific kinematics of the athlete so reach out to the athlete's coaches or a local coach who you know and respect to have them lend a hand with aiding in providing expert advice as the athlete begins their long awaited sport-specific rehabilitative (throwing, swimming, overhead exercise, etc.) program.

Criteria for Return to Sport

General

- Normal scapulothoracic and glenohumeral kinematics via qualitative assessment. Full AROM without instability or scapular dyskinesis.
  - This is a subjective, objective and functional way of determining return to sport. Does the athlete report any symptoms of looseness or instability while performing sport-specific tasks? Assess scapular mechanics/stability through a variety of movement patterns at various speeds and versus a variety of different resistances. Could be done manually (using mirror) and/or while athlete is performing sport-specific activity. The use of video to review mechanics can also be helpful.
- Minimum of 90% (side to side) symmetry on isokinetic testing of muscular strength, power, and endurance. ER to IR ratio at least 70%.
- CKC testing and integrated power tests with good quality of motion, maintenance of scapulothoracic and core stability throughout the tests with no report of shoulder pain or instability.
  - Upper extremity power tests may include, but are not limited to: plyo-pushups, plyoback (one and two

arm throws into mini-tramp), bilateral manual testing (IR/ER at 30°, 45° and 90°, D2 pattern, movement pattern specific to sport).
- Medical clearance from surgeon.

Sport-Specific

- Implementation of return to sport criteria must include a demand/needs analysis of the chosen sport.
- The rehabilitation specialist should be able to analyze the demands on the shoulder complex and create a sufficient series of tests and exercises to ensure readiness for return to preinjury levels of activity.
- Pain free during and after sport-specific training and recovery within normal timeframe so as to be able to repeat the program in an expected and acceptable timeframe.

After Return to Sport

- Continue total body fitness and rehabilitation exercises.
- Typically these exercises are referred to as maintenance exercises; however, if some of the exercises are not challenging to the rehabilitative shoulder and to the athlete, then the athlete will usually lose strength and stamina over the course of their playing season.
- Be aware of this and conduct period checks of their ROM and strength each month throughout their season.

Exercises and Other Techniques for Prevention of Recurrent Injury

- Prevention of recurrence requires continued maintenance of dynamic neuromuscular control (strength, mobility, kinesthetic awareness, and proprioception). Degradation in any of these areas could put the athlete at risk for reinjury if they continue to place a high degree of physical demands on the surgically repaired glenohumeral joint.
- Although sport-specific training is essential to ensure readiness for return to sport, a training program that does not include reactive drills and a diversity of training modalities can result in a shoulder complex unable to adapt to the ever changing demands of athletic competition.

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Multiple-Choice Questions

QUESTION 1. If arthroscopic labral repair was performed without involvement of the rotator cuff musculature or bicep tendon, when typically may the sling be discontinued?

A. 2 to 3 weeks
B. 4 to 5 weeks
C. 7 to 8 weeks
D. 9 to 10 weeks

QUESTION 2. If SLAP repair or biceps tenodesis has been performed, there should be NO biceps muscle activation performed during what time frame?

A. 0 to 2 weeks
B. 0 to 4 weeks
C. 0 to 8 weeks
D. 0 to 12 weeks

QUESTION 3. _____ has shown to activate reflex contraction of the rotator cuff muscles which will stimulate glenohumeral mechanoreceptors?

A. Gripping
B. Scapular elevation
C. Abdominal bracing
D. Neck retraction

QUESTION 4. Which phase has a goal of full pain-free AROM?

A. Phase I (0 to 2 weeks)
B. Phase II (2 to 6 weeks)
C. Phase III (6 to 10 weeks)
D. Phase IV (10 to 14 weeks)

QUESTION 5. Which phase has a goal of 5/5 MMT of rotator cuff, shoulder, and scapular stabilizers?

A. Phase II (2 to 6 weeks)
B. Phase III (6 to 10 weeks)
C. Phase IV (10 to 14 weeks)
D. Phase V (14 to 24 weeks)

Answer Key

QUESTION 1. Correct answer: **B** (see Brief Summary of Surgical Treatment)

QUESTION 2. Correct answer: **C** (see Phase I: Immediate Postoperative Period, Clinical Pearl #2)

QUESTION 3. Correct answer: **A** (see Phase I: Immediate Postoperative Period, Clinical Pearl #5)

QUESTION 4. Correct answer: **C** (see Phase III: Immediate Postoperative Period, Goals)

QUESTION 5. Correct answer: **D** (see Phase V)

POSTOPERATIVE REHABILITATION FOLLOWING ARTHROSCOPIC ROTATOR CUFF REPAIR

Todd S. Ellenbecker, DPT, MS, SCS, OCS, CSCS, and David S. Bailie, MD

Indications for Surgical Treatment

- Failure of nonoperative treatment of rotator cuff tear
- Severe impact on functional activities and presence of shoulder pain at night and at rest
- Significant weakness of the shoulder and upper extremity limiting functional performance

Brief Summary of Surgical Treatment

Major Surgical Steps

- Place patient in beach chair position with arm draped free with use of assistant to hold arm or articulated arm holder

- Examine under anesthesia to evaluate for any loss of motion as early frozen shoulder can occur with RCT
- Inflate joint with 20 to 30 ml of elaine from a posterior approach using an 18G spinal needle
- Enter joint from posterior approach using 30° arthroscope
- Swelling can be minimized by running inflow through the arthroscope at low pressure (40 to 45 mmHg)
- Perform complete diagnostic arthroscopy and establish surgical plan, including confirming size, location, and tear pattern of RCT
- Treat intraarticular pathology as needed
- Place arthroscope in subacromial space and confirm burial side tear pattern
- Establish accessory working portals: lateral in mid-clavicle line and anterior at level of AC joint using cannulas
- Perform subacromial decompression if needed (limit to only downward projecting bone anterior medial to anterolateral from the clavicle forward).
- Perform distal clavicle excision if warranted based on clinical symptoms and anatomy.
- Prepare cuff insertion site using a shaver, burr, and/or an arthroscopic rasp. Do not fully decorticate as this will weaken the bone but insure good bleeding surface.
- Perform margin convergence of any longitudinal splits or delaminated portions of the RCT using arthroscopic suture passers and #2 high tensile strength suture.
- Authors prefer offset single row repair technique: Place triple loaded anchors (typically one or two for most tears and three for large to massive tears) in a slightly offset pattern within the middle of the RC footprint. Authors prefer biocomposite anchors but any modern cuff anchor is satisfactory.
- Create small accessory portal (no cannula) either anterolateral or posterolateral or both to allow for suture management. Pull all sutures into these portals keeping them organized with hemostats. Pull suture to be passed through tear edge into lateral portal alone so it does not tangle with other sutures.
- Start repair by passing sutures in divergent simple pattern, or a combination of horizontal mattress and simple (modified Mason-Allen or rip-stop) depending on tissue quality and tear pattern. Begin either posteriorly and move anteriorly or vice-versa watching suture spacing as you progress.
- Once all sutures are passed, begin tying from posterior to anterior in order of suture passing. Be sure to only have the two limbs of sutured to be tied in the working portal while other sutures are housed in the accessory portals
- Complete the repair by tying all sutures. If there appears to be a dog ear while tying, simply repass the suture from the anchor OR pass an additional free suture and anchor.

Factors That May Affect Rehabilitation

- Patient pain levels may be elevated if an acromioplasty is performed along with the rotator cuff repair; this will be noticed during initial postoperative rehabilitation during shoulder elevation (both actively and passively) caused by pain generated during subacromial contact.
- Patient pain levels will be elevated with cross arm adduction if a distal clavicular excision is performed (Mumford procedure) and noticed by the clinician during early range of motion activity following rotator cuff repair.
- Slower progression of range of motion and initiation of resistive exercise for large and massive rotator cuff tears.

Before Surgery: Overview of Goals, Milestones, and Guidelines[2]

GUIDING PRINCIPLES OF POSTOPERATIVE REHABILITATION

- Protection of tissue repair
- Early passive range of motion to prevent capsular adhesions and glenohumeral joint stiffness
- Gradual progression of resistive exercise from multiple angle isometrics, to manual resistance to isotonics, isokinetics, plyometrics, and functional exercise
- Balance and optimize muscular force couples
- Prevent scapular compensatory patterns (shrug sign) through the use of proper resistive exercise sequence and optimal loading strategies

Postoperative Rehabilitation Protocol

Initial postsurgical rehabilitation focuses on a range of motion to prevent capsular adhesions while protecting the surgically repaired tissues. Some postsurgical rehabilitation protocols have specific range of motion limitations to be applied during the first 6 weeks of rehabilitation. Several basic science studies have been published that provide rationale for the safe application of glenohumeral joint range of motion and the movements allowing joint excursion, and capsular lengthening, yet safe and protective inherent tensions produced in the repaired tendon. Hatakeyama et al.,[1] using a cadaveric model, repaired 1 × 2 cm supraspinatus tears and studied the effects of humeral rotation range of motion on the tension in the supraspinatus in 30° of elevation in the coronal, scapular, and sagittal planes. Results showed that, compared to tension in a position of neutral rotation, 30° and 60° of external rotation actually showed a decrease in the tension within the supraspinatus muscle tendon unit. In

[2]*Prehabilitation, if appropriate, is described in the Nonoperative Rehabilitation section of this chapter.*

contrast, 30° and 60° of internal rotation showed increases in tension within the supraspinatus tendon. This study provides important insight into the ability to perform early passive range of motion into the directions of external rotation following rotator cuff repair. Additionally, since most patients are placed in positions of internal rotation following surgery during the period of immobilization, movement of the shoulder into internal rotation is performed despite the increased tension identified by Hatakeyama et al.[1] One final aspect of clinical relevance in the study by Hatakeyama et al.[1] was the comparison of the intrinsic tensile load in the repaired supraspinatus tendon between the frontal or coronal plane, scapular plane, and the sagittal planes during humeral rotation. Significantly higher loading was present in the supraspinatus tendon during humeral rotation in the sagittal plane as compared to both the frontal and scapular planes. Therefore, based on this important basic science study, early passive range of motion is performed into the directions of both external and internal humeral rotation using the scapular plane position to minimize tensile loading in the repaired tendon.[1]

One additional basic science study provides guidance for range of motion application in the early postoperative phase. Muraki et al.[2], studied the effects of passive motion on tensile loading of the supraspinatus tendon in cadavers similar to the study by Hatakeyama et al.[1] They found no significant increases in strain during the movement of cross-arm adduction in either the supraspinatus or infraspinatus tendons at 60° of elevation. However, internal rotation performed at 30° and 60° of elevation did place increased tension in the inferior most portion of the infraspinatus tendon over the resting or neutral position. This study provides additional guidance to clinicians for the selection of safe range of motion positions following surgery. It also shows the importance of knowing the degree of tendon involvement and repair as posteriorly based rotator cuff repairs (those involving the infraspinatus and teres minor) may be subjected to increased tensile loads if early internal rotation is applied during postoperative rehabilitation. Therefore, communication between the surgeon and treating therapist is of vital importance to ensure that optimal range of motion is performed following repair.

One area of initial concern in the rehabilitation process following rotator cuff repair lies in the progression from passive based range of motion applications to active-assistive and active range of motion. Some disagreement as to the degree of muscular activation occurring during commonly used rehabilitation activities exists that can be clarified by a review of the appropriate literature. Research by McCann et al.[3] provides clear delineation of the degree of muscular activation of the supraspinatus during supine assisted range of motion and seated elevation with the use of a pulley. Although both activities arguably produce low levels of inherent muscular activation in the supraspinatus, the upright pulley activity produces significantly more muscular activity as compared to the supine activities studied by McCann and colleagues.

Additionally, research by Ellsworth et al.[4] has quantified levels of muscular activation during Codman's pendulum exercise. Their study shows minimal levels of muscular activation in the rotator cuff musculature during Codman's pendulum exercise; however, the exercise cannot be considered passive as the musculature is truly activated, especially in individuals with shoulder pathology. Additionally, although many therapists, including the authors of this chapter, do not recommend the use of weight application in the hand during pendulum exercises caused by the potential for unwanted anterior translation, Ellsworth et al.[4] found that muscular activity in the rotator cuff musculature was not changed between the performance of pendulum exercise with and without weight application. Pendulum exercises without weight have the same effect on muscular activity as weight application, questioning the use of pendulum exercises in the early postsurgery phase in cases where only passive movements may be indicated.

These studies give objective guidance for the early application of assisted range of motion activities that can be applied safely in the early postsurgical rehabilitation following rotator cuff repair. As further research becomes available, clinicians will be able to make evidence based decisions regarding the appropriateness of specific rehabilitation exercises based on their inherent muscular activation. Rehabilitation in the first 2 to 4 weeks following rotator cuff repair typically consists of the use of truly passive, as well as several minimally active or active-assistive, exercises for the rotator cuff such as active assisted elevation, overhead pulleys, and pendulums. Additionally, the use of the balance point position (90° of shoulder flexion) in the supine position where the patient is queued to perform small active motions of flexion/extension from the 90° starting position to recruit rotator cuff and scapular muscular activity. These exercises coupled with early scapular stabilization via manual resistance techniques emphasizing direct hand contacts on the scapula to bypass force application to the rotator cuff and optimize trapezius, rhomboid, and serratus anterior muscular activation are recommended (see Figure 6-78). Kibler et al.[5] have published EMG quantification of low-level closed chain exercise such as weight-shifting on a rocker board and highlighted the low levels (<10%) activation of the rotator cuff and scapular musculature during application.



FIGURE 6-78. Side-lying manual scapular resistance applied by the physical therapist to improve scapular stabilization.

Phase I: Immediate Postoperative Period (days 0 to 14)

Clinical Pearls

- Early scapular exercise via manual contacts on the scapula to protect healing rotator cuff and allow for initial activation of scapular force couple components (Figure 6-78)
- Progression using submaximal isometrics (step-outs) (Figure 6-79) and manual resistive IR and ER by the physical therapist (Figure 6-80) 4 to 6 weeks postoperatively to begin early contraction of the rotator cuff and scapular stabilizers.



FIGURE 6-79. External rotation step-outs (dynamic isometrics) using elastic resistance.

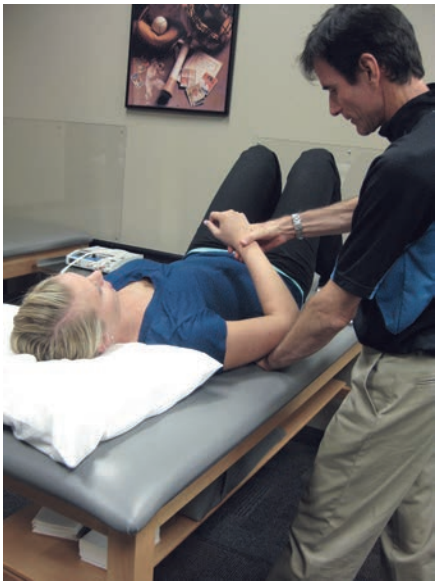

FIGURE 6-80. Manual external rotation resistance performed by the physical therapist early in the first phase to activate the posterior rotator cuff.

Goals

- Initiate passive range of motion to prevent range of motion loss of the glenohumeral joint
- Initiate scapular stabilization exercise with protection of the rotator cuff repair
- Minimize disuse atrophy of the upper extremity kinetic chain through the use of distal upper extremity exercise such as grip squeezes and wrist and hand exercise
- Provide patient with home exercise program and immediate postoperative care

Protection

- Sling with abduction pillow (DonJoy Ultrasling) worn for first 4 to 6 weeks postoperatively especially in precarious situations (outside the home)

Management of Pain and Swelling

- Use of electrical stimulation to affected area for pain reduction and before treatment coupled with moist heat to improve circulation and promote healing response.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Accessory and physiological mobilization in all planes of motion and directions based on restrictions encountered during initial evaluation and subsequent reevaluations

Soft Tissue Techniques

- As needed to provide pain control

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Physiologic range of motion in all planes of glenohumeral joint and scapular thoracic joint

Other Therapeutic Exercises

- TAS activity including wrist f/e curls, forearm pron/sup and ball squeezes to minimize effects of disuse atrophy in distal upper extremity

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Exercises to begin submaximal contraction of the rotator cuff (primarily the infraspinatus and teres minor and subscapularis following a supraspinatus repair, as well as the serratus anterior, trapezius, and rhomboids.)

Sensorimotor Exercises

- Joint mobilization in addition to rhythmic stabilization to promote coactivation and challenge proprioception

Open and Closed Kinetic Chain Exercises

- A combination of open and closed kinetic chain exercises are used in the early phase, most notable closed



FIGURE 6-81. Ball approximation exercise performed with a physio ball to support the extremity and allow patient to perform safe active range of motion.



FIGURE 6-82. Supine rhythmic stabilization exercise in 90° of shoulder flexion.

chain exercises are gentle weight shifts with hands on plinth or countertop as well as ball approximation exercise (weightbearing or supported Codman's exercise) (Figure 6-81). This minimizes joint distraction for patients with anterior instability as well as promoting relaxation caused by the patient's extremity being supported on top of the ball.

Techniques to Increase Muscle Strength, Power, and Endurance

- Submaximal rotator cuff and scapular exercise is initiated during this stage using exercise movement patterns emphasizing short lever arms, minimal resistance loading, and high numbers of repetitions to promote muscular fatigue. Movement patterns with known muscular activation levels of the rotator cuff (Reinold et al.[6], Townsend et al.[7] and scapular musculature: Moesley et al.[8], Kibler et al.[5] are used). These include side-lying external rotation, low row, shoulder extension to neutral, serratus punch, robbery.

Neuromuscular Dynamic Stability Exercises

- Rhythmic stabilization is used in the 90° elevated balance point position initially (Figure 6-82) with the therapist providing submaximal provocations to induce dynamic stabilization.

Milestones for Progression to the Next Phase

- Glenohumeral joint range of motion progression in all planes of movement beginning initially with rotational range of motion in the 60° to 90° abducted position (for IR and ER range of motion).

TIMELINE 6-6: **Postoperative Rehabilitation after Open or Arthroscopic Posterior Shoulder Stabilization**

PHASE I (weeks 1 to 2)	PHASE II (weeks 3 to 6)	PHASE III (weeks 6 to 10)
• Sling • PT modalities • ROM-scapular plane elevation to 90° • Active assistive Codman's exercises • TBS/TAS/TLS activities as recommended & tolerated	• Sling • PT modalities • ROM-wk-4-scapular plane elevation to 120° • ROM-wk-6-scapular plane elevation to 160° • ROM-wk-4-Start flexion to 90° • ROM-wk-6-ER to 30° • ROM-wk-6-IR to 0° • TBS/TAS/TLS activities as recommended & tolerated • Scapular exercises • Week 4- AAROM exercises • Week 4- submax isometrics for GH joint muscles • Week 6- submax isometrics for ER	• DC sling • PT modalities as needed • PROM-full • Mobilizations as needed • TBS/TAS/TLS activities as recommended & tolerated • Scapular exercises—PREs • TAS—biceps/triceps PREs • Glenohumeral exercises—PREs • Rotator cuff exercises—PREs • Limit IR exercises to minimize strain to posterior capsule • PNF exercises • OKC rhythmic stabilization exercises • CKC exercises • Week 10 seated press-ups and increased weightbearing through joint • CKC manual perturbation exercises

- Tolerance of submaximal rotator cuff and scapular exercise using movement patterns and exercise listed in stage 1 of this program.

Phase II (weeks 6 to 12)

Clinical Pearls

- When applying strengthening progression for rotator cuff musculature in the elevated position, it is recommended that the scapular plane be used due to its functional implications and optimal bony congruency characteristics.[9] This position (scapular plane) is also better tolerated symptomatically than the coronal plane position which places greater anterior capsular tension during rotational exercise.

Goals

- Continue with range of motion in all planes/all positions
- Initiate and progress rotator cuff and scapular strengthening program
- Progress to 80° to 90° abducted position for rotator cuff and scapular strengthening at 10 to 12 week time period
- Initiate uncompensated elevation exercise to improve functional capacity of postoperative extremity

Protection

- Sling is typically discontinued at 4 to 6 weeks for many activities and situations, with sling use for up to 12 weeks for massive rotator cuff repairs or in repairs of nonoptimal tissue/fixation.



FIGURE 6-83. Cross arm adduction stretching using scapular stabilization to address posterior capsule and posterior muscle tendon tightness.

Management of Pain and Swelling

- Continued use of modalities are recommended such as interferential electrical stimulation and/or ultrasound to increase local blood flow and provide pain control particularly in patients following acromioplasty and distal clavicular excision who often present with continued increases in pain secondary to those bone-based procedures.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Continued use of mobilization and passive stretching techniques to achieve terminal ranges of motion in all planes. Important use of scapular stabilization (Figure 6-83) during both cross arm adduction and internal

TIMELINE 6-6: **Postoperative Rehabilitation after Open or Arthroscopic Posterior Shoulder Stabilization** (Continued)

PHASE IV (weeks 10 to 14)	PHASE V (weeks 14 to 24)	PHASE VI (weeks 24 to 52)
• PT modalities as needed • PROM-full • Mobilizations as needed • Week 12- IR sleeper stretch • TBS/TAS/TLS activities as recommended & tolerated • Scapular exercises—PREs • TAS—biceps/triceps PREs • Glenohumeral exercises—PREs • Rotator cuff exercises—PREs • Thrower's Ten • Limit IR exercises to minimize strain to posterior capsule • PNF exercises • OKC rhythmic stabilization exercises • CKC exercises • CKC manual perturbation exercises	• PROM—maintain full motion • Mobilizations as needed • TBS/TAS/TLS activities as recommended & tolerated • Scapular exercises—PREs • TAS—biceps/triceps PREs • Glenohumeral exercises—PREs • Rotator cuff exercises—PREs • Thrower's Ten progress intensity • PNF exercises • OKC rhythmic stabilization exercises • CKC exercises • CKC manual perturbation exercises • Plyometrics—2 arm progressing to 1 arm • Overhead strengthening exercises • Sport-specific exercises begin • Overhead throwing athletes can begin with an easy interval throwing program • 20 weeks—begin full windup throwing	• PROM—maintain full motion • Mobilizations as needed • TBS/TAS/TLS activities as recommended & tolerated • Scapular exercises—PREs • TAS—biceps/triceps PREs • Glenohumeral exercises—PREs • Rotator cuff exercises—PREs • IR/ER exercises at 90° • Thrower's Ten progress intensity • PNF exercises • OKC rhythmic stabilization exercises • CKC exercises • CKC manual perturbation exercises • Plyometrics—2 arm chest passes progressing to 90/90 1 arm plyos • Overhead strengthening exercises • Sport-specific exercises progressed • Overhead throwing athletes progress through an interval throwing program



FIGURE 6-84. Internal rotation stretch with the extremity placed in the scapular plane in 80° of abduction coupled with a posterior glide stabilization force provided by the therapists hand placed upon the anterior aspect of the glenohumeral joint.

rotation stretches (Figure 6-84). Note the humeral position in the internal rotation stretching in Figure 6-84, where the therapist's upper leg is used to place the shoulder in the scapular plane position, allowing both of the therapist's hands to be available to provide a posterior glide and scapular stabilization as well as provide internal rotation overpressure.

Soft Tissue Techniques

- As needed based on periscapular muscular spasm secondary to overuse of these muscles during compensatory ADL usage.

Other Therapeutic Exercises

- Continued use of total arm strengthening techniques are recommended during this stage through the use of distal wrist and forearm strengthening such as wrist curls, ball dribbling, and bicep and tricep curls performed in positions with the glenohumeral joint in neutral resting (at the side) positions so as not to overload the rotator cuff during execution of these accessory exercises.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- At 6 weeks postoperation, muscular activation of the supraspinatus is initiated using known patterns of rotator cuff activation such as prone horizontal abduction[6] via a pain-free range of motion. This particular movement pattern is favored over the classic empty can exercise which was previously advocated and has since been found to produce activation levels similar to the prone horizontal abduction exercise[10]. Recent research by Thigpen et al.[11] has shown that the empty can places the scapular in positions of increased anterior tilting and internal rotation which can aggravate the impingement process.



FIGURE 6-85. Ball on wall exercise performed in the scapular plane with 90° of elevation.

Sensorimotor Exercises

- Exercises such as rhythmic stabilization (Figure 6-82) are continued to be used in this phase of rehabilitation with increased intensity application for the perturbation.

Open and Closed Kinetic Chain Exercises

- Open kinetic chain exercise for the rotator cuff and scapular musculature predominate in this phase of training with the traditional Jobe exercises all using open kinetic chain environments. However, closed chain exercises like the ball on the wall (Figure 6-85) and step-up exercise for serratus anterior activation both use the closed kinetic chain environment for the exercise and are recommended during this phase of rehabilitation.

Techniques to Increase Muscle Strength, Power, and Endurance

- Progression to exercises to improve strength, power, and endurance are followed during this phase and at approximately 12 to 14 weeks postoperatively for small to large rotator cuff repairs, isokinetic exercise is initiated. The modified base or Davies 30-30-30 position is advocated for initial introduction of isokinetic exercise for internal and external rotation using 30° of elevation in the scapular plane[12] (Figure 6-86). Speeds of 120° to 240° per second are used with progression to speeds ranging between 180° and 300° per second in athletic individuals. Multiple sets of 15 to 20 repetitions are used to increase rotator cuff strength and provide an accommodating resistance overload to the patient to improve strength and endurance of the rotator cuff musculature. Isokinetic testing occurs at 12 to 14 weeks postoperation to determine strength levels and the continuation of rehabilitation. Moderate strength deficiencies are typically encountered in the posterior rotator cuff (external rotators) at 12 weeks following rotator cuff repair of tears ranging in size between small to large.[13]



FIGURE 6-86. Isokinetic modified base Davies 30/30/30 position to improve internal and external rotation strength and muscular endurance on the Biodex isokinetic dynamometer.

Milestones for Progression to the Next Phase

- Isokinetic ER/IR strength within 15% to 20% of contralateral side
- Isokinetic ER/IR ratios of 60% to 66% or greater
- Pain-free range of motion within 10° of contralateral side
- Negative impingement and provocation tests (i.e., subluxation/relocation test, empty can test, O'Brien's test)

Phase III (weeks 12 to 16)

Clinical Pearls

- Imperative to use and incorporate functional movement simulation into the clinical rehabilitation program to prepare the patient for entry into an interval sport return program.
- The use of very light medicine balls, 0.5 to 1 kg to perform single arm plyometric movements for deceleration and control are an important precursor to returning to throwing activity.
- Two hand plyometric exercises are also important for golf and other sport functional return programs.

Goals

- Advance overhead function in the 90° abducted scapular plane position
- Achieve terminal range of motion in all planes
- Increase muscular strength and endurance (fatigue resistance)
- Begin interval sport return programming
- Initiate and progress upper extremity plyometric program
- Prepare for discharge from formal physical therapy with detailed home exercise program if applicable (large and massive tears often require additional in-clinic rehabilitation to gain full strength in elevation

Protection

- No sling or brace is used during this stage

Management of Pain and Swelling

- Typically patients are weaned from any modality care at this time; however, the use of heat before rehabilitation and exercise is advocated, and continued use of ice following treatment, exercise, or functional return programming is followed.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Continued use of the previously mentioned ROM and mobilization techniques is applied to achieve terminal ROM. Continued emphasis and development of independent stretching techniques for the patient is recommended. The sleeper stretch and cross-arm stretch are advocated to improve and maintain internal rotation ROM.[14,15]

Other Therapeutic Exercises

- Total arm strength activities continue through the use of the rehabilitation program of rotator cuff and scapular strength as well as a continued emphasis for the throwing and racquet sport athlete on distal forearm and wrist strengthening to ensure competence of those important muscles upon the return to activity phase.

Sensorimotor Exercises

- Continued use of rhythmic stabilization and closed chain (ball on wall) exercises continues during this phase to provide proprioceptive, and kinesthetically enriched, activity to the shoulder complex

Techniques to Increase Muscle Strength, Power, and Endurance

- The paradigm of multiple sets of 15 to 20 repetitions coupled with time based exercises of 30 seconds or more during external rotation oscillation exercise or body blade exercises continues in this later stage of rehabilitation due to the importance of establishing local muscular endurance in the rotator cuff and scapular musculature to provide glenohumeral compression and stabilization[16]. Additionally, the use of the isokinetic and plyometric exercises moves toward establishing and improving muscular power in the upper extremity.

Neuromuscular Dynamic Stability Exercises

- The use of closed chain rhythmic stabilization exercise (quadruped) and tripod positions (Figure 6-87) enable the patient to work both core and scapular stabilization and can also be used for functional progressions



FIGURE 6-87. Quadruped rhythmic stabilization exercise to improve scapular stabilization and begin to implement functional weightbearing activity.

to weightbearing and sport-specific activities (diving and landing).

Plyometrics

- Several plyometric exercises can be used starting with very light medicine balls (0.5 to 1.0 kg in weight). The side-lying ball drop/catch, and side-lying partner catch are two exercises that can be used to provide an overload stress for the posterior rotator cuff and scapular musculature before the initiation of any upper extremity sport activity. (Figures 6-88 and 6-89) Multiple sets of this exercise using 15 to 20 repetitions of the catches and working toward 20 to 30 second sets of catch and drop activity are recommended.



FIGURE 6-88. Side-lying plyometric external rotation drop exercise.

Functional Exercises

- In addition to the use of plyometric exercises that do mimic the functional movement patterns of overhead



FIGURE 6-89. A-D, Side-lying plyometric external rotation catch exercise with partner.

sports, interval sport return programs are followed before the patient is allowed back to any sport activity. These programs start with simulation of the activity without a ball or implement, and progress to very low levels of activity at shorter distances, or lower intensities to allow for a gradual return. The reader is directed to programs referenced here in Chapter 8 of this text. (Box 6-1)

Criteria for Return to Sport

General

- See Chapter 11 for an interval throwing program.
- Isokinetic ER/IR strength within 15% to 20% of contralateral side
- Isokinetic ER/IR ratios of 66% or greater
- Pain-free range of motion within 10° of contralateral side
- Pain-free IR and ER ROM endpoints that allow for uncompensated simulation of sport specific movement patterns after appropriate warmup and preparation.
- Negative impingement and provocation tests (i.e., subluxation/relocation test, empty can test, O'Brien's test)

After Return to Sport

Continuing Fitness or Rehabilitation Exercises

- Need for continued adherence to the rotator cuff and scapular exercise programming used in earlier rehabilitation phases
- Key to continue maintenance exercise for posterior rotator cuff as patients often discharged from therapy following rotator cuff repair with lower than optimal ER/IR ratios and require balancing via specific exercises
- A return to traditional lifting and sport activity most often is characterized by a dependence on internal rotation dominant activities. This can lead to increases in internal rotation strength without concomitant external rotation increases if diligent maintenance programs for rotator cuff and scapular exercise are not maintained.

Exercises and Other Techniques for Prevention of Recurrent Injury

- As in section above for strength
- Use of range of motion and stretching exercise particularly for internal rotation for those patients who return to throwing type activities after surgery and rehabilitation

BOX 6-1 Rehabilitation Protocol Following Arthroscopic Rotator Cuff Repair

General Guidelines:

- Progression of resistive exercise and ROM is dependent on patient tolerance.
- Resistance exercise should not be performed with specific shoulder joint pain.
- A sling is provided to the patient for support as needed with daily activities and to wear at night. The patient is weaned from the sling as tolerated and as directed by the referring physician.
- Early home exercises given to the patient following surgery including stomach rubs, sawing, and gripping activity.
- Progression to AROM against gravity and the initiation of resistive exercise are predicated by the size of the rotator cuff tear, and quality of the tissue and fixation.

Postop Weeks 1 & 2:

1. Early PROM to patient tolerance during the first 4 to 6 weeks:
   - flexion
   - scapular plane abduction
   - IR/ER with 90° to 45° scapular plane elevation
2. Mobilization of the glenohumeral joint and scapulothoracic joint. Passive stretching of elbow, forearm, and wrist to terminal ranges.
3. Side-lying scapular protraction/retraction resistance to encourage early serratus anterior and lower trapezius activation and endurance.
4. Home exercise instruction:
   - Instruction in PROM and AAROM home exercises with T-bar, pulleys, or opposite arm assistance in supine position using ROM to patient tolerance.
   - Weightbearing (closed chain) Codman's exercise instruction over a ball or counter-top/table.
   - Theraputty for grip strength maintenance

Postop Week 3:

1. Continue above shoulder PROM with progression to AAROM to patient tolerance.
2. Add upper body ergometer (UBE) if available.
3. Begin active scapular strengthening exercises and continue side-lying manual scapular stabilization exercise:
   - scapular retraction
   - scapular retraction with depression

Continued on following page

BOX 6-1 Rehabilitation Protocol Following Arthroscopic Rotator Cuff Repair *(Continued)*

4. Begin resistive exercise for total arm strength using positions with glenohumeral joint completely supported including:
   - bicep curls
   - tricep curls
   - wrist curls—flexors, extensors, radial and ulnar deviators
5. Begin submaximal rhythmic stabilization using the balance point position (90°-100° of elevation) in supine position to initiate dynamic stabilization.

Postop Weeks 5 & 6:

1. Initiate isotonic resistance exercise focusing on the following movements:
   - side-lying ER
   - prone extension
   - prone horizontal abduction (limited range to 45°)

   A low resistance/high repetition (i.e., 30 reps) format is recommended using no resistance initially (i.e., weight of the arm).
2. Progression to full PROM and AROM in all planes including ER and IR in neutral adduction progressing from the 90° abducted position used initially postop.
3. External rotation oscillation (resisted ER with towel roll under axilla and oscillation device) and Bodyblade to encourage local muscular endurance.
4. Home exercise program for strengthening the rotator cuff and scapular musculature with isotonic weights and/or elastic tubing (Thera-Band).

Postop Week 8:

1. Begin closed chain step-ups and quadruped rhythmic stabilization exercise.
2. Initiate upper extremity plyometric chest passes and functional two-hand rotation tennis groundstroke or golf swing simulation using small exercise ball progressing to light medicine ball as tolerated.

Postop Week 10:

1. Initiation of submaximal isokinetic exercise for IR/ER in the modified neutral position.
   Criterion for progression to isokinetic exercise:
   - Patient has IR/ER ROM greater than that used during the isokinetic exercise
   - Patient can complete isotonic exercise program pain-free with a #2 to #3 weight or medium resistance surgical tubing or Thera-Band
2. Progression to 90° abducted rotational training in patients returning to overhead work or sport activity.
   - prone external rotation
   - standing external/internal rotation with 90° abduction in the scapular plane
   - statue of liberty (external rotation oscillation)

Postop Week 12 (3 months):

1. Progression to maximal isokinetics in IR/ER and isokinetic testing to assess strength in modified base 30/30/30 position. Formal documentation of AROM, PROM, and administration of shoulder rating scales.
2. Begin interval return programs if criterion has been met below:
   - IR/ER strength minimum of 85% of contralateral extremity
   - ER/IR ratio 60% or higher
   - Pain-free range of motion
   - Negative impingement and instability signs during clinical exam

Postop Week 16 (4 months):

1. Isokinetic reevaluation, documentation of AROM, PROM, and shoulder rating scales.
2. Progression continues for return to full upper extremity sport activity (i.e., throwing, serving in tennis, etc.)
3. Preparation for discharge from formal physical therapy to home program phase.

Evidence

Ellenbecker TS, Elmore E, Bailie DS: Descriptive report of shoulder range of motion and rotational strength 6 and 12 weeks following rotator cuff repair using a mini-open deltoid splitting technique. *J Orthop Sports Phys Ther* 36:326–335, 2006.

This study followed patients 6 and 12 weeks postoperation following rotator cuff repair with a mini-open deltoid splitting technique and provided objective measure of range of motion and rotational strength. At 12 weeks postoperatively, patients' range of motion compared to their contralateral extremity showed 5° to 7° deficits in abduction, internal and external rotation and 9° great forward flexion than their contralateral side. Deficits in isokinetically documented strength for external rotation were 5% to 7% on the operative extremity and 2% to 11% greater internal rotation strength was measured on the operative extremity at 12 weeks postoperatively. The subjective portion of the ASES rating scale was 38/45 points for these patients at 12 weeks postop. (Level IV evidence)

Galatz LM, Charlton N, Das R, et al: Complete removal of load is detrimental to rotator cuff healing. *J Shoulder Elbow Surgery* 18:669–675, 2009.

This studied used a rat model and consisted of three groups following rotator cuff repair. These groups consisted of either botox injection, botox injection with complete immobilization, or saline injection with cast immobilization. The saline casted group had greater amounts of scar volume and greater cross sectional area as compared to the groups treated with botox and botox with immobilization. This study shows the detrimental effects of paralysis and immobilization on the healing and response of the tendon following rotator cuff repair. The complete removal of stress from the tendon resulted in a lower ultimate load to failure and decreased scar volume which jeopardizes healing and full function from the repair construct. (Level IV evidence)

Koo SS, Parsley BK, Burkhart SS, et al: Reduction of postoperative stiffness after arthroscopic rotator cuff repair: Results of a customized physical therapy regimen based on risk factors for stiffness. *Arthroscopy* 27:842–848, 2011.

This study reviewed results of rotator cuff repair surgery and identified several concomitant factors that led to stiffness and ROM complications following rotator cuff repair. These factors included calcific tendonitis, PASTA lesions, SLAP repairs, and single tendon RTC repairs. For patients with these characteristics, this study then implemented an additional rehabilitation intervention that consisted of a closed chain table slide exercise which places the patient's shoulder into a forward flexed position and can be done independently at home. This procedure was used in patients with risk factors for glenohumeral joint stiffness after rotator cuff repair and found to minimize range of motion complication in these patients. It is recommended that specific interventions be applied to patients with these stiffness risk factors to optimize recovery following rotator cuff repair. (Level IV evidence)

Lee BG, Cho NS, Rhee YG: Effect of two rehabilitation protocols on range of motion and healing rates after arthroscopic rotator cuff repair: Aggressive versus limited early passive exercise. *Arthroscopy* 28:34–42, 2012.

This prospective randomized trial examined two rehabilitation protocols for medium and large size rotator cuff repairs. Patients in the aggressive rehabilitation group had immediate early passive range of motion performed by a therapist two times per day along with unlimited patient self ROM with no ROM limitations. Patients in the limited passive range of motion rehabilitation group had continuous passive range of motion devices used without the assistance of the therapist to 90° of elevation only and limited self ROM during the first 6 weeks following surgery. At 3 months, the patients in the aggressive passive range of motion group had significantly great ROM in all planes than those patients in the group with only CPM use. By 1-year postop, however, there was no significant difference between groups. From a healing rate perspective, there were no significant differences in MRI documented retears of the rotator cuff at 7.6 months postop, with rates of retear of 23% in the aggressive passive rehabilitation group and 9% in the limited passive range of motion group. This study shows that early range of motion does lead to significantly great range of motion following arthroscopic rotator cuff repair. (Level IV evidence)

Namdari S, Baldwin K, Ahn A, et al: Performance after rotator cuff tear and operative treatment: A case-control study of major league baseball pitchers. *J Athletic Training* 46:296–302, 2011.

This study examined, via public records and statistics, the performance characteristics of professional baseball pitchers (n = 33) who underwent operative treatment for rotator cuff tears in their dominant pitching shoulder. These pitchers were compared to an age matched control population (n = 117) who did not have documented rotator cuff tears. This study showed that pitchers who had rotator cuff tear surgery did not return to baseline values of preoperative status. Characteristics of pitchers who needed rotator cuff surgery were that they were more experienced and had better earned run averages than pitchers studied who did not have rotator cuff tears. This study does show a return to presurgical performance levels in professional pitchers who undergo surgery for rotator cuff tears. (Level IV evidence)

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Multiple-Choice Questions

QUESTION 1. According to Hatakeyama et al.[1], what ranges of motion are considered safe following rotator cuff repair based on their cadaveric study?

A. All ranges of motion are safe
B. Humeral rotation of up to 90° in internal rotation is safe
C. Humeral rotation in the scapular plane of up to 60° of external rotation is safe
D. Scapular plane rotational motion is more stressful to the repaired supraspinatus tendon than the sagittal plane

QUESTION 2. Which of the following statements about early scapular stabilization exercise is/are true?

A. Manual scapular stabilization is recommended with direct contacts on the scapula to minimize stress to the repaired tendon
B. The movements of scapular protraction and retraction are important for inclusion
C. Multiple sets of 15 to 20 repetitions are recommended to improve strength and endurance of the scapular stabilizers
D. All of the above are correct

QUESTION 3. What statement is not true about the empty can exercise?

A. Increased anterior tilting of the scapular is inherent in this exercise compared to the full can exercise position
B. The empty can exercise is superior with respect to muscle activation of the supraspinatus compared with the prone horizontal abduction Blackburn exercise
C. The combined movements of internal rotation and elevation in the empty can exercise can produce impingement
D. Increased internal rotation of the scapula has been reported in the empty can position as compared to the full can position

QUESTION 4. What exercises are not indicated in postoperative rehabilitation following rotator cuff repair?

A. Side-lying external rotation
B. Rowing
C. Pushup and military press
D. Prone horizontal abduction

QUESTION 5. What are key indicators used to determine a patient's readiness to return to sport activity following rotator cuff repair?

A. ER/IR ratios above 60% to 66%
B. Pain-free range of motion
C. Negative impingement and labral tests
D. All of the above are key indicators

Answer Key

QUESTION 1. Correct answer: **C** (see Phase I)

QUESTION 2. Correct answer: **D** (see Phase I)

QUESTION 3. Correct answer: **B** (see Phase II)

QUESTION 4. Correct answer: **C** (see Phase II)

QUESTION 5. Correct answer: **D** (see Phase III)

BEYOND BASIC REHABILITATION: RETURN TO TENNIS AFTER ROTATOR CUFF REPAIR

Neal M. Berger, MD, Jeremy Vail, PT, OCS, ATC, and Seth C. Gamradt, MD

Epidemiology and Mechanism of Injury

- The game of tennis imparts great physiologic and mechanical stresses on the shoulder.[1]
- Consequently many recreational and competitive tennis players suffer from shoulder pain. The incidence of shoulder pain in tennis athletes has been studied. Safran and Hutchinson reported a 35% prevalence of shoulder pain in 370 girls playing in the National Hard Court Championships 16 and under division and a 24% prevalence of shoulder pain in 480 boys playing in the National Hard Court Championships 16 and under and 18 and under division.[1,2]
- Lehman reported a 24% incidence of shoulder pain in younger players, ages 12 to 19, and as high as a 50% incidence in middle age players.[3]

- The high incidence of shoulder complaints in even young athletes underscores the demand placed on the shoulder for a lifelong tennis player.
- For the older athlete, increasing shoulder pain and a decreased ability to play tennis can be a sign of rotator cuff pathology. Most shoulder pain in tennis players is attributed to overuse and involves the rotator cuff and/or biceps tendon.[1]
- More specifically, rotator cuff injuries in tennis can be caused by repetitive microtrauma, a single episode of macrotrauma, or degeneration associated with aging.
- In younger athletes, microtrauma and overuse are believed to be the most common cause of pain. Fortunately, it is very unusual for athletes less than 35 years of age to have full-thickness rotator cuff tears.[4]
- As such, tennis players in this younger age group can most often be successfully treated conservatively with physical therapy, rest, and nonsteroidal antiinflammatory agents (NSAIDs).
- However, with aging, the rotator cuff is susceptible to partial and full thickness tears that can jeopardize pain-free participation in tennis.
- It is well accepted that the incidence of rotator cuff tears increases with age in both athletes and nonathletes. Many individuals continue to play tennis into their 5th and 6th decades when there is a dramatic increase in the incidence of rotator cuff tears.
- The cause of tears in this age group is often hypothesized to be caused by a combination of extrinsic compression from subacromial impingement and intrinsic rotator cuff degeneration.
- Microtrauma secondary to subacromical impingement during the overhead movements in tennis can certainly contribute to tearing the degenerative rotator cuff of older tennis players.[4]

Surgical Outcomes

- Bigliani et al. reported on a series of rotator cuff tears in tennis players aged 50 and 70 and found an inciting traumatic event as the cause of rotator cuff tear in 11 of 23 players. Six of the eleven reported injury while playing tennis.[5]
- Bertand, in his series of 51 surgically treated rotator cuff tears in tennis players age 39 to 67 years old, reported that 22 of the 51 patients had a specific traumatic episode. Two of his patients had a concomitant anterior shoulder dislocation.[4]
- Although these studies show there may have been a specific inciting event in which these tennis players suffered their rotator cuff tears, the acute tears probably occurred in a rotator cuff weakened by degenerative changes that are almost universal with aging.
- When a significant rotator cuff tear occurs in a tennis player, tennis can become very difficult to play without pain, particularly the serving motion.
- For a chronic rotator cuff tear, a trial of rest, NSAIDs, injection, and physical therapy is most often attempted to restore a pain-free shoulder with activities of daily living. This is followed by a gradual return to sporting activity.
- When this trial of nonoperative therapy fails (3–6 months), surgical repair of the rotator cuff is often performed to restore function and relieve pain.
- In patients with an acute traumatic event and full thickness rotator cuff tear, surgical repair is often performed acutely. Many of these patients state that besides the obvious goals of improving pain and restoring strength, one of the main goals of rotator cuff surgery is to restore function including sporting activities such as tennis.
- Several studies have reported on the results of rotator cuff repair specifically in tennis players. Bigliani et al., reported on 23 patients with full thickness rotator cuff tears that prevented them from playing tennis. The average age of the patients was 58 years (range, 39 to 71). The patients were largely recreational tennis players who averaged 3 days per week playing tennis preoperatively. These patients were surgically treated with an open rotator cuff repair and anterior acromioplasty. At average follow-up of 42 months, 83% of the patients were pain-free and were playing tennis at their preinjury level. Thirteen percent of the patients had some residual weakness and were playing tennis, but at a lower level than before the surgery. One patient was unable to play tennis and had pain with activities of daily living. All four of the patients who did not return to their preinjury playing level had massive tears. Although four other patients with massive tears had successful outcomes, the authors concluded that tennis players with massive rotator cuff tears should be made aware preoperatively that they may not return to their preinjury level. More importantly, they concluded that the majority of patients with symptomatic rotator cuff tears preventing them from playing tennis could return to tennis after open rotator cuff repair and acromioplasty.[5]
- Sonnery-Cottet et al. reported the results of a retrospective review where 51 tennis players, with an average age of 51 years, underwent surgical treatment for a rotator cuff tear. Thirty-two of the patients were recreational tennis players and 19 competed in tournaments on a national level at least in their age group. Overall, the patients averaged 3.5 hours of tennis per week. Patients varied in pathology from partial or full thickness tears of the supraspinatus, infraspinatus and/or subscapularis. Treatments varied from arthroscopic debridement (9 patients) to open repair (42 patients). Concomitant procedures were also performed in some patients and included bursectomy, coracoacromial ligament release, acromioplasty, and biceps tenodesis. They reported that 78% of the patients returned to playing tennis after surgery, with 61% returning to play at their preinjury level or higher. There is very little literature specifically examining the rehabilitation for tennis after rotator cuff repair. Rehabilitation specifically for tennis is demanding caused by the significant role the rotator cuff plays in tennis and its various strokes.[4]

EMG Analysis of Tennis Strokes

- Before developing an advanced rehabilitation protocol for returning to tennis, it is crucial to understand the

contribution each muscle makes during each tennis stroke.

- Jobe et al. investigated muscular activity during tennis strokes using electromyogram (EMG) and measured percentages of maximum voluntary isometric contraction (MVIC) of the shoulder musculature during forehand, backhand, and serve. The important work of Jobe's group deserves detailed mention here because it highlights the huge differences that occur in muscle activity during different strokes and during different phases of each stroke.
- During the cocking stage of serve, which involves shoulder abduction and external rotation while flexing the elbow, the percentages of MVIC were 53% for the supraspinatus, 41% for the infraspinatus, 25% for the subscapularis, 39% for the biceps brachii, and 70% for the serratus anterior.
- During the acceleration stage of serve, there is internal rotation and adduction of the shoulder with MVIC percentages of 113% for the subscapularis, 115% for the pectoralis major, and 74% for the serratus anterior.
- In the follow-through stage there was 63% of MVIC for the subscapularis and 53% of MVIC for the serratus anterior.[6]
- Forehand produces powerful internal rotation and adduction, with high activity of the subscapularis, biceps brachii, and serratus anterior.
- The follow-through had an increase in activity of the infraspinatus and a decrease in activity of the biceps brachii, subscapularis, and serratus anterior.
- The acceleration phase of the backhand consists of external rotation and abduction with high activity seen in the middle deltoid, supraspinatus, and infraspinatus.
- In the follow-through phase, there is decreased but continued moderate activity in the supraspinatus and infraspinatus.[6]
- Jobe's data quantifies the demand placed on specific muscle groups during tennis and allows the surgeon and physical therapist to tailor the patients' advanced rehabilitation activities based on what rotator cuff muscles were repaired. More importantly, a patient who is having difficulty with a particular stroke would benefit by strengthening the major muscles used during that stroke.

Rehabilitation Protocol

- After rotator cuff repair, both athletes and nonathletes proceed through rotator cuff rehabilitation protocols that are commonly subdivided into four phases: immediate postoperative, range of motion, early strengthening, and advanced strengthening.[7]
- However, many patients undergo rotator cuff repair to return to sporting activities, such as tennis. Thus, rehabilitation of a tennis player requires an advanced rehabilitation protocol that will increase the probability that the patient will be able to return to tennis without jeopardizing the structural integrity of the repair and the success of the surgery.
- After completing the standard rehabilitation and clearance by the surgeon, the patient can begin tennis specific exercises, drills, and activities. This is generally not before 4 or 5 months postrepair.
- These sport-simulating exercises are then slowly progressed until the therapist feels that the athlete is ready for an interval sports program.[8]
- The basic rehabilitation protocol shown in Box 6-2 must be completed and tolerated by the patient to progress to the advanced rehabilitation stages.

Return to Sports Program

- Reinold et al. highlight certain key points in developing a rehabilitation approach for return to sport. Applying these concepts to returning to tennis, the interval sports program should: 1) prepare the whole body for return to tennis with upper extremity, lower extremity, and core ROM and strengthening, 2) slowly

BOX 6-2 Rehabilitation Protocol

Phase I. Postoperative (0 to 6 weeks)

GOALS

- Edema control
- Protect repair
- Avoid shoulder stiffness in safe range

PRECAUTIONS

- Sling with abduction pillow at all times except showering (until week 4)
- No lifting
- No supporting body weight
- No AROM against gravity

WEEKS 0 TO 2 POSTOPERATIVE

- PROM-forward elevation in the scapular plane to 90°
- Passive ER to neutral
- Cryotherapy until swelling is diminished then after therapy and as needed
- Modalities PRN
- Hand, wrist, elbow AROM 3 times per day

BOX 6-2 Rehabilitation Protocol *(Continued)*

WEEKS 2 TO 4 POSTOPERATIVE

- Start pendulums.
- Passive supine elevation, passive ER (Goals: FE 120, ER 30, IR hip).
- Pulley exercises for flexion, as tolerated. Use cane for ER; IR in scapular plane.
- Begin scapular strengthening program, in protective range.
- Deltoid and rotator cuff isometrics, submaximal and pain free.

WEEKS 4 TO 6 POSTOPERATIVE

- Joint mobilization & gentle PROM as necessary to restore near full PROM by week 6 (passive supine elevation, passive ER and IR in scapular plane at 45° abduction)
- Continue scapular strengthening
- Brace may be weaned at week 4 for small and medium size tears

Phase II. Protection and Range of Motion (6–12 weeks)

PRECAUTIONS:

- Avoid lifting and carrying
- No sudden shoulder movements
- Avoid supporting bodyweight

GOALS:

- Reestablish dynamic shoulder stability
- Avoid stressing healing rotator cuff
- Establish pain-free AROM

6 TO 8 WEEKS POSTOPERATIVE

- Initiate AAROM activities
- Flexion, unlimited, use arm support in supine position
- Progress to AROM in scapular plane, ER/IR at 45° and 90° of abduction
- Deltoid isotonics in plane of scapula
- Continue with modalities prn
- Joint mobilization for inferior humeral glide
- Manual therapy techniques to the posterior cuff and shoulder complex to ensure normal accessory motion, specifically with overhead movements
- Incorporate cardiovascular exercise, conditioning, and lower extremity work.

WEEKS 8 TO 12 POSTOPERATIVE

- Restore full AROM by 10 to 12 weeks
- Continue with scapular strengthening exercises
- Begin isotonic IR/ER in adduction with tubing, emphasize eccentrics (week 10)
- Continue with flexibility activities to maintain PROM
- Proprioceptive neuromuscular facilitation (PNF) patterns
- Manual resistance/assistance
- Rhythmic stabilization beginning in mid-range and progressing through entire range as able.

Phase III. Early Strengthening (12–18 weeks postoperative)

PRECAUTIONS:

- Lifting: 5 lbs.
- No overhead lifting

GOALS:

- Full active ROM
- Return to low level functional activities
- Improve muscular endurance
- Restore normal glenohumeral and scapulothoracic rhythm.

12 TO 18 WEEKS POSTOPERATIVE

- Continue extremity PREs to maintain full PROM
- Initiate rotator cuff strengthening protocol
  - IR/ER isotonic tubing exercises
  - Lateral raises

Continued on following page

BOX 6-2 Rehabilitation Protocol *(Continued)*

- Full can
- Prone rowing
- Prone abduction
- Side-lying ER
- Biceps/triceps
- Scap pushups (pushup plus)
- Step-up with overhead reach
- Multidirectional lunges with reach

Phase IV. Advanced Strengthening/Sport-Specific Training (18 weeks+)

- The advanced strengthening phase of any rehabilitation program must be undertaken with great care and caution
- The potential for complication and accumulation of tissue stress increases as the volume and load of exercise increases
- To ensure the appropriate training effect is applied to the athlete's body and specifically the integration of the lower body, core and upper body, the following guidelines for progression should be observed.

Guidelines for Progression to Advanced Strengthening

- Full AROM and PROM of glenohumeral joint
- Normalized and symmetrical scapulohumeral and scapulothoracic rhythm. This is measured by evaluating the contralateral uninjured shoulder.
- Normalized thoracic spine extension and coupled extension/rotation. This is measured by evaluating the contralateral uninjured shoulder.
- Normalized age-specific cervical spine stability and AROM, with specific emphasis on the coupled motions of bilateral lateral flexion/rotation.
- Tolerates standard rotator cuff strengthening (Phase 3).
- Specific components of the advanced strengthening phase of rehabilitation should seek to improve both muscular strength as well as power development, and with respect to the tennis swing, key emphasis must be placed on the efficient transfer through the kinetic chain to the racket head.
- This efficient transfer is a combination of both acceleration and, more importantly, deceleration of the hips, trunk, and shoulders to pass to the racket head with maximal velocity at impact with the ball.
- Program design should take into account the staging of sets, reps, and appropriate load to address muscular hypertrophy, strength and ultimately power development, but keeping at the forefront the concept that the rotator cuff, and specifically the surgically repaired cuff is not the principal generator of the forces that swing the tennis racket, but function to center the humeral head in the glenoid fossa during the swing.
- Additionally, given the specific demands, multitude of swings (forehand, backhand, overhead, serve) and techniques (i.e., double vs. single hand forehand/backhand) and the repetitive nature of the sport, an estimated or projected 1 Repetition Maximum would be appropriate to determine loads for the above mentioned training cycles specific to the shoulder.
- Ultimately, these loads must be adjusted to ensure that during performance of the exercises, there is correct maintenance of posture and technique, to include proper stability through the hip complex and appropriate respiratory patterns that avoid development of a high-threshold strategy compensation.
- Prior to progression to the power development portion of a return to play program, it would be appropriate to administer a form-of-movement screen or functional assessment to evaluate not only the repaired shoulder but the entire kinetic chain's preparedness to initiate this type of training and conditioning.
- It is well documented that the contribution of the rotator cuff to power generation during the tennis swing varies with each phase of the swing.[6]
- Given this fact, tennis-specific exercises should focus on strengthening the shoulder muscles as a group and identify any underlying dysfunction elsewhere in the kinetic chain that contributed to the initial injury.
- Tennis-specific exercises performed in addition to traditional advanced strengthening may include the following:
  - Half-kneeling chop and lift—bar (Figures 6-90 and 6-91)
  - Half-kneeling chop and lift—rope (Figures 6-92 and 6-93)
  - Half-kneeling chop slam (Figure 6-94)
  - Half-kneeling deceleration ball toss (Figure 6-95)
  - Concentric/eccentric ball toss (Figure 6-96)
  - Wide stance trunk rotations (Figure 6-97)
  - Standing side toss (Figure 6-98)
  - Lunge and side toss (Figure 6-99)
- These exercises can be performed in the advanced strengthening phase of the rehabilitation program initially one set of 8 to 10 repetitions 2 to 3 times per week, advancing to two sets of 8 to 10 repetitions every other day. When this protocol is tolerated, the interval return to tennis program can be initiated. Typically, this portion of the rehabilitation program lasts for 1 to 2 months depending on progression before starting the interval tennis protocol (Table 6-2).
- Return to the sport of tennis, specifically at the higher levels of competition have been discussed in this chapter and cited in multiple studies.
- To ensure that all aspects of the athlete's return to play are addressed, there must be considerable attention paid to the cardiovascular as well as the above mentioned power development.

BOX 6-2 Rehabilitation Protocol *(Continued)*

- Inherent in this development are Olympic-style lifts and plyometric training programs. These are keys to the development of whole body power that is essential to maximize the athlete's return. They require a considerable amount of proper coaching, supervision and occasional modification where appropriate given the specific athlete's needs and goals.
- As such, a properly educated strength and conditioning expert well versed in the specifics of the sport of tennis should be consulted.
- Lastly, given the aforementioned overhead, repetitive nature of the game of tennis, avoidance of overhead pressing, straight bar bench press, barbell snatch lifts and upright rowing is considered prudent.
- The use of the power clean should be used judiciously, with caution given to the stress placed on the athlete's wrist.
- Coinciding with the power development portion of the program, the interval sport program must be instituted and progressed through before final clearance from the surgeon and return to unrestricted play.
- It is critical to keep in mind that compensations, or biomechanical inefficiencies, that had played a role in the initial injury most likely will continue to be present as the athlete works through the interval sport program and if still present after recovery can lead to reinjury.
- A qualified coach/instructor is an excellent adjunct at this phase of the rehabilitation as the competitor returns to competitive or recreational tennis.



FIGURE 6-90. Half-kneeling lift—bar. (**A**) Starting position, (**B**) Finishing position.



FIGURE 6-91. Half-kneeling chop—bar. (**A**) Starting position, (**B**) Finishing position.



FIGURE 6-92. Half-kneeling lift—rope. (**A**) Starting position, (**B**) Finishing position.



FIGURE 6-93. Half-kneeling chop—rope. (**A**) Starting position, (**B**) Finishing position.



FIGURE 6-94. Half-kneeling chop slam. (**A**) Weighted ball in chop position, (**B**) ball is slammed to floor obliquely into (**C**) finishing position.

increase forces on the surgically repaired shoulder, 3) incorporate a tennis specific warmup program and regimen of regular exercises, and 4) focus on proper stroke technique to lessen the chance of reinjury or new injury.[8]

Surgical Considerations for the Rehabilitation Program

- In developing an advanced tennis rehabilitation program, the surgeon must consider the individualized aspects of each patient's pathology, surgical repair, and goals. With respect to pathology, the surgeon must consider the size of the tear, the location of the tear, the quality of the rotator cuff preoperatively, the associated shoulder pathology, and the quality of fixation. These factors will affect the basic rehabilitation, the progression of the advanced rehabilitation, and the timeline for return to tennis.
- Generally, larger tears require a slower, more conservative rehabilitation. In addition, these patients can often take closer to a year to return to sport as opposed to 6 months for smaller tears.
- Also, as shown from the work of Bigliani et al., patients with massive tears may return at a lower level of play or not at all.[5]
- With respect to tissue quality, preoperative MRIs will allow the surgeon to assess the amount of fat atrophy versus muscle in the affected rotator cuff muscles. Patients with more fat atrophy will likely be progressed

TIMELINE 6-7: **Postoperative Rehabilitation after Rotator Cuff Repair**

PHASE I (weeks 0 to 6)	PHASE II (weeks 6 to 12)
Weeks 0–2	**Weeks 6–8**
• Cryotherapy until swelling is diminished then after therapy and as needed • Modalities PRN • Hand, wrist, elbow AROM 3 times per day	• Initiate AAROM activities • Flexion, unlimited, use arm support in supine position • Progress to AROM in scapular plane, ER/IR at 45° and 90° of abduction • Deltoid isotonics in plane of scapula • Continue with modalities prn • Joint mobilization for inferior humeral glide • Manual therapy techniques to the posterior cuff and shoulder complex to ensure normal accessory motion, specifically with overhead movements • Incorporate cardiovascular exercise, conditioning, and lower extremity work
Weeks 2–4	**Weeks 8–12**
• Joint mobilization & gentle PROM as necessary to restore near full PROM by week 6 (passive supine elevation, passive ER and IR in scapular plane at 45° abduction) • Continue scapular strengthening • Brace may be weaned at week 4 for small and medium size tears	• Restore full AROM by 10–12 weeks • Continue with scapular strengthening exercises • Begin isotonic IR/ER in adduction with tubing, emphasize eccentrics (week 10) • Continue with flexibility activities to maintain PROM • Proprioceptive neuromuscular facilitation (PNF) patterns • Manual resistance/assistance • Rhythmic stabilization beginning in mid-range and progressing through entire range as able



FIGURE 6-95. Half-kneeling deceleration ball toss. (**A**) Ball is tossed from behind patient into (**B**) patient's dominant hand. (**C**) Patient then decelerates ball into (**D**) finishing position.

more slowly in rehabilitation and will have a more conservative prognosis for time to return to play.
- The strength of the surgical fixation will also affect the speed of progression of the rehabilitation. The stronger the repair, the more quickly the rehabilitation can be advanced.
- Several investigations have reported improved time-zero biomechanical strength of double row and transosseus equivalent repairs, but it is unclear if these repairs will allow an earlier return to athletics.[9]

Preoperative Goals

- The patient's preoperative goals will also have to be considered prior to initiation of the advanced rehabilitation. Many highly competitive athletes will have unrealistic timelines for return to tennis.
- In addition, these patients may have a tendency to progress their own rehabilitation without the clearance of their therapist or surgeon. These patients will need preoperative and postoperative education and guidance to understand the duration of rehabilitation and the character of pain acceptable during rehabilitation.
- It is well accepted that patients may have dull, sore, or aching pains in their muscles or tendons during advanced rehabilitation which is not necessarily a sign of reinjury. However, sharp pain, worsening ROM, and/or new onset weakness should prompt cessation of athletic activity and a reassessment by the physical therapist and surgeon.[8]

TIMELINE 6-7: **Postoperative Rehabilitation after Rotator Cuff Repair** (Continued)

PHASE III (weeks 12 to 18)

- Continue extremity PREs to maintain full PROM
- Initiate rotator cuff strengthening protocol
  - IR/ER isotonic tubing exercises
  - Lateral raises
  - Full can
  - Prone rowing
  - Prone abduction
  - Side-lying ER
  - Biceps/Triceps
  - Scap pushups (pushup plus)
  - Step-up with overhead reach
  - Multidirectional lunges with reach

PHASE IV (weeks 18+)

- Begin advanced strengthening phase with great care and caution
- Full AROM and PROM of glenohumeral joint
- Normalized thoracic spine extension and coupled extension/rotation
- Normalized age-specific cervical spine stability and AROM
- Tolerates rotator cuff strengthening protocol (Phase III)
- Tennis-specific exercises
  - Half-kneeling chop & lift—bar
  - Half-kneeling chop & lift—rope
  - Half-kneeling chop slam
  - Half-kneeling deceleration ball toss
  - Concentric/eccentric ball toss
  - Wide stance trunk rotations
  - Standing side toss
  - Lunge and side toss

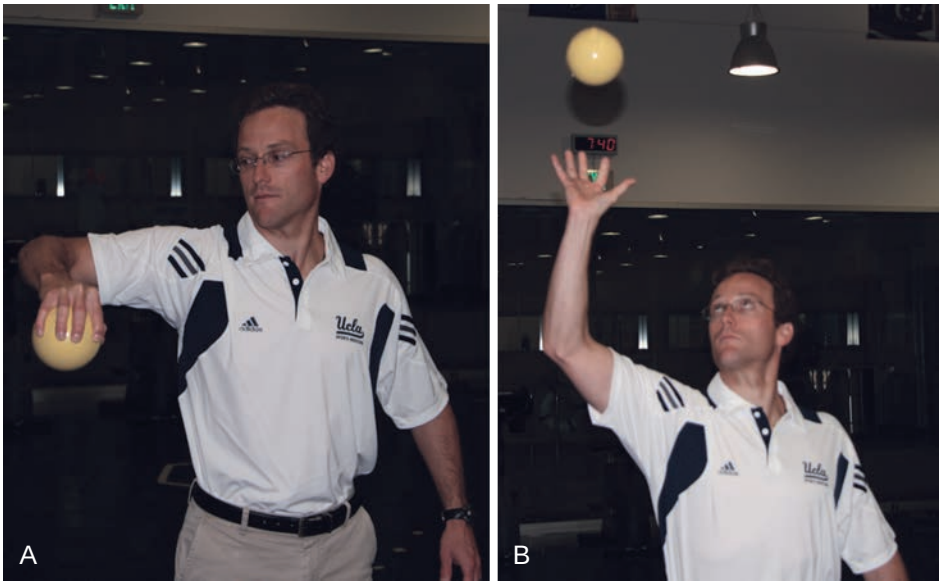

FIGURE 6-96. Concentric/eccentric ball toss. **A,B,** Ball is tossed concentrically using external rotation, caught, and eccentrically decelerated into starting position to repeat exercise.

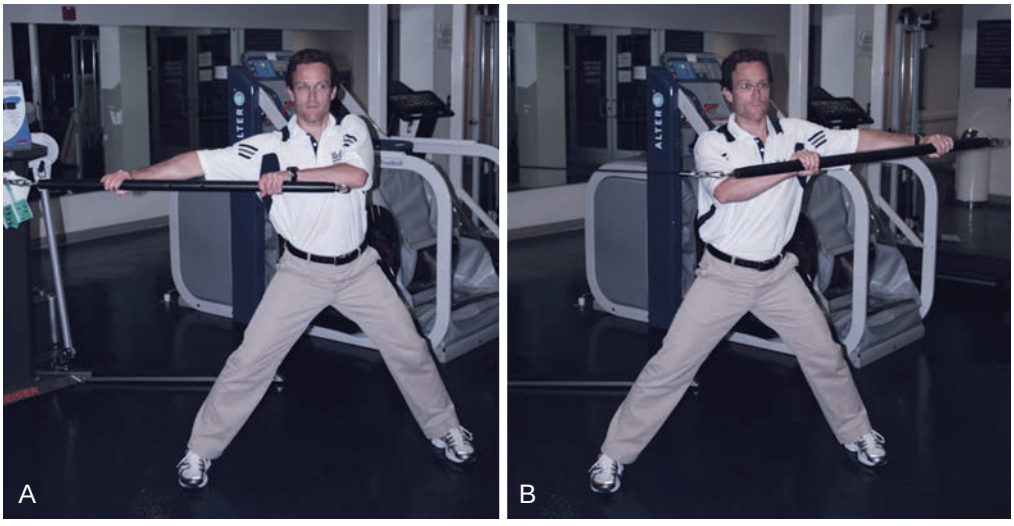

FIGURE 6-97. Wide stance trunk rotations. (**A**) Starting position, (**B**) Finishing position.



FIGURE 6-98. Standing side toss. (**A**) Weighted ball side tossed into (**B**) finishing position.



FIGURE 6-99. Lunge and side toss. **A,** Weighted ball is tossed incorporating a lunge (**B**) into finishing position (**C**).

Table 6-2 Interval Tennis Program

	Monday	Wednesday	Friday
Week 1	12 FH 8 BH 10 min rest 13 FH 7 BH	15 FH 8 BH 10 min rest 15 FH 7 BH	15 FH 10 BH 10 min rest 15 FH 10 BH
Week 2	25 FH 15 BH 10 min rest 25 FH 15 BH	30 FH 20 BH 10 min rest 30 FH 20 BH	30 FH 25 BH 10 min rest 30 FH 25 BH
Week 3	30 FH 25 BH 10 SR 10 min rest 30 FH 25 BH 10 SR	30 FH 25 BH 15 SR 10 min rest 30 FH 25 BH 15 SR	30 FH 30 BH 15 SR 10 min rest 30 FH 15 SR 10 min rest 30 FH 30 BH 15 SR
Week 4	30 FH 30 BH 10 SR 10 min rest Play 3 games 10 FH 10 BH 5 SR	30 FH 30 BH 10 SR 10 min rest Play set 10 FH 10 BH 5 SR	30 FH 30 BH 10 SR 10 min rest Play 1.5 sets 10 FH 10 BH 3 SR

SR = serves; FH = forehand shots; BH = backhand shots

From Reinold MM, Wilk KE, Reed J, Crenshaw K, Andrews JR: Interval sport programs: guidelines for baseball, tennis, and golf. J Orthop Sports Phys Ther, 32:293–298, 2002.

Physician-Therapist-Patient Communication

- Lastly, the surgeon and physical therapist must communicate concerning the timing of progression to advance rehabilitation, the design of the program, and the timeline for return to tennis.
- The surgeon will often base their rehabilitation restrictions on the clinical factors described above, whereas the physical therapist is critical in assessing progression through the phases of rehabilitation while evaluating milestones for safe advancement.
- An effective surgeon/physical therapist relationship will increase the likelihood that patients will return to sport after rotator cuff repair.
- In this chapter, we present an abbreviated version of our complete rotator cuff rehabilitation protocol with an emphasis on the fourth phase of rehabilitation (advanced strengthening) and beyond, during which we incorporate tennis-specific functional exercises in preparation for the interval sport program described by Reinold et al.[8]

Evidence

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An older but classic book describing the treatment of all types of athletic shoulder injuries.

Bigiliani LU, Kimmel J, McCann PD, et al: Repair of rotator cuff tears in tennis players. *Am J Sports Med* 20:112–117, 1992.

Twenty-three patients (average age 58 years) with full thickness rotator cuff tears that prevented them from playing tennis underwent open repair and acromioplasty. At average

follow-up of 42 months, 83% of the patients were pain-free and were playing tennis at their preinjury level. All four of the patients who did not return to their preinjury playing level had massive rotator cuff tears.

Ghodadra NS, Provencher MT, Verma NN, et al: Open, mini-open, and all-arthroscopic rotator cuff repair surgery: indications and implications for rehabilitation. *J Orthop Sports Phys Ther* 39:81–89, 2009.

This is one of the best and most detailed review papers for surgeons and physical therapists discussing rehabilitation and timelines after rotator cuff repair. (Level IV evidence)

Lehman RC: Shoulder pain in the competitive tennis player. *Clin Sports Med* 7:309–327, 1988.

Shoulder pain in the competitive tennis player ranges from 24% in the young player to 50% in the middle aged player. (Level IV evidence)

Millett PJ, Wilcox RB, 3rd, O'Holleran JD, et al: Rehabilitation of the rotator cuff: an evaluation-based approach. *J Am Acad Orthop Surg* 14:599–609, 2006.

An outstanding rotator cuff rehabilitation review that divides the rehabilition of the repaired shoulder into four phases: immediate postoperative, range of motion, early strengthening, and advanced strengthening. (Level IV evidence)

Reinold MM, Wilk KE, Reed J, et al: Interval sport programs: guidelines for baseball, tennis, and golf. *J Orthop Sports Phys Ther* 32:293–298, 2002.

This paper provides a timeline for tendon healing in and helps guide rehabilitation milestones based on biology of tendon repair and healing. (Level IV evidence)

Ryu RK, McCormick J, Jobe FW, et al: An electromyographic analysis of shoulder function in tennis players. *Am J Sports Med* 16:481–485, 1988.

Jobe et al. investigated muscular activity during tennis strokes using electromyogram (EMG) and measured percentages of maximum voluntary isometric contraction (MVIC) of the shoulder musculature during forehand, backhand, and serve. This study highlights the huge differences in muscle activity that occur during different strokes and during different phases of each stroke. (Level II evidence)

Safran MR, Hutchinson HM: *Unpublished Data*, 1995.

Unpublished data reporting a 35% prevalence of shoulder pain in 370 girls playing in the National Hard Court Championships 16-and-under division and a 24% prevalence of shoulder pain in 480 boys playing in the National Hard Court Championships 16-and-under and 18-and-under division. (Level IV evidence)

Sonnery-Cottet B, Edwards TB, Noel E, et al: Rotator cuff tears in middle-aged tennis players: results of surgical treatment. *Am J Sports Med* 30:558–564, 2002.

Fifty-one tennis players with an average age of 51 years who underwent surgical treatment for a rotator cuff tear were evaluated. Treatments varied from arthroscopic debridement (9 patients) to open repair (42 patients). Seventy-eight percent of the patients returned to playing tennis after surgery, with 61% returning to play at their preinjury level or higher.

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1. Andrews JR, Wilk KE: The Athlete's shoulder, New York, 1994, Churchill Livingstone.
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3. Lehman RC: Shoulder pain in the competitive tennis player. *Clin Sports Med* 7:309–327, 1988.
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9. Ghodadra NS, Provencher MT, Verma NN, et al: Open, mini-open, and all-arthroscopic rotator cuff repair surgery: indications and implications for rehabilitation. *J Orthop Sports Phys Ther* 39:81–89, 2009.

Multiple-Choice Questions

QUESTION 1. Based on retrospective, level-IV evidence, which of the following preoperative patient factors carries a high risk of poor outcome and failure to return to tennis after rotator cuff tear?

A. Full thickness rotator cuff tear
B. Age greater than 50
C. Concomitant acromioplasty
D. Massive rotator cuff tear

QUESTION 2. Based on observational and epidemiological data, what percentage of tennis players experience shoulder pain?

A. Less than 5%
B. 10%
C. 15%
D. More than 20%

QUESTION 3. Regarding EMG of the shoulder during tennis serve, forehand, and backhand, which of the following is an incorrect statement

A. During EMG of the shoulder during serving, the highest values of shoulder maximum voluntary isometric contraction (MVIC) occurred during the acceleration phase of serve.
B. The MVIC values of rotator cuff activity were similar regardless of stroke being evaluated.
C. Rotator cuff muscles remain active in the follow through phase of forehand and backhand.
D. The amount and location of muscle activity changes depending on which stroke is being evaluated.

QUESTION 4. Criteria to proceed with advanced strengthening and sport-specific exercises include all of the following except:

A. Full active shoulder range of motion
B. Full passive shoulder range of motion
C. Restoration of scapula-humeral rhythm
D. Continued mild pain with rotator cuff strengthening

QUESTION 5. An acceptable rehabilitation timeline for

restoring full active range of motion in a shoulder after rotator cuff repair is:

A. 2–4 weeks
B. 6–8 weeks
C. 10–12 weeks
D. 24 weeks

Answer Key

QUESTION 1. Correct Answer: **D** (see Surgical Outcomes of Rotator Cuff Tear in Tennis)

QUESTION 2. Correct Answer: **D** (see Epidemiology)

QUESTION 3. Correct Answer: **B** (see the EMG Analysis of Tennis Stroke)

QUESTION 4. Correct Answer: **D** (see Rehabilitation Timeline)

QUESTION 5. Correct Answer: **D** (see Rehabilitation Timeline)

BEYOND BASIC REHABILITATION: RETURN TO GOLF AFTER ROTATOR CUFF REPAIR

Seth C. Gamradt, MD, Jeremy Vail, PT, OCS, ATC, and Neal M. Berger, MD

Introduction

- Shoulder injuries are one of the most common injuries in both amateur and professional golfers; injuries to the shoulder rank third in frequency behind wrist/hand injuries and lumbar spine injuries in professional golfers.[1–3]
- Although not commonly thought of as an overhead sport, 30% of the golf swing is spent with the arms elevated above 90° (Figure 6-100).
- Further, golf involves an asymmetric attainment of extremes of shoulder range of motion at the top of the backswing and at the end of the follow-through that can exacerbate impingement and rotator cuff disease.

Epidemiology

- Jobe reviewed 412 patients with golf injuries and found the incidence of shoulder pain to be 20%, with the majority of shoulder pathology being impingement or rotator cuff disease.[4]

EMG Analysis of Golf Swing

- Jobe et al evaluated the activity of eight muscles during the asymptomatic golf swing using electromyography and high-speed motion cameras.[4]
- Surprisingly, the rotator cuff and deltoid were relatively inactive during the golf swing. The pectoralis major and latissimus dorsi muscles were the most active and provided power for downswing, acceleration, and follow-through. The deltoid was active in the lead shoulder just before ball contact and the supraspinatus fired at a low level in both shoulders throughout the swing but was more active in the lead shoulder. The subscapularis was the most active of the three rotator cuff muscles tested.[4] These EMG results have clinical implications for returning to golf after rotator cuff repair.



FIGURE 6-100. Stages of the golf swing.

Return to Sport

- Return to sport after repair of full or partial thickness rotator cuff tears has been unpredictable in overhead athletes (particularly pitchers), and many authors therefore advocate for debridement of rotator cuff tears alone in this population unless the tear involves greater than 50% of the thickness of the footprint.[5]
- It is possible that a higher percentage of golfers could return to sport after rotator cuff repair caused by the comparatively low demand (at least by EMG) on the rotator cuff in golf.
- Unfortunately, there is very limited evidence to evaluate the success or failure of rotator cuff repair in return to golf. Only one study has specifically evaluated rotator cuff repair in golfers; a 2001 retrospective study by Vives et al. reported excellent success after mini-open or open rotator cuff repair with a high level of satisfaction in a group of 29 recreational golfers with an average age of 60 years. They found that all but two golfers were able to return to their previous level of golf without detriment to driving distance or handicap.[6] Although this study shows excellent results, the results are certainly not applicable across all sizes of rotator cuff tear and level of golfing ability.
- Because golf is played by millions of Americans and is popular in the older age groups in which rotator cuff disease is common, designing an advanced rehabilitation protocol that will predictably return an athlete to golf is an important goal of surgeons and therapists alike.
- Often, the main impetus for a patient undergoing a rotator cuff repair is to return to an active lifestyle without shoulder pain, including golf. The ideal advanced rehabilitation protocol should be tailored to each patient/athlete with respect to the type and severity of injury and also the athletic goals.

Postoperative Rehabilitation

- Postoperative rehabilitation for return to sport after rotator cuff repair follows a stepwise progression to safely restore range of motion (ROM) followed by return of muscle strength and endurance.[7]
- Dynamic neuromuscular training with function and sport-specific drills then precedes an interval training program which transitions an athlete into full return to competition.[8]
- There are several key factors to consider when designing a rehabilitation protocol for return to golf after rotator cuff repair:
  1) Size and location of tear: Rotator cuff tears vary in size and location. A larger tear is generally rehabilitated more slowly than a large tear. Precautions are different depending on the location of the tear (e.g., protect against external rotation with a subscapularis repair).
  2) Tissue quality: Rotator cuff tears vary in tissue quality and tissue mobility. This affects the security of the repair and can limit the speed and eventual success of rehabilitation.
  3) Security of fixation: Double row fixation theoretically should allow for an accelerated rehabilitation protocol.
  4) Concomitant pathology: Subacromial impingement, acromioclavicular joint osteoarthritis, long head biceps pathology, and adhesive capsulitis are often all treated in the setting of rotator cuff repair.
  5) Skill level and goals of athlete: A high-level golfer desiring a maximal exertional swing will differ in rehabilitation needs from a recreational golfer.
  6) Short game: Chipping and putting can often be allowed relatively early in the rehabilitation program caused by the low demand on the cuff.

TIMELINE 6-8: **Postoperative Rehabilitation after Rotator Cuff Repair**

PHASE I (weeks 0 to 6)

Weeks 0 to 2

- PROM-forward elevation in the scapular plane using the opposite hand to 90°.
- Cryotherapy 15–20 min 4–6 times per day until swelling is diminished then after therapy and as needed.
- Modalities PRN
- Hand, wrist, elbow AROM 3 times per day

Weeks 2 to 4

- Start pendulums
- Passive supine elevation, passive ER (Goals FE 120, ER 30, IR hip)
- Pulley exercises for flexion, as tolerated. Use cane for ER; towel to increase IR
- Begin scapular strengthening program, in protective range
- Deltoid and rotator cuff isometrics, submaximal and pain free

Weeks 4 to 6

- Joint mobilization and gentle PROM as necessary to restore near full PROM by week 6
- Begin submaximal IR/ER isometric exercises in neutral, arm at side (week 4)
- Continue scapular strengthening
- Brace may be weaned at week 4 for small and medium size tears

PHASE II (weeks 6 to 12)

Weeks 6 to 8

- Initiate AAROM activities
- Flexion, unlimited, use arm support in supine position
- Progress to AROM in scapular plane, ER/IR at 45° and 90° of abduction
- Deltoid isotonics in plane of scapula
- Continue with modalities as needed
- Joint mobilization for inferior humeral glide
- Incorporate cardiovascular exercise, conditioning, and lower extremity work with lunge matrix followed by lunge-reach matrix

Weeks 8 to 12

- Restore full AROM by 10–12 weeks
- Continue with scapular strengthening exercises
- Begin isotonic IR/ER in adduction with tubing, emphasizing eccentrics (week 10)
- Continue with flexibility activities to maintain PROM
- Proprioceptive neuromuscular facilitation (PNF) patterns
- Manual resistance/assistance
- Rhythmic stabilization beginning in mid-range and progressing through entire range as able

Physician-Therapist-Patient Communication

- Obviously, surgeon/therapist communication is critical at the initiation of the rehabilitation protocol to obtain the details regarding tear size, location, tissue quality, and security of repair.
- This will allow the therapist or athletic trainer to implement the correct precautions as well as the pace of advancement.
- Also, a line of communication must remain open between the physical therapist and surgeon regarding progression through the sequence of rehabilitation phases.

Rehabilitation Protocol

- Any publication describing a rehabilitation protocol for rotator cuff repair is subject to debate and scrutiny regarding the initiation of key facets of rehabilitation progression.
- Formal recommendations are difficult to make using level-one clinical evidence comparing the success or failure of rotator cuff repair protocols caused by a paucity of high quality randomized comparative trials. Furthermore, in vivo studies in humans assessing the true rate and progression of enthesis restoration and healing are also not available.
- Therefore, the healing rate of the rotator cuff has been extrapolated from animal models of tendon-bone healing. It must be noted that animal models may not replicate the clinical situation of rotator cuff healing in humans as young animal models do not take into account the dysvascularity and degeneration often present in the aging rotator cuff in humans.
- From animal models, it is commonly thought that fibrous scar is present at 6 weeks and that progression to a mature repair takes 3 months.[9]
- These studies are referenced as evidence to refrain from active range of motion for 6 weeks postrepair and from strengthening until 3 months.
- Lastly, some surgeons prefer an accelerated rehabilitation protocol with early advancement of active ROM/strengthening and others prefer a decelerated protocol, especially in larger tears.
- Detailed rotator cuff repair rehabilitation protocols are described elsewhere in this text and in the literature.[10–12]
- Preceding return to sport, rotator cuff rehabilitation protocols are commonly subdivided into four phases: immediate postoperative, range of motion, early strengthening, and advanced strengthening.[12] Box 6-3 presents an abbreviated version of the complete rotator cuff rehabilitation protocol with an emphasis on the fourth phase of rehabilitation (advanced strengthening and functional rehabilitation) during which golf-specific functional exercises were incorporated in preparation for the interval sport program described by Reinold[8] (Table 6-3).

Summary

- Return to golf after rotator cuff repair is a goal of many rotator cuff patients.
- Successful rehabilitation of the repaired cuff relies on restoration of normal glenohumeral motion and strength prior to the institution of sports-specific exercises.
- When sports-specific exercises are tolerated with repetition pain-free, the interval sports program can be instituted.
- Careful attention must be paid to individual patient factors such as tear size, repair type, tissue quality, and patient goals. Each rehabilitation program can therefore be individualized to maximize the potential for the patient to return to golf.

TIMELINE 6-8: **Postoperative Rehabilitation after Rotator Cuff Repair** (Continued)

PHASE III (weeks 12 to 18)	PHASE IV (weeks 18+)

• Continue extremity PREs to maintain full PROM
• Initiate rotator cuff strengthening protocol
  • IR/ER isotonic tubing exercises
  • Lateral raises
  • Full can
  • Prone rowing
  • Prone abduction
  • Side-lying ER
  • Biceps/triceps
  • Scap pushups (pushup plus)
  • Chipping and putting is permitted at this point. Even light swings should be off a tee or without a divot to protect the newly repaired shoulder
  • Hitting fat places tremendous stress on the shoulder and can lead to reinjury
	• Begin advanced strengthening phase with great care and caution
	• Full AROM and PROM of glenohumeral joint
	• Normalized and symmetrical scapula-humeral and scapula-thoracic rhythm
	• Normalized thoracic spine extension and coupled extension/rotation
	• Normalized cervical spine stability and AROM, with specific emphasis on the coupled motions of bilateral lateral flexion/rotation.
	• Tolerates rotator cuff strengthening protocol (Phase 3)
	• Golf-specific exercises
	  • Half-kneeling chop & lift—bar
	  • Half-kneeling chop & lift—rope
	  • Half-kneeling chop slam
	  • Golf stance—Bodyblade stabilization through swing
	  • Standing chop slam
	  • Standing side toss

BOX 6-3 Rehabilitation Protocol for Return to Golf

Phase I. Postoperative (0–6 weeks)

GOALS:

- Edema control
- Protect repair
- Avoid shoulder stiffness in safe range

PRECAUTIONS:

- Sling with abduction pillow at all times except showering (until week 4)
- No lifting
- No supporting body weight
- No AROM against gravity

0 TO 2 WEEKS

- PROM-forward elevation in the scapular plane using the opposite hand to 90.
- Passive ER to neutral.
- Cryotherapy 15 to 20 minutes 4 to 6 times per day until swelling is diminished, then after therapy and as needed.
- Modalities PRN
- Hand, wrist, elbow AROM 3 times per day

2 TO 4 WEEKS

- Start pendulums
- Passive supine elevation, passive ER (Goals FE 120, ER 30, IR hip)
- Pulley exercises for flexion, as tolerated. Use cane for ER; towel to increase IR.
- Begin scapular strengthening program, in protective range
- Deltoid and rotator cuff isometrics, submaximal, and pain-free.

4 TO 6 WEEKS

- Joint mobilization and gentle PROM as necessary to restore near full PROM by week 6 (passive supine elevation, passive ER and IR in scapular plane at 45° abduction)
- Begin submaximal IR/ER isometric exercises in neutral, arm at side (week 4)
- Continue scapular strengthening
- Brace may be weaned at week 4 for small and medium size tears

Phase II. Protection and Range of Motion (6–12 weeks)

PRECAUTIONS

- Avoid lifting and carrying
- No sudden shoulder movements
- Avoid supporting bodyweight

GOALS

- Reestablish dynamic shoulder stability
- Avoid stressing healing rotator cuff
- Establish pain-free AROM

6 TO 8 WEEKS

- Initiate AAROM activities
- Flexion, unlimited, use arm support in supine position
- Progress to AROM in scapular plane, ER/IR at 45° and 90° of abduction
- Deltoid isotonics in plane of scapula,
- Continue with modalities as needed
- Joint mobilization for inferior humeral glide
- Posterior cuff tissue work
- Incorporate cardiovascular exercise, conditioning, and lower extremity work with lunge matrix followed by lunge-reach matrix

8 TO 12 WEEKS

- Restore full AROM by 10 to 12 weeks
- Continue with scapular strengthening exercises
- Begin isokinetic IR/ER in adduction with tubing, emphasize eccentrics (week 10)
- Continue with flexibility activities to maintain PROM
- Proprioceptive neuromuscular facilitation (PNF) patterns
- Manual resistance/assistance
- Rhythmic stabilization beginning in mid-range and progressing through entire range as able

BOX 6-3 Rehabilitation Protocol for Return to Golf *(Continued)*

Phase III. Early Strengthening (12–18 weeks)

PRECAUTIONS:

- Lifting: 5 lbs
- No overhead lifting

GOALS:

- Full active ROM
- Return to low level functional activities
- Improve muscular endurance
- Restore normal glenohumeral and scapula-thoracic rhythm

12 TO 18 WEEKS

- Continue extremity PREs to maintain full PROM
- Initiate rotator cuff strengthening protocol[7]
  - IR/ER isotonic tubing exercises
  - Lateral raises
  - Full can
  - Prone rowing
  - Prone abduction
  - Side-lying ER
  - Biceps/triceps
  - Scap pushups
  - Pushup plus exercises
  - Chipping and putting is permitted at this point. Even light swings should be off a tee or without a divot to protect the newly repaired shoulder.
  - Hitting fat places tremendous stress on the shoulder and can lead to reinjury.

Phase IV. Advanced Strengthening/Sport-Specific Training (18 weeks+)

- The advanced strengthening phase of any rehabilitation program must be undertaken with great care and caution.
- The potential for complication and accumulation of tissue stress increases as the volume and load of exercise increases.
- To ensure the appropriate training effect is applied to the athlete's body and specifically the integration of the lower body, core and upper body, the following guidelines for progression should be observed:

Guidelines for Progression to Advanced Strengthening

- Full AROM and PROM of glenohumeral joint
- Normalized and symmetrical scapulohumeral and scapulothoracic rhythm
- Normalized thoracic spine extension and coupled extension/rotation
- Normalized cervical spine stability and AROM, with specific emphasis the coupled motions of bilateral lateral flexion/rotation.
- Tolerates standard rotator cuff strengthening (Phase 3)
- Specific components of the advanced strengthening phase of rehabilitation should seek to improve both muscular strength as well as power development, and to ensure the efficient transfer of this power through the kinetic chain to the club head.
- This efficient transfer, commonly referred to as the kinematic sequence as it relates to the golf swing, is a combination of both acceleration and more importantly, deceleration of the hips, trunk, and shoulders to pass to the club head with maximal power at impact with the ball.
- Program design should take into account the staging of sets, reps, and appropriate load to address muscular hypertrophy, strength, and ultimately power development, but keeping at the forefront the concept that the rotator cuff, and specifically the surgically repaired cuff, is not the principal generator of the forces that swing the golf club, but merely to aid in the centration of the humeral head in the glenoid fossa during the swing.
- Additionally, given the specific demands of the golf swing and its repetitive nature, an estimated or projected 1 repetition maximum derived from a 10 repetition performance would be appropriate to determine loads for the above mentioned training cycles.
- Ultimately, the load must be adjusted to ensure that during performance of the exercises, there is correct maintenance of erect or golf stance posture, to include proper stability through the hip complex and appropriate respiratory patterns that avoid development of a high-threshold strategy compensation.
- Additionally, at this point in the rehabilitation program it would be appropriate to administer a form of movement screen or assessment to evaluate not only the repaired shoulder but the entire kinetic chain.
- It is well documented that the contribution of the rotator cuff to power generation during the golf swing varies with each phase of the swing.[4]
- Given this fact, golf-specific exercises should focus on strengthening the shoulder muscles as a group and identify any underlying dysfunction elsewhere in the kinetic chain that contributed to the initial injury.
- Golf-specific exercises that are performed in addition to traditional advanced strengthening include the following:

Continued on following page

BOX 6-3 Rehabilitation Protocol for Return to Golf *(Continued)*

- Half-kneeling chop and lift—bar (Figures 6-101 and 6-102)
- Half-kneeling chop and lift—rope (Figures 6-103 and 6-104)
- Half-kneeling chop slam (Figure 6-105)
- Golf stance—Bodyblade stabilization (Figure 6-106)
- Standing chop slam (Figure 6-107)
- Standing side toss (Figure 6-108)

- These exercises can be performed in the advanced strengthening phase of the rehabilitation program initially one set of 8 to 10 repetitions 2 to 3 three times per week, advancing to two sets of 8 to 10 repetitions every other day. When this protocol is tolerated, the interval return to golf program can be initiated. Typically, this portion of the rehabilitation program lasts for 1 to 2 months depending on progression before starting the interval golf protocol).
- Once these exercises are tolerated with repetition, the interval sport program can be instituted.
- It is critical to keep in mind that specific swing faults should be avoided or corrected, as these swing flaws could have been contributors to the initial injury and if still present after recovery can lead to reinjury.
- These flaws are:
  1. Steep swing plane
  2. Fat divots (use a tee)
  3. Casting
  4. Vertical trail arm (without adequate ER and scapular retraction)
  5. Limited follow-through
- A qualified swing instructor is an excellent adjunct at this phase of the rehabilitation as the competitor returns to competitive or recreational golf.

Table 6-3 Interval golf program

	Monday	Wednesday	Friday
Week 1	10 putts 10 chips 5 min rest 15 chips	15 putts 15 chips 5 min rest 25 chips	20 putts 20 chips 5 min rest 20 putts 20 chips 5 min rest 10 chips 10 short irons
Week 2	20 chips 10 short irons 5 min rest 10 short irons 15 medium irons (5-iron off tee)	20 chips 15 short irons 10 min rest 15 short irons 15 chips Putting 15 medium irons	15 short irons 20 medium irons 10 min rest 20 short irons 15 chips
Week 3	15 short irons 20 medium irons 10 min rest 15 short irons 15 medium irons 5 long irons 10 min rest 20 chips	15 short irons 15 medium irons 10 long irons 10 min rest 10 short irons 5 long irons 5 wood	15 short irons 15 medium irons 10 long irons 10 min rest 10 short irons 10 medium irons 10 long irons 10 wood
Week 4	15 short irons 15 medium irons 10 long irons 10 drives 15 min rest Repeat	Play 9 holes	Play 9 holes
Week 5	Play 9 holes	Play 9 holes	Play 18 holes

Chips, Pitching wedge; *short irons*, wedge, 9-iron; *medium irons*, 7-iron, 6-iron, 5-iron; *long irons*, 4-iron, 3-iron, 2-iron; *woods*, 3-wood, 5-wood; *drives*, driver

(From Reinold MM, Wilk KE, Reed J, Crenshaw K, Andrews JR: Interval sport programs: guidelines for baseball, tennis, and golf. J Orthop Sports Phys Ther 32:293–298, 2002.)

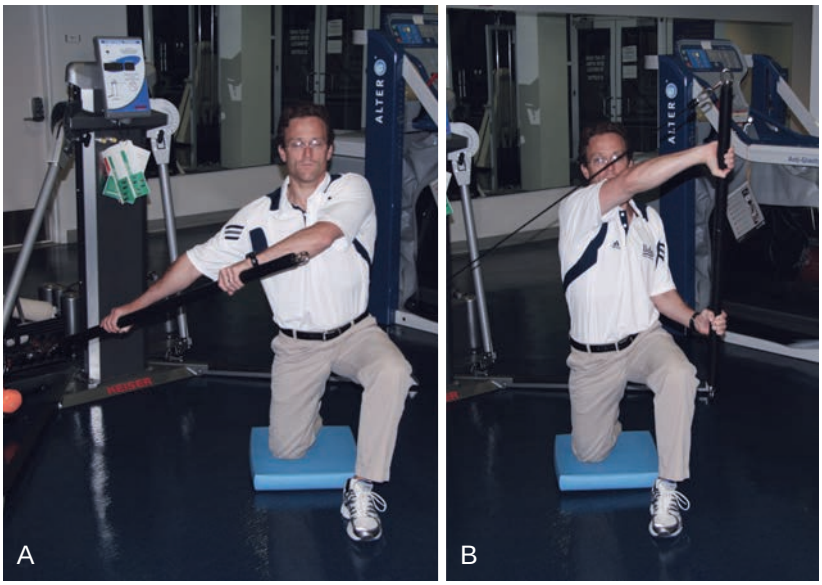

FIGURE 6-101. Half-kneeling lift—bar. **A,** Starting position. **B,** Finishing position.



FIGURE 6-102. Half-kneeling chop—bar. **A,** Starting position. **B,** Finishing position.



FIGURE 6-103. Half-kneeling lift—rope. **A,** Starting position. **B,** Finishing position.

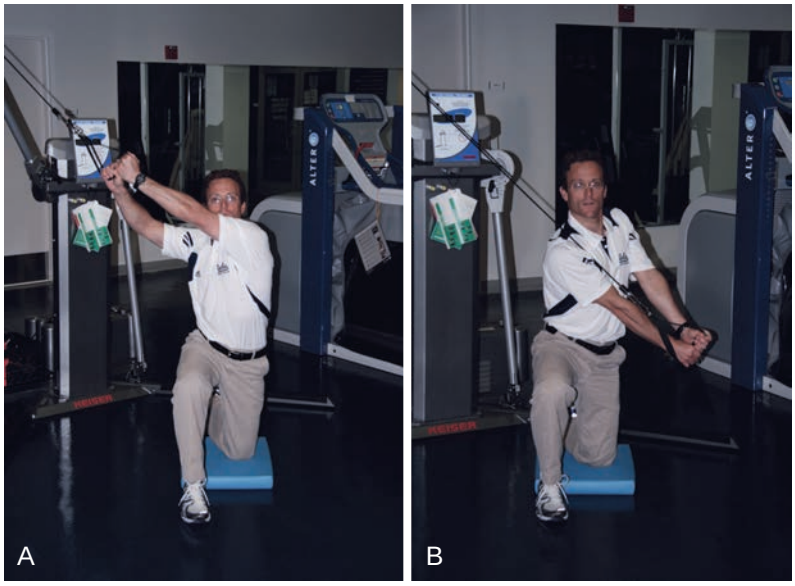

FIGURE 6-104. Half-kneeling chop—rope. **A,** Starting position. **B,** Finishing position.

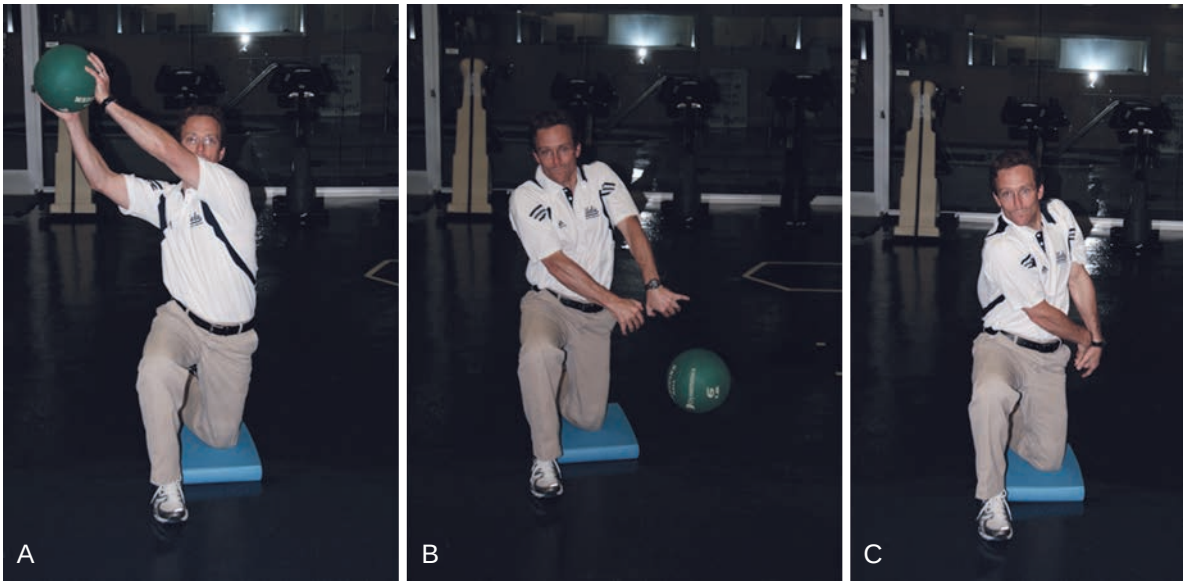

FIGURE 6-105. Half-kneeling chop slam. **A,** Weighted ball in chop position. **B,** Ball is slammed to floor obliquely into **C,** finishing position.



FIGURE 6-106. Golf Stance, Bodyblade stabilization golf stance, Bodyblade stabilization through simulated golf swing.

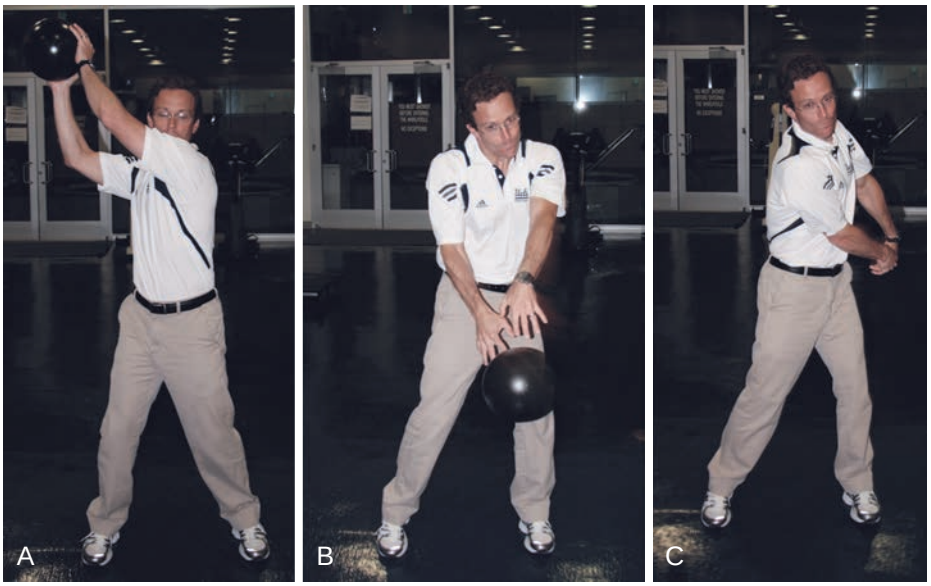

FIGURE 6-107. Standing chop slam. **A,** Weighted ball in chop position. **B,** Ball is slammed to floor obliquely into **C,** finishing position.

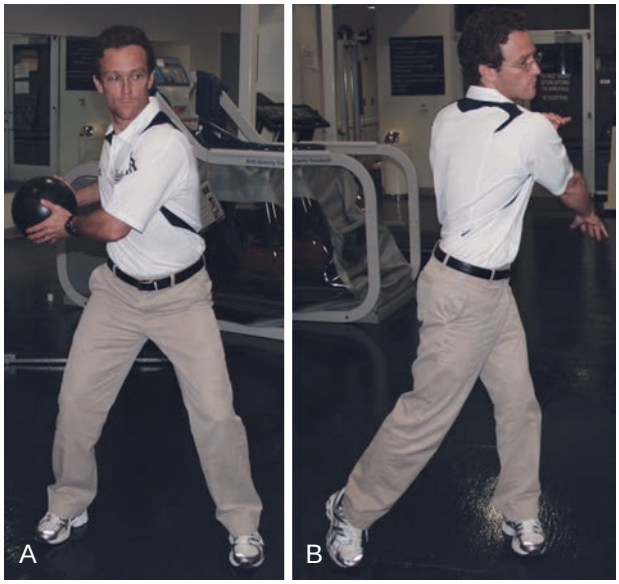

FIGURE 6-108. Standing side toss. (**A**) Weighted ball side tossed into (**B**) finishing position.

Evidence

Andrews JR, Wilk KE: *The athlete's shoulder*, 1994, New York, 1994, Churchill Livingstone.

An older but excellent book describing the treatment of all types of athletic shoulder injuries.

Drakos MC, Rudzki JR, Allen AA, et al: Internal impingement of the shoulder in the overhead athlete. *J Bone Joint Surg Am* 91:2719–2728, 2009.

An outstanding review of the pathophysiology and current thinking in shoulder dysfunction of the overhead athlete. (Level IV evidence)

Ekdahl M, Wang JH, Ronga M, et al: Graft healing in anterior cruciate ligament reconstruction. *Knee Surg Sports Traumatol Arthrosc* 16:935–947, 2008.

This paper provides a timeline for tendon healin, and helps guide rehabilitation milestones based on biology of tendon repair and healing. (Level IV evidence)

Ghodadra NS, Provencher MT, Verma NN, et al: Open, mini-open, and all-arthroscopic rotator cuff repair surgery: indications and implications for rehabilitation. *J Orthop Sports Phys Ther* 39:81–89, 2009.

This is one of the best and most detailed review papers for surgeons and physical therapists discussing rehabilitation and timelines after rotator cuff repair.

Gosheger G, Liem D, Ludwig K, et al: Injuries and overuse syndromes in golf. *Am J Sports Med* 31:438–443, 2003.

An excellent review of golf injuries not limited to the shoulder.(Level IV evidence)

Jobe FW, Moynes DR, Antonelli DJ: Rotator cuff function during a golf swing. *Am J Sports Med* 14:388–392, 1986.

An excellent article discussing EMG of the shoulder during the golf swing. The rotator cuff is relatively inactive during the golf swing. The most active muscles are the pectoralis major and latissimus dorsi. The most active rotator cuff muscle is the subscapularis. (Level II evidence)

McCarroll JR: The frequency of golf injuries. *Clin Sports Med* 15:1–7, 1996.

Injuries to the shoulder are third most common among golfers after injuries to the hand/wrist and lumbar spine. (Level IV evidence)

Millett PJ, Wilcox RB, 3rd, O'Holleran JD, et al: Rehabilitation of the rotator cuff: an evaluation-based approach. *J Am Acad Orthop Surg* 14:599–609, 2006.

Another outstanding rotator cuff rehabilitation review that divides the rehabilition of the repaired shoulder into four phases: Immediate postoperative, range of motion, early strengthening, and advanced strengthening.

Reinold MM, Wilk KE, Reed J, et al: Interval sport programs: guidelines for baseball, tennis, and golf. *J Orthop Sports Phys Ther* 32:293–298, 2002.

This paper provides detailed timelines for returning an athlete back to baseball, tennis, and golf. More focused on return to sport rather than early rehabilitation of the shoulder. (Level IV evidence)

Theriault G, Lachance P: Golf injuries. An overview. *Sports Med* 26:43–57, 1998.

An overview of golf injuries. A basic primer on the injuries sustained by golfers. (Level IV evidence)

Vives MJ, Miller LS, Rubenstein DL, et al: Repair of rotator cuff tears in golfers. *Arthroscopy* 17:165–172, 2001.

A retrospective review of the success rate of return to recreational golf among 29 patients (average age: 60) after rotator cuff repair. All but two patients were able to return to recreational golf at their previous level. (Level IV evidence)

Wilk KE, Arrigo C: Current concepts in the rehabilitation of the athletic shoulder. *J Orthop Sports Phys Ther* 18:365–378, 1993.

A classic article that is an excellent precursor to modern shoulder rehabilitation. (Level IV evidence)

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Multiple-Choice Questions

QUESTION 1. What percentage of the golf swing is spent with the arm elevated past 90°?

A. 5%
B. 15%
C. 30%
D. 50%

QUESTION 2. The most active muscles during the electromyographic evaluation of the golf swing are:

A. Supraspinatus and infraspintus
B. Subscapularis and teres minor
C. Biceps and triceps
D. Pectoralis major and latissimus dorsi

QUESTION 3. All of the following are important goals of the first phase of a rotator cuff repair rehabilitation program except:

A. Edema control
B. Protect repair
C. Avoid shoulder stiffness in safe range
D. Active forward elevation

QUESTION 4. An acceptable rehabilitation timeline for restoring full active range of motion in a shoulder after rotator cuff repair is:

A. 2 to 4 weeks
B. 6 to 8 weeks
C. 10 to 12 weeks
D. 24 weeks

QUESTION 5. During EMG testing of the shoulder, the rotator cuff muscle that was most active was the:

A. Subscapularis
B. Supraspinatus
C. Infraspinatus
D. Teres minor

Answer Key

QUESTION 1. Correct answer: **D** (see Introduction)

QUESTION 2. Correct answer: **D** (see EMG Analysis of Golf Swing)

QUESTION 3. Correct answer: **D** (see Phase I of Rehabilitation)

QUESTION 4. Correct answer: **C** (see Rehabilitation Timeline)

QUESTION 5. Correct answer: **A** (see EMG Analysis of Golf Swing)

ACROMIOCLAVICULAR AND STERNOCLAVICULAR JOINT INJURIES

Chapter 7



Acromioclavicular Joint Injuries and Sternoclavicular Joint Injuries

INTRODUCTION

John Apostolakos, BS, Mark P. Cote, PT, DPT, MSCTR, Knut Beitzel, MA, MD, and Augustus D. Mazzocca, MS, MD

Epidemiology

- Acromioclavicular (AC) joint injuries are considered among the most common orthopedic injuries to the shoulder in the young athletic population.[1-12]
- Incidence often reported to be either 9% or 12% of all injuries to the shoulder; however, review of citations reveals the source of these percentages to be a book published in 1958.
- In Chapter 17, Rowe and Marble report on an analysis of 1603 shoulder girdle injuries treated at Massachusetts General Hospital of which 52 (3.2%) were injuries to the AC joint.[13]
- Type I, II, and III are the most common.[7]

Age

- Most common among patients in their 20s (43.5%)[2,4,7,11]
- A majority of injuries affecting this joint occur in the first three decades of life (66%)[7]

Sex

- AC dislocation has been reported to be more common in males than females (5:1 to 10:1).[2,4,7,10-12]

Sport

- AC dislocation is the most prevalent sports injury to participants in contact sports including hockey, rugby, and American football.[2,4,7,10,11,14]
- AC injury has been reported as 38.5% of shoulder injuries in athletes.[7,15]
- The incidence has been reported as 40% and 41% of all shoulder injuries in contact athletes such as National Football League (NFL) quarterbacks and collegiate football players respectively.[2,10,11,16,17]

Position

- Kaplan et al.[17] conducted a study of 336 elite collegiate American football players to determine position specific trends in shoulder injuries and reported the following AC joint injuries by position (%=number of AC joint injuries for position/$n \times 100$; n = total shoulder injuries by position):
  - Running Backs 47% ($n = 19$)
  - Quarterbacks 56% ($n = 25$)
  - Wide Receivers 70% ($n = 33$)
  - Tight Ends 43% ($n = 7$)
  - Offensive Lineman 18% ($n = 28$)
  - Defensive Lineman 32% ($n = 37$)
  - Defensive Backs 36% ($n = 44$)
  - Linebackers 38% ($n = 29$)
  - Place Kickers 0% ($n = 4$)

Pathophysiology

Intrinsic Factors

- Subcutaneous position of the joint, without a large amount of muscle protection, theoretically increases the incidence of AC joint injury[4,8]

Extrinsic Factors

- Trainer et al.[2] report an overall decline in the incidence of AC joint injuries in American football players but a steady rate among ice hockey players.
  - A possible explanation is that protective gear in American football is specifically designed for repeated force to the shoulder.
  - Ice hockey pads have a more loose fit designed for greater mobility.

Traumatic Factors

Direct Force

- Fall or blow to the superior aspect of the shoulder with arm in the adducted position driving the acromion downward and medially (most common mechanism) (Figure 7-1).[1,2,4-9,11,12,18]
- The magnitude of force determines severity of injury.[8,11]

Indirect Force

- Caused by falling on an adducted outstretched hand or elbow, causing the humerus to translocate superiorly, driving the humeral head into the acromion[4-7,11]

Classification of Injury/Pathological Findings

- Evaluation based on bilateral Zanca radiograph comparing the injured to uninjured shoulder

Type I Injury[4-12,18]

- AC ligament sprain
- No displacement on radiographs

Type II Injury[4-12,18]

- AC ligament tear, CC ligaments intact
- Lateral end of the clavicle superior in relation to acromion but not 100% displaced

Type III Injury[4-12,18]

- AC and CC ligaments torn
- 100% displacement of the clavicle on radiographs (Figure 7-2A)

Type IV Injury[4-12]

- Complete dislocation with posterior displacement of the distal clavicle into or through trapezius muscle
- Posteriorly displaced clavicle on axillary radiographs

Type V Injury[4-12]

- Exaggerated superior dislocation of the AC joint between 100% to 300% on radiographs (Figure 7-2B)
  - CC ligament distance increased two to three times
  - Disruption of the delto-trapezial fascia

Type VI Injury[4-12]

- Complete dislocation with inferior displacement of the distal clavicle into a subacromial or subcoracoid position

Clinical Presentation

History

- History of direct blow/fall to the AC joint[2,4,11]
- Complaints of pain over the joint[2,4]



FIGURE 7-1. The most common mechanism of injury is a fall or blow to the superior aspect of the shoulder with arm in the adducted position driving the acromion downward and medially.

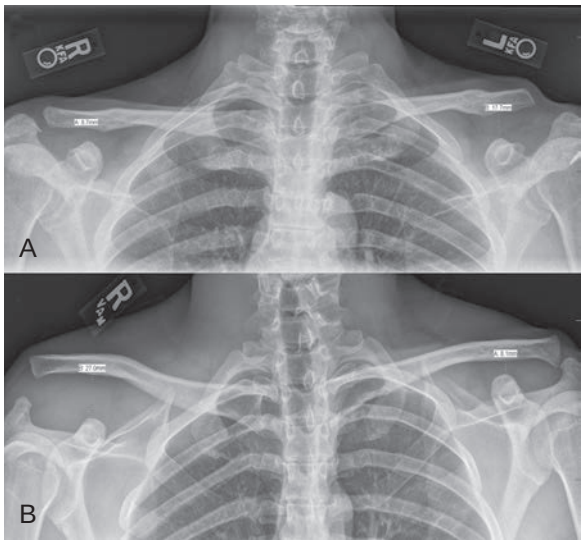

FIGURE 7-2. Bilateral Zanca view for distinguishing between grade III and grade V AC separation. **A,** Grade III AC separation with 100% displacement of the clavicle. **B,** Grade V with exaggerated superior dislocation of the AC joint between 100 and 300% on radiographs.

Physical Examination

- Point tenderness[4,8,11]
- Deformity at the AC joint and is palpable and different from contralateral (uninjured) side
- Pain at AC joint with forward elevation greater than 140° (Figure 7-3A)
- Pain at joint with cross-arm adduction[2,4,8,11]
  - May also be indicative of AC joint arthrosis
  - Cross-arm adduction test performed with arm elevated to 90° and then adducted across the chest with the elbow bent at 90° (Figure 7-3B)
  - Pain will be specifically at the AC joint
- Relief of symptoms by injection of a local anesthetic agent[4,5,8]
  - May also be indicative of AC joint arthrosis
  - Injection with or without corticosteroid can be used both diagnostically and therapeutically[5]
    - Relief of pain implicated AC joint as source of pain
    - Examination should be performed pre- and post-injection to determine change in symptoms
- Whenever possible, patient should be examined standing or sitting so the weight or the arm pulling downward stresses the AC joint and will make deformity more apparent[7,9,12]

Basic Mechanisms, Radiographic Examinations, and Clinical Examinations

- Type I (Figure 7-4)
  - Direct force to the shoulder causing sprain of AC ligaments[4,5,7,12]
  - CC and AC ligaments intact[4,5,7,12]
  - Swelling and joint tenderness[5,7,12]
  - Normal radiographic examination[4,7]
- Type II (Figure 7-4)
  - Force to shoulder causing rupture of AC ligaments[4,5,7]
  - CC ligaments intact[4,5,7]
  - Clavicular instability to direct stress examination[4,7]
  - On radiographic examination the lateral end of the clavicle may be elevated[4,5,7]
    - Stress views fail to show 100% separation of clavicle from acromion
- Type III (Figure 7-4)
  - Complete disruption of both AC and CC ligaments[4,5,7,12,18]
  - No significant disruption of the deltoid and trapezial fascia[4,5,7,12,18]
  - Upper extremity held in an adducted position[4,5,7,12,18]
    - Acromion depressed
    - Clavicle appears "high riding"
  - Clavicular instability in both the horizontal and vertical planes[4,7]
  - Abnormal stress views on radiographic examination[4,7]
    - Clavicle appears high on the upper extremity however in reality the acromion and remained of upper extremity is displaced inferior to the horizontal plane of the lateral clavicle
  - Severe pain with motions 1 to 3 weeks after injury[4]
  - Negative shrug test
- Type IV (Figure 7-4)
  - Distal clavicle displaced posteriorly into the trapezius muscle[4,7,12]
    - Easily seen on an axillary radiograph
  - Important to evaluate the sternoclavicular (SC) joint in this type of injury as there can be anterior dislocation of the SC joint and posterior dislocation of the AC joint[4,7]

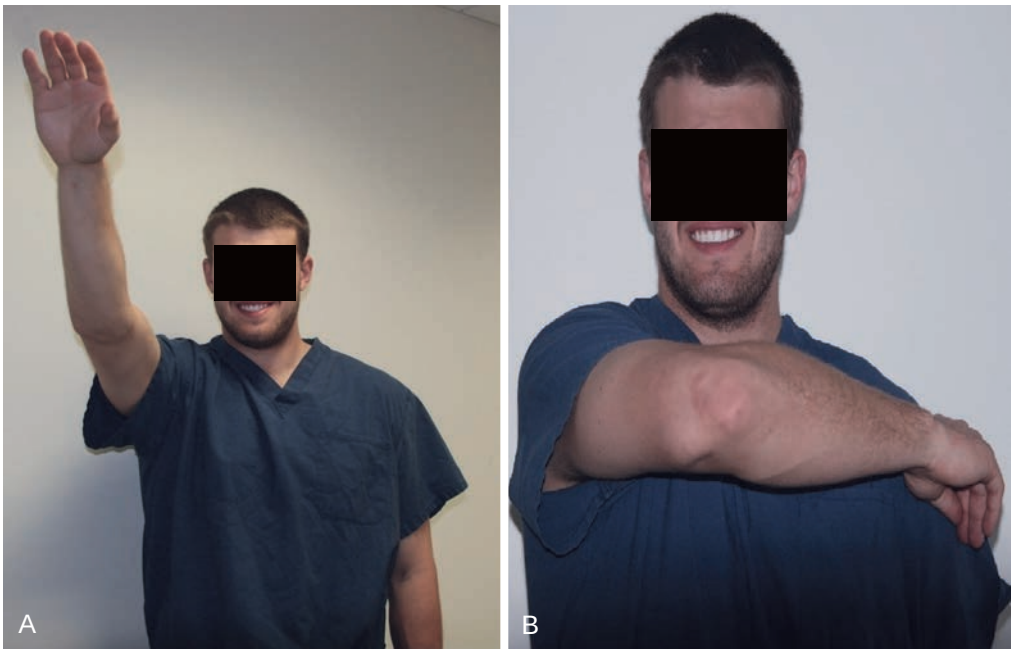

FIGURE 7-3. Physical exam. **A,** Pain at AC joint with forward elevation greater than 140° is indicative AC joint injury. **B,** Pain at joint with cross-arm adduction with arm elevated to 90° and then adducted across the chest with the elbow bent at 90° may also be indicative of AC joint arthrosis.

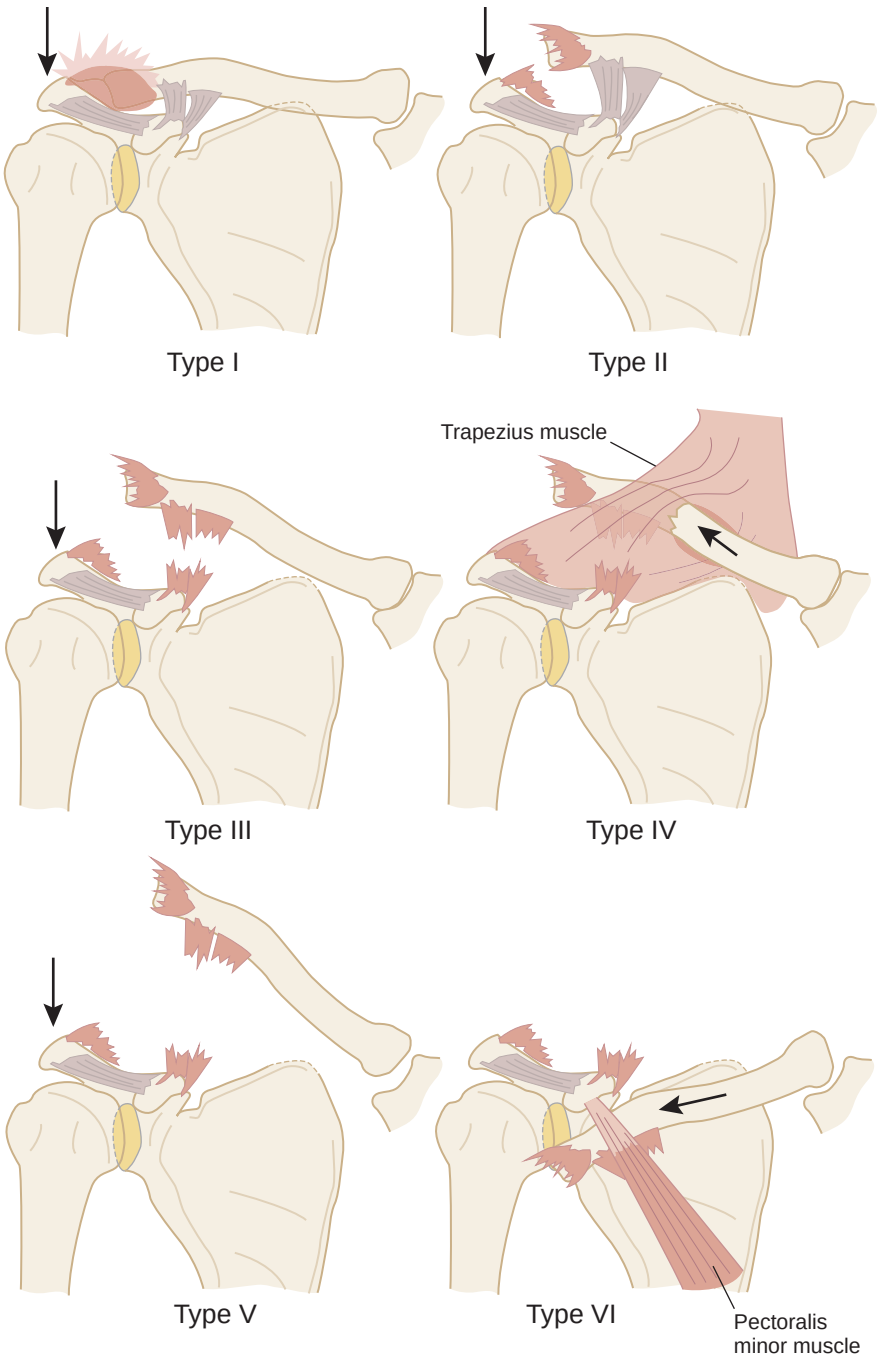

FIGURE 7-4. Diagnosis of AC joint injuries includes classification according to extent of ligament damage. Type I sprains involve a partial disruption of the AC ligament and capsule; type II sprains entail a ruptured AC ligament and capsule with incomplete injury to the CC ligament; type III separations exhibit complete tearing of the AC and CC ligaments; type IV injuries involve clavicular displacement posteriorly into or through the trapezius muscles; type V injuries are severe type III injuries with a greater CC interval; and type VI injuries entail displacement of the clavicle inferior to the coracoid process. *(From Bach BR, Van Fleet TA, Novak PJ: Acromioclavicular injuries: controversies in treatment. Physician Sports Med. 1992;20(12):87–95.)*

- Type V (Figure 7-4)
  - More severe form of type III injury with trapezial and deltoid fascia stripped off the acromion and clavicle[4,5,7]
  - On radiographic examination 100% to 300% increase in clavicle to acromion distance[4,7]
  - Severe droop secondary to downward displacement of the scapula and humerus[4,5,7]
  - Weight of the arm combined with the shape of the chest wall cause an anterior-inferior translation of the scapula around the thorax[4]
    - Referred to as the third translation of the scapula
  - Positive shrug test
- Type VI (Figure 7-4)
  - Inferior dislocation of the distal clavicle under the coracoid process[4,7]
  - Rare injury caused by severe trauma and is frequently accompanied by other injuries[4,7]
  - Mechanism of injury is believed to be severe hyperabduction and external rotation of the arm combined with retraction of the scapula[4]
  - Distal clavicle is found in either of two orientations[4,7]
    - Subacromial
    - Subcoracoid
- Clavicle becomes lodged behind the intact conjoined tendon

- The posterior superior AC ligaments which are often attached to the acromion get displaced into the AC interval

Imaging

- Radiographs of AC joint taken by a routine shoulder exam will be overpenetrated[4,5,7-9,11]
  - Radiographs of "acromioclavicular joint" must be specifically requested to avoid overlooking subtle lesions
- Bilateral Zanca view where both AC joints are visualized on a single exposure is helpful in determining asymmetry between injured and contralateral normal AC joints[2,5]
  - Zanca view is the preferred view of the AC joint[2,4-9,11,12]
  - View is obtained by tilting the x-ray beam 10° to 15° toward the cephalic direction and using only 50% of the standard shoulder anteroposterior (AP) penetration strength
- Varying configuration of AC joint on AP radiographs[2,4,5,9,11,19,20]
  - Zanca[19] reported a normal AC joint width of 1–3 mm
  - Petterson[20] reported diminishing joint space with age and considered the normal width of a 60-year-old AC joint to be 0.5 mm
- Axillary view useful for differentiating type III versus type IV injury[2,4,5,8,9,11]
  - Visualization of the scapula anterior to the clavicle indicates a type IV lesion
- Stryker notch view useful for determining a coracoid fracture in a complete AC dislocation with normal coracoclavicular interspace[6]
  - Coracoid process fracture should be suspected when radiographs reveal AC dislocations with a normal CC distance
- Stress views can be used to distinguish between type II and III injuries by testing the integrity of the CC ligaments[7-9,11,12]
  - Difference in type II and III injury is rarely significant and stress views typically aren't necessary for diagnosis[5,8]

Differential Diagnosis

O'Brien test[2,4,5,21]

- Useful for differentiating AC joint injury versus intra-articular lesions
  - Especially useful with lesions of the superior glenoid labrum
- Arm is elevated to 90°, elbow in extension, adduction of 10° to 15°, and maximum pronation of the forearm with obligate internal rotation of the arm, examiner applies downward force resisted by the patient
  - Referred pain directed to the top of the shoulder and confirmed by palpation of the joint indicate AC damage
  - Referred pain to the glenohumeral joint suggest superior labral or long head of the biceps injury

Radiographs for Differential Diagnosis

- Axillary view useful for differentiating type III versus type IV injury[2,4,5,8,9,11]
  - Visualization of the scapula anterior to the clavicle indicates a type IV lesion
- Stryker notch view useful for determining a coracoid fracture in a complete AC dislocation with normal coracoclavicular interspace[6]
  - Coracoid process fracture should be suspected when radiographs reveal AC dislocations with a normal CC distance
- Stress views can be used to distinguish between type II and III injuries by testing the integrity of the CC ligaments[7-9,11,12]
  - Difference in type II and III injury is rarely significant and stress views typically aren't necessary for diagnosis[5,8]

Shrug Test

- Used to distinguish type III from type V injuries (Figure 7-5)[5,11]
  - In a type V injury the degree of displacement is exaggerated

Manipulation of Joint

- Helpful in distinguishing type III and V injuries[5]
  - Reduction of deformity suggests an intact deltotrapezial fascia (type III)
  - Failure to reduce indicates violation of fascia with the distal clavicle buttonholed through it (type V)



FIGURE 7-5. The shrug test is performed by having the patient shrug their shoulders and observing for reduction of the clavicle. As a result of the trapezial and deltoid fascia being stripped off the acromion and clavicle, shrugging of the shoulders will not reduce the clavicle indicating a grade V injury.

Treatment

- Type I and II (incomplete injuries) are typically treated nonoperatively[1-5,7-9,11,12]
- Type IV, V, and VI (complete injuries) are typically treated operatively due to significance of morbidity[1-5,8,11,12]
- Type III injuries remain the most controversial
  - Current trends lean more towards initial nonoperative treatment[1-5,8,9,11,12,22]

Nonoperative Management

Acute Injury

- Periods of immobilization and rehabilitation[3,5,9,10,12]
  - Sling for 1 to 4 weeks with rehabilitation

Chronic Injury

- Activity modifications of rest[5]
- Antiinflammatories[5]
- Intraarticular corticosteroid injections[5]
  - Corticosteroid injections are not used by the senior author for acute injuries but are used for treatment of chronic injuries defined as pain at 3 months postinjury

Guidelines for Choosing Among Nonoperative Treatments

- Despite the numerous forms of nonoperative treatment including braces/harnesses, taping, casts, etc., no evidence proves any of these methods to be better than the use of a sling with concurrent rehabilitation

Surgical Indications

- Over 150 surgical procedures and technique variations have been described on the AC joint that can be broken down into four major categories[7]
  - Primary acromioclavicular joint fixation
  - Primary coracoclavicular ligament fixation
  - Excision of distal end of clavicle
  - Dynamic muscle transfers
- The senior author prefers an anatomical surgical treatment: Anatomical Coracoclavicular Ligament Reconstruction (ACCR)[1,4,5]
  - Tendon graft used placed in an anatomic position to reproduce conoid and trapezoid ligaments
  - Excision of 10 mm of distal clavicle

Controversial Treatments

Operative versus Nonoperative Treatment of Type III Injury

- Demands on the shoulder need to be taken into account when determining treatment[4]
  - Hand dominance
  - Occupation
  - Heavy labor
  - Position/sport requirements
  - Scapulothoracic dysfunction
  - Risk of reinjury
- General consensus for nonoperative treatment[2-4,8,11,12]
- Phillips et al.[23] conducted a literary review of 1172 type III injuries treated and identified 88% and 87% success rates for operatively and nonoperatively treated patients respectively[5]

Athletes With Type III Injury

- General consensus for nonoperative treatment of contact athletes (where risk for reinjury is high) (Figure 7-6) [4,7,11]
- Surgical treatment reserved for patients with persistent symptoms after 3 to 6 months[4,11]
- Time of injury in relation to season
  - Athletes sustaining a grade III AC injury in early preseason or offseason may lean toward reconstruction, as the window of time for recovery is large, whereas athletes with AC injury mid or late season may opt for nonoperative treatments to allow participation in sport to continue.

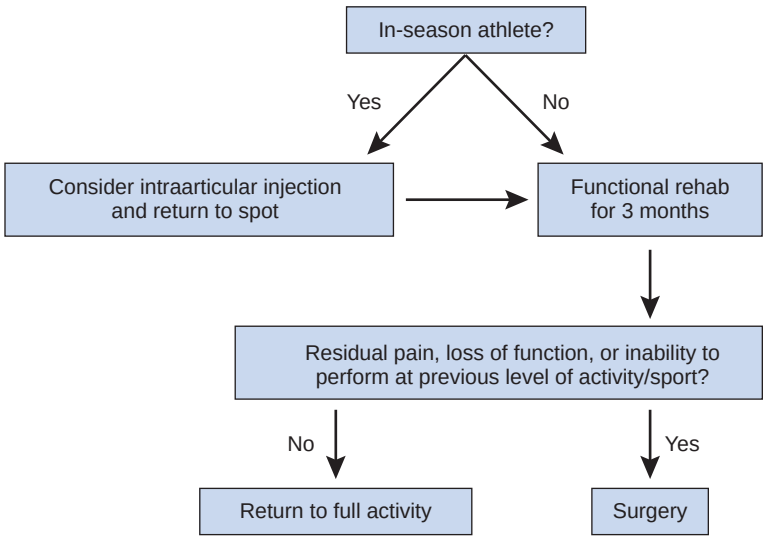

FIGURE 7-6. Algorithm that can be used when treating an athlete with an acromioclavicular joint injury.

- Position of the athlete
  - The tasks and demands of the upper extremity vary from position to position, sport to sport and as such may be affected differently by the loss of joint stability occurring with a grade III AC separation.
  - Positions that involve specific positioning of the hand throughout space (baseball pitcher, football quarterback, etc.) may be greatly affected by a loss of stability at the AC joint in comparison to other positions such as those in kicking sports or positions in which the uninjured extremity can assist in overcoming a loss of joint stability (football lineman, etc.).
- Level of play
  - In determining an athlete's appropriateness for surgical reconstruction, level of participation (recreational vs. collegiate vs. professional) should be considered.
  - Balancing the risks and time associated with surgical reconstruction with the importance of maximizing stability to allow full sport participation may be different for the recreational athlete who can change sports or positions to accommodate their shoulder versus the professional athlete whose livelihood and career is largely dependent on their ability to use their shoulder.

Evidence

Kaplan LD, Flanigan DC, Norwig J, et al: Prevalence and variance of shoulder injuries in elite collegiate football players. *Am J Sports Med* 33:1142–1146, 2005.

A study reporting on musculoskeletal injuries in elite American football players evaluated at the National Football League Combine during physical testing. Players were categorized by position to identify correlations between athletic position and occurrence of various shoulder injuries. (Level III evidence)

Kelly BT, Barnes RP, Powell JW, et al: Shoulder injuries to quarterbacks in the national football league. *Am J Sports Med* 32:328–331, 2004.

A retrospective review of all injuries to quarterbacks reported to the National Football League (NFL) between 1980 and 2001 utilizing the National Football League Injury Surveillance System (NFLISS). This review evaluated injuries based on several factors including playing time lost, injury patterns, and occurrence rates of specific injuries. (Level III evidence)

Tamaoki MJ, Belloti JC, Lenza M, et al: Surgical versus conservative interventions for treating acromioclavicular dislocation of the shoulder in adults. *Cochrane Database Syst Rev* 4: CD007429, 2010.

A systematic review aimed at assessing the relative effects of operative versus nonoperative treatment of acromioclavicular joint dislocations in adults. Included studies were randomized and quasi-randomized trials obtained in a search of the Cochrane Bone, Joint and Muscle Trauma Group Specialized Register (to February 2009), the Cochrane Central Register of Controlled Trials (The Cochrane Library 2009, Issue 1), MEDLINE (1966 to February 2009), EMBASE (1988 to February 2009), and LILACS (1982 to February 2009), trial registries and reference lists of articles. (Level II evidence)

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Multiple-Choice Questions

QUESTION 1. Which of the following patients is most likely to endure an injury to the AC joint?

A. a 85-year-old inactive male
B. a 25-year-old active female
C. a 21-year-old inactive male
D. a 22-year-old active male

QUESTION 2. What is the most common mechanism of injury to the AC joint?

A. Direct force to the superior aspect of shoulder
B. Indirect force to the superior aspect of shoulder
C. Direct force caused by falling on an adducted outstretched hand
D. Indirect force caused falling on an adducted outstretched hand

QUESTION 3. Which of the following is true regarding treatment of a type III injury?

A. Surgical intervention is always needed.
B. Surgical intervention is never needed.
C. Demands on the affected shoulder should NOT be taken into account when determining treatment.
D. Treatment of type III should be individualized based on demands of the shoulder.

Answer Key

QUESTION 1. Correct answer: **D** (see Epidemiology)

QUESTION 2. Correct answer: **A** (see Pathophysiology)

QUESTION 3. Correct answer: **D** (see Treatment)

NONOPERATIVE REHABILITATION OF ACROMIOCLAVICULAR JOINT SPRAIN/SEPARATION

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GUIDING PRINCIPLES OF NONOPERATIVE REHABILITATION

- Restoring stability to the AC joint through strength training of the supporting muscles of the shoulder girdle is the primary focus of rehabilitation.
- Early intervention is directed toward reducing pain and inflammation to allow strength-based exercise to begin as soon as possible.

Phase I (48 hours to weeks 2)

Goals

- Various treatments, both operative and nonoperative, have been described for patients with injury or dysfunction of the AC joint.[1-35]
  - Grades I and II separations appear to respond favorably to conservative management.
  - Considerable controversy exists over the efficacy of surgical reconstruction versus nonoperative intervention for grade III type injuries.
  - Grades IV, V, and VI often require surgical reconstruction.
- Rehabilitation both as a part of conservative management as well as the postoperative care plays an important role in the management of each of these injuries.[9]
- When discussing the approach to rehabilitation, we feel it is best to outline guidelines based on anatomy, pathoanatomy, and biological healing for the progression of activities.
  - These guidelines were designed to allow the rehab clinician to safely and appropriately progress patients through the healing and recovery process.
  - With an understanding and appreciation for the rationale for these guidelines, the rehab clinicians can utilize their entire skillset in a safe and efficient manner, thereby maximizing the quality of care provided to patients.

Protection

- Immobilization via a sling is used on as needed basis.
- The amount of time immobilized will vary depending on the grade of injury.
- Grade I separations typically require little to no sling use.
- Grade II separations involve disruption of ligamentous tissue that may result in prolonged periods of pain associated with early phases of tissue healing. During this time, a sling may be required to avoid stress on the AC joint. The sling is discontinued following cessation of pain with the arm at the side and with self-care activities. Generally speaking, this time period does not exceed 1 week.
- Grades III and V involve complete ligament rupture with little to no potential for healing. While sling use up to 4 weeks for these higher-grade AC separations has been previously reported therefore, we believe

patients should be encouraged to cease sling use as soon as their symptoms allow.
- In all cases, immobilization is discontinued following the cessation of pain at rest with the arm at the side and with self-care activities.

Management of Pain and Swelling

- Ice
- Sling

Techniques for Progressive Increase in Range of Motion

- Low load range active-assistive motion exercise is initiated within the first week of injury in an effort to decrease associated morbidity.
- Avoidance of motions that may increase stress on the AC joint is recommended.
- Behind the back internal rotation, cross body adduction, and end range forward elevation involve motion at the AC joint and therefore are approached cautiously as they have the potential to provoke pain and slow progression; however, they are not expressly limited as stability is less of a concern than in higher grade separations.

Manual Therapy Techniques

- Manual therapy techniques such as gentle grade I and II joint mobilization may be helpful modulating pain.
- Given the wide range of manual techniques and modalities, selection of these potential therapeutic interventions are at the discretion of the treating rehab clinician.

Activation of Primary Muscles Involved

- Muscle activation of scapular stabilizers with closed chain scapular exercises and kinetic chain activities to allow the patient to focus on scapular control and established movement patterns without creating excessive loads about the shoulder.[36-38]

Open and Closed Kinetic Chain Exercises

- Table slides progressing to graduated wall slides are also utilized to encourage restoration of shoulder elevation initially prescribed at a high frequency, low intensity, and short duration (Figure 7-7).
- Graduated table slide would be performed 20 to 30 times, three to four times a day (high frequency), within a comfortable or minimal discomfort range of motion (low intensity), repeatedly with no "holding" of end range for stretch (short duration).
- Supine flexion and pulley exercises are added to assist in increasing forward elevation.
- Progress reclined flexion to upright forward elevation (Figure 7-8).
- Scapular clocks for muscle activation (Figure 7-9).

Milestones for Progression to the Next Phase

- Full passive motion without pain
- Out of sling

Phase II (weeks 2 to 6)

Techniques for Progressive Increase in Range of Motion

- Active-assistive range of motion is progressed within a comfortable range of motion. In our experience, accelerating care by moving through painful and stressful ranges of motions tends to encourage continued pain and inflammation, making it difficult to progress. By allowing exercises to be progressed within the guidelines of avoiding motions or exercise producing AC joint pain, the patient can maximize their own potential for progress.

Other Therapeutic Exercises

- Conditioning (bike or elliptical)
- Nonweight bearing upper extremity core stability (bridge, crunch, etc.)

Activation of Primary Muscles Involved

- Isotonic strengthening exercises directed at restoring and maintaining adequate scapular retraction

TIMELINE 7-1: **Nonoperative Rehabilitation after AC Joint Separation**

PHASE I (first 48 hours to weeks 2)	PHASE II (weeks 2 to 6)

• Sling
  • Grade I—as needed for pain
  • Grade II—up to 2 weeks
  • Grade III—discontinue sling at 2 weeks (earlier if symptoms allow)
  • D/C sling if the patient is no longer having pain with the UE at the side during ADLs
• PT Modalities and Manual Techniques
  • As indicated to reduce pain
• Exercise
  • Closed chain AAROM (table slides, etc.)
  • Supine ER with a cane
  • Isometrics (submaximal, nonpainful)
  • Scapular clocks
	• Exercise
	  • AAROM progressing to AROM
	  • Progressive forward elevation to the wall
	  • Pulleys FE
	  • Reclined active flexion progressing to upright
	  • Gentle horizontal adduction
	  • Gentle shoulder extension
	  • Scapula strengthening exercises (emphasizing retraction to stabilize the AC joint)
	  • When there is good stability of scapula—strengthening exercises focus on the deltoid, trapezius, and rotator cuff
	  • Manual
	  • Pushup plus (protraction/retraction against the wall)
	  • Continue kinetic chain exercise
	  • Restrictions—shoulder press, bench press, pullovers, and pectoralis flys



FIGURE 7-7. Closed chain progression of active-assistive range of motion.

TIMELINE 7-1: **Nonoperative Rehabilitation after AC Joint Separation** (Continued)

PHASE III (weeks 6 to 12)	PHASE IV (weeks 12+)

• Exercise
  • 3 level rowing with tubing
  • RC muscle strengthening exercise (ER/IR) with tubing
  • Prone scapula exercises—Blackburn exercises or Ts and Ys (start with no weight and high repetitions to fatigue)
  • PNF patters with tubing
  • Pushup on wall progressing towards ground
  • Continued Kinetic chain exercise
	• Exercise
	  • Plyometric exercise (chest pass with medicine ball, etc.)
	  • Continued Kinetic chain exercise
	  • Start chest press
	  • Sport-specific training



FIGURE 7-8. Open chain progression of active-assistive range of motion.



FIGURE 7-9. Scapular clocks to facilitate muscle activity of the scapular muscles.

Open and Closed Kinetic Chain Exercises

- Pushup plus (protraction/retraction against the wall) at shoulder level or below to assist in activating the serratus anterior with less upper trapezius activity when compared to overhead activity[39]
- Multilevel rows (Thera-tubing or cable column)
- External rotation (ER) and internal rotation (IR) for RC musculature (Thera-tubing or cable column)

Neuromuscular Dynamic Stability Exercises

- Rhythmic stabilization in supine (Figure 7-10)

Functional Exercises

- Lower extremity exercise including shoulder dumps[38] (Figure 7-11), single leg trunk flexion bends, single leg balance, hip hike, squats

Sport-Specific Exercises

- Pain-free nonathletic ADLs
- Full active ROM (equal to the uninjured side with visual estimation) without pain

Phase III (weeks 6 to 12)

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Continued conditioning described in phase II
- Initiate upper extremity weight-bearing core stability exercise, e.g., plank, side plank (grades I and II may tolerate before or at 6 weeks)

Activation of Primary Muscles Involved

- Isotonic exercises are progressed at this phase with continued emphasis on maintaining scapula retraction.



FIGURE 7-10. Rhythmic stabilization. The rehab clinician applies manual resistance in alternating directions to challenge the patient's ability to stabilize the shoulder.

Scapular dyskinesis has been shown to be present in among patients with grade III AC separation reinforcing the importance of exercise encouraging scapular retraction.[40] Exercise to address scapular dyskinesis often focus on retraction to encourage normal positioning and movement patterns of the scapula. Conscious correction of scapular position has been shown increase activation levels of the trapezius in overhead athletes. When prescribing exercises for the shoulder, maintenance and correction of scapular position is encouraged to improve muscle activation and function.[41]

- With improved strength, exercise tubing or cable resistance exercises are utilized to progress the strengthening program.
- Strengthening targeted at the rotator cuff muscles (emphasis on ERs), biceps brachii, pectoralis major, and minor and scapular rotators.
- PNF utilizing rubber tubing is introduced at this time.

Techniques to Increase Muscle Strength, Power, and Endurance

- Multilevel rows
- Prone scapula exercises—Is, Ts and Ys (start with no weight and high repetitions to fatigue)[42]
- PNF patterns with tubing (D2 pattern—proprioceptive neuromuscular facilitation)
- IR/ER (tubing/cable)
- Scaption
- Upper Extremity PREs (for biceps, triceps, etc.)

Neuromuscular Dynamic Stability Exercises

- Rhythmic stabilization in supine
- Manual proprioceptive neuromuscular facilitation (PNF) patterns
- One-hand pushup on wall with light ball (Figure 7-12)

Plyometrics

- 90-90 supine ball toss (Figure 7-13A)
- Overhead supine ball toss (Figure 7-13B)
- Medicine ball chest pass

Functional Exercises

- Lower extremity exercises including shoulder dumps[38], trunk bends, single leg balance, hip hike, squats



FIGURE 7-11. Shoulder dump exercise as described by McMullen J and Uhl TL[48] to facilitate shoulder external rotation and scapular retraction. To perform the exercise for the right shoulder, the athlete stands with the left foot forward and left hip flexed and the trunk flexed and rotated to the left with the right arm positioned at the level of the knee (**A**). The athlete is then instructed to shift weight back to the right foot while extending and rotating the trunk and to move back to an upright position (**B**). As the athlete moves through this movement, the shoulder is externally rotated and the scapula retracts, as if dumping or pouring something out.



FIGURE 7-12. Pushup on the wall with light ball.

Sport-Specific Exercises

- Sports specific movements with advancement to use of lower limb or trunk from double lower extremity to single lower extremity

Milestones for Progression to Advanced Sport-Specific Training and Conditioning

- Overhead activities including ADLs without pain.
- Able to bear weight through involved upper extremity without pain. This can be evaluated by asking the athlete to hold the starting position of a pushup. If the athlete can stay in this position for a few seconds without pain or signs of difficulty (e.g., lowering to the floor, or shifting weight away from the injured side), progression to the next stage is warranted.

Phase IV (weeks 12+)

Techniques to Increase Muscle Strength, Power, and Endurance

- Return to gym (grades I and II typically can start gym activity at or before 8 weeks)
- Bench press at 50% or less than presurgical; one repetition maximum; form changes for bench press include narrower grip; avoid full lock out to minimize stress on healing tissues
- Overhead press at 50% or less than presurgical; 1 repetition maximum; form changes for bench press include narrower grip; avoid full lock out to minimize stress on healing tissues and behind the neck pressing

Manual Therapy Techniques

- Continued conditioning described in phase II

Neuromuscular Dynamic Stability Exercises

- Continue one hand ball pushup on wall. As exercise becomes less challenging, the athlete can move away from the wall to increase the amount of load through the arm to increase difficulty.

Plyometrics

- Plyometrics should start with two-hand chest pass followed by two-hand overhead pass. When two-handed activities are no longer challenging, progress to single-hand passes.

Progression is as follows: Two-handed medicine ball chest pass, standing two-handed overhead chest pass, single-hand 90/90 ball toss to upright with rebounder.

Functional Exercises

- Continue lower extremity exercises.

Sport-Specific Exercises

- Initiate throwing program. Our throwing program is adopted and modified from review of previous published programs[43-45] (Box 7-1).
- General strength and conditioning of the UE may begin during this phase if the patient demonstrates full pain-free AROM throughout all planes, full strength throughout the affected UE, and ability to bear weight on the injured side as demonstrated by successive pushups without shifting away from the injured side or complaints of pain. Measurements of strength can be made using a handheld dynamometer, which should reflect a 5% difference or less in strength in comparison to the uninvolved side. If a dynamometer is not available, 5/5 strength with manual muscle testing throughout the UE should be present.
- Exercises that the athlete will return to doing in the gym should be added on at this point at low intensity with close observation by clinician. Gym exercises tend to vary by the sport program in which the athlete is involved. The primary exercises that require vigilance for proper form are the bench press and overhead press. Guidelines listed previously should direct clinician observation. Additional exercises such as biceps



FIGURE 7-13. A, 90-90 supine ball toss. **B,** Overhead supine ball toss.

curls, triceps pushdowns and dips can be performed according to athlete's sport-specific gym program. All movements must also remain completely pain free.
- Sport-specific exercises include football lineman-contact drills, light sled push, swimming maneuvers, wrestler-partner drills in quadruped, grappling, basketball-lay up drills with defensive partner to stimulate contact, racket sports-progressive swing /volley drills starting with ground strokes and progressing to overhead service.

Milestones for Progression to Advanced Sport-Specific Training and Conditioning

- No pain at the AC joint
- Forward elevation without scapular dyskinesis as measured by the Scapular Dyskinesis Test.[46,47] The Scapular Dyskinesis Test, which classifies scapula dyskinesis as either present or absent, is used to determine the presence of dyskinesis. This system involves viewing of the scapula during humeral elevation to observe for "winging" (abnormal prominence of the medial and/or inferior boarder of the scapula) or dysrhythmia with grading of these of findings as normal, subtle (mild, questionable, or inconsistent), and obvious (striking, clear, and consistent)
- Full shoulder strength in all planes with handheld dynamometer or manual testing of the shoulder

Criteria for Abandoning Nonoperative Treatment and Proceeding to Surgery or More Intensive Intervention

- In our experience, patients who have little response after 6 weeks are offered surgical intervention.
- Patients who benefit and have a significant reduction of symptoms are encouraged to continue with rehabilitation for up to 12 weeks.
- After 12 weeks the athlete should be pain free with all shoulder motions, able to bear weight per previously listed criteria, and able to demonstrate upper extremity movements related to their sport in a controlled environment, i.e., in the clinic or gym. In our experience, patients who have little response after 6 weeks are offered surgical intervention.

BOX 7-1 Interval Throwing Program: Adult-Aged Players

- Each phase should be completed before progressing to the next level.
- Long throws represent target distance for eventual long throw workouts. We recommend 180 feet as that distance to begin with for adult rehab interval programs. Actual long throw distance is the maximum distance thrown when healthy to a specified 20-feet-wide target area.

Phase I

a) Warm up
b) 15 throws arched—45 feet
c) 15-minute rest
d) 15 throws arched—45 feet
e) Cool down

Phase II

a) Warm up
b) 20 throws arched—60 feet
c) 15-minute rest
d) 20 throws arched—60 feet
e) Cool down

Phase III

a) Warm up
b) 20 throws arched—90 feet
c) 15-minute rest
d) 20 throws on a line—45 feet
e) 15-minute rest
f) 20 throws arched—90 feet
g) Cool down

Phase IV

a) Warm up
b) 20 throws arched—120 feet
c) 15-minute rest
d) 15 throws on a line—60 feet
e) 15-minute rest
f) 20 throws arched—120 feet
g) Cool down

Phase V Long

a) Warm up
b) 20 throws arched—180 feet
c) 15-minute rest
d) 25 throws arched—180 feet
e) 15-minute rest
f) 20 throws arched—180 feet
g) Cool down

Phase VI

a) Warm up
b) 15 throws arched—120 feet
c) 15-minute rest
d) 15 throws on a line—90 feet
e) 15-minute rest
f) 15 throws on a line—90 feet
g) 15-minute rest
h) 15 throws arched—120 feet
i) Cool down

Phase VII

Return to regular work-out regimen

Courtesy of the New England Musculoskeletal Institute; UConn Health Center. Website http://nemsi.uchc.edu.

Specific Criteria for Return to Sports Participation: Tests and Measurements

- Full active range of motion without scapular dyskinesis as measured by the Scapular Dyskinesis Test
- Full shoulder with handheld dynamometer or manual testing of the shoulder strength with manual muscle testing
- Pain-free overhead activities
- Pain-free sport-specific motions and maneuvers
  - Ability to perform sport-specific activities without pain or difficulty. (This includes successful completion of the throwing program for throwers and contact without symptoms for the collision and contact athlete.)

Evidence

Bannister GC, Wallace WA, Stableforth PG, et al: The management of acute acromiclavicular dislocation. *J Bone Joint Surg Br* 71-B(5):848–850, 1989.

This prospective randomized control trial compared operative treatment (reduction and fixation with a Kirschner screw) to conservative management consisting of 2 weeks of rest followed by a rehabilitation program. Conservatively treated patients regained motion quicker, returned to work and sport earlier, and had less unsatisfactory results compared to operative treatment. (Level II evidence)

Galpin RD, Hawkins RJ, Grainger RW: A comparative analysis of operative versus nonoperative treatment of grade II acromioclavicular separations. *Clin Orthop Relat Res* 193:150–155, 1985.

Retrospective review of 37 patients who either opted for early motion and rehabilitation or treatment by Bosworth clavicu-locoracoid screw. Patients in the nonoperative group had equal if not superior results, with an earlier return to activities, sports, and work. (Level IV evidence)

Gstettner C, Tauber M, Hitzl W, et al: Rockwood type III acromioclavicular dislocation: surgical versus conservative treatment. *Clin Orthop Relat Res* 455:38–44, 2007. *J Shoulder Elbow Surg.* 17:220–225, 2008.

Retrospective review of 41 of 50 patients treated either operatively with a hook plate to stabilize the AC joint or conservatively consisting of immobilization in a sling followed by a course of rehabilitation. Mean constant score of 80.7 was observed for the conservative group compared to 90.4 in the operative group. (Level IV evidence)

Gumina S, Carbone S, Postacchini F: Scapular dyskinesis and SICK scapula syndrome in patients with chronic type III acromioclavicular dislocation. *Arthroscopy* 25(1):40–45, 2009.

Scapulothoracic motion and clinical outcome were studied in 34 patients with chronic AC dislocation. Chronic type III AC dislocation was associated with the presence of scapular dyskinesis in 70.6% of patients. The values for the Constant score and SST were lower in patients with dyskinesis. (Level IV evidence)

Spencer EE, Jr: Treatment of grade III acromioclavicular joint injuries: a systematic review. *Clin Orthop Relat Res* 455:38–44, 2007.

A systematic review of the literature to determinate efficacy of operative vs. nonoperative care for grade III AC joint separations. Review revealed limited low-evidence literature exists on the treatment of grade III injury. Nonoperative treatment was deemed more appropriate than traditional operative treatments on account of surgical intervention being associated with higher complication rates and time away from work and sport. (Level III evidence)

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Multiple-Choice Questions

QUESTION 1. The primary goal of phase I after nonoperative AC joint injury is:

A. Immobilization
B. Increase strength
C. Reduce pain and inflammation
D. Reduce ROM

QUESTION 2. When initiating strength exercises in Phase II following nonoperative AC injury, it is best to start with what type of exercise?

A. Closed kinetic chain
B. Isokinetic
C. Isotonic
D. Open kinetic chain

QUESTION 3. When the AC ligaments rupture the scapula migrates in which direction?

A. Upward
B. Downward
C. Medial
D. Lateral

QUESTION 4. _____ targets strengthening for serratus anterior.

A. Horizontal Abduction
B. Rowing
C. Wall pushup with plus
D. Scapular Clock

Answer Key

QUESTION 1. Correct answer: **C** (see Phase I)

QUESTION 2. Correct answer: **A** (see Phase II)

QUESTION 3. Correct answer: **B** (see Phase II)

QUESTION 4. Correct answer: **C** (see Phase II)

POSTOPERATIVE REHABILITATION AFTER DISTAL CLAVICULAR RESECTION (MUMFORD)

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Indications for Surgical Treatment

- Pain at the acromioclavicular (AC) joint exacerbated with cross body adduction.
- Failure of conservative management (≥3 months of physical therapy, nonsteroidal antiinflammatory drugs, steroid injection into the AC joint)
- Radiographic findings consistent with AC joint disease

Brief Summary of Surgical Treatment

Major Surgical Steps

- Open Approach[1,2]
  - A transverse or "saber" type incision is made over the AC joint with careful dissection of the superior AC ligament, deltoid and trapezial fascia from their flap to expose the distal clavicle.
  - An oscillating saw resects 5 to 10 mm of the distal clavicle from superolateral to inferomedial.[3]
  - The superior joint capsule and deltoid insertion are repaired to preserve clavicular stability and preserve continuity of the deltotrapezial attachment.
- Arthroscopic Approach—Direct[4]
  - Anterosuperior and posterosuperior portals are created with two small stab incisions in line with the AC joint.
  - A 2.7-mm arthroscope and motorized bur is used to excise 2 to 3 mm off the acromial spur and 5 to 7 mm off the distal clavicle for a total of 8 to 10 mm of excision (confirmed with c-arm and spinal needles).
  - Once the joint is sufficiently widened, a standard 4-mm arthroscope is introduced to complete the resection.
- Arthroscopic Approach—Indirect[5,6]
  - Standard arthroscopic anterior, posterior, and lateral portals are created to allow bursectomy and permit visualization of the AC joint.
  - A round or oval bur is used to resect the inferior distal clavicle cortex

Factors That May Affect Rehabilitation

- Rarely does the AC pathology that leads to a Mumford procedure occur in isolation, and has been shown to occur as occult pathology in up to 50% of apparent AC joint cases.[7]

- The concurrent pathology (impingement, labral tear, etc.) will frequently lead to concurrent surgical procedures. This is an important consideration as the nature of concurrent procedures will often dictate the pace of rehabilitation, or will lead to the consideration of other tissues that will need to heal. Recognition of the other involved tissues will allow for a more comprehensive rehabilitation program.

Before Surgery: Overview of Goals, Milestones, and Guidelines[1]

GUIDING PRINCIPLES OF POSTOPERATIVE REHABILITATION

- Biologic tissue healing time frames guide progression of rehabilitation.
- Concomitant operative procedures often involve tissue repair and therefore guide progression of therapeutic activities.
- Absent of any concomitant procedures, pain is the limiting factor for progression of therapeutic activity. Therapeutic intervention early in the postoperative period should be directed at reducing pain to optimize the potential recovery.
- Educate patient to the principles guiding to rehabilitation.

Phase I: Immediate Postoperative Period (days 0 to 14)

Clinical Pearl

- Following distal clavicular resection (DCE), immediate motion can be very painful and difficult to perform. Glenohumeral joint mobilization can be useful in this stage for both pain control and ROM.
- The use of a wedge under the scapula can be useful to isolate motion and avoid stresses through the AC joint soft tissues while inflammation subsides.
- With the scapula stabilized, restrictions on the glenohumeral joint, should they exist, can be addressed (Figure 7-14).

Goals

- D/C sling (if concomitant procedures do not conflict)
- Reduce pain
- Ensure adequate patient education to allow patient to progress motion accordingly

[1]*Prehabilitation, if appropriate, is described in the Nonoperative Rehabilitation section of this chapter.*



FIGURE 7-14. Positioning for glenohumeral mobilization with wedge to stabilize scapula. In this set up, the rehab clinician would perform general joint mobilizations for pain relief and ROM while avoiding excessive stress to the AC joint and surrounding soft tissue.

Management of Pain and Swelling

- Use of sling and ice for the first 24 to 48 hours (additional immobilization to be directed by concomitant procedures)

Techniques for Progressive Increase in Range of Motion

- If concomitant procedures do not conflict, range of motion (ROM) can be progressed according to the patient's pain response.
- Motion should start with forward elevation in the plane of scapula and external rotation at 30° of abduction with the arm supported.
- Upper extremity motion of the elbow, forearm, wrist, and hand is also encouraged.
- Begin passive and active-assisted ROM through formal rehabilitation and home exercise program 2 days postoperatively.

Open and Closed Kinetic Chain Exercises

- CKC: ROM exercises with limb-supported activities like the table or wall slide. These closed chain exercises have been shown to elicit low amounts of shoulder muscle activity.[8]
- OKC: Supine forward elevation and cane ER.

Neuromuscular Dynamic Stability Exercises

- The use of side lying manually resisted proprioceptive neuromuscular facilitation (PNF) patterns to the scapula can be useful to initiate strength and control activities without stressing inflamed tissues by allowing for immediate modification of the amount and direction of force applied to the shoulder. This early initiation of resisted exercises may help offset post-operative atrophy and inhibition in the athlete (Figure 7-15).



FIGURE 7-15. Positioning for PNF patterns in side lying. The use of manually resisted PNF patterns to the scapula can be useful to initiate strength and control activities without stressing inflamed tissues. This positioning allows for immediate modification of the amount and direction of force applied to the shoulder.

Phase II (weeks 2 to 6)

Clinical Pearls

- In isolated cases of distal clavicle excision (no concomitant procedures), progression of rehabilitative activities is based upon the patient's tolerance to these activities.
- If pain is persistent, ROM exercises can be adjusted to focus on high frequency (motion exercises three to four times a day), at low intensity (within a pain-free or to-pain ROM) for short durations (20 to 30 repetitions or 2 to 3 minutes worth). This approach allows existing motion to be maintained and carefully increased while facilitating a reduction in pain and inflammation. It is in these cases that initiating strength training too quickly will lead to continued pain and stiffness.
- As the patient's tolerance to rehabilitation (ability to improve mobility without increases in pain) increases, motion exercises can be adjusted to produce more permanent gains, and strengthening can then be initiated.

Goals

- Full active range of motion equal to uninvolved shoulder
- Initiate scapular strengthening
- Return to non-athletic ADLs

Protection

- Continued immobilization via a sling only if indicated by nature of concomitant procedures, e.g., rotator cuff repair, labral repair, etc.

Management of Pain and Swelling

- Continued immobilization via a sling only if indicated by nature of concomitant procedures, e.g., rotator cuff repair, labral repair, etc.

Techniques for Progressive Increase in ROM

- Progressive ROM exercise emphasizing closed chain (limb supported) and moving to open chain exercises as patient's tolerance and response to treatment allows.
- In the absence of concomitant procedures, ROM is progressed at the patient's tolerance to rehabilitation (ability to improve mobility without increases in pain).
- Cross-body adduction should be avoided, as it can be provocative at this stage.

Other Therapeutic Exercises

- Conditioning (bike or elliptical)
- Nonweight bearing upper extremity core stability (bridge, crunch, etc.)
- Exercises with uninvolved arm (i.e. "cross-talk"/ contralateral overflow)

Open and Closed Kinetic Chain Exercises

- Closed chain exercises performed on a flat surface can be gradually progressed to inclined surfaces and finally a vertical surface (Figure 7-7).
- Supine flexion and pulley exercises can be added to assist in increasing forward elevation.
- Reclined flexion progressed to upright forward elevation (Figure 7-8).
- Scapular clocks for muscle activation[9] (Figure 7-9).

Neuromuscular Dynamic Stability Exercises

- Continued use of side lying manually resisted PNF patterns to the scapula

TIMELINE 7-2: **Postoperative Rehabilitation after Distal Clavicular Resection (DCE) (Mumford)**

PHASE I (weeks 1 to 2)	PHASE II (weeks 3 to 6)
• Sling (48 h unless concomitant procedures conflict) • Ice • ROM-scapular plan elevation, supine cane ER • Active-assistive table slides for forward elevation • Glenohumeral mobilization with wedge • Scapular PNF exercises in side lying	• ROM—active-assistive ROM in all planes permitted • Avoid excessive horizontal adduction • Progressive active-assistive motion from closed chain to open chain • Closed chain scapular exercises • Glenohumeral rhythmic stabilization in supine • Lower extremity exercise and conditioning

- Initiate GH rhythmic stabilization in supine (Figure 7-10)

Functional Exercises

- Lower extremity exercises including shoulder dumps[11] (Figure 7-11) trunk bends, single leg balance, hip hike, squats.

Milestones for Progression to the Next Phase

- Absence of pain at rest
- Full active ROM that is pain free. Residual soreness at the beginning or following activity that subsides on its own is expected and is not considered "pain" in terms of establishing appropriateness to progress to Phase III. It is important to distinguish between lactic acid pain, which resolves following the completion of an exercise or activity, and other sources of pain. Pain that is persistent between therapeutic treatments may be a sign of continued inflammation or delayed onset muscle soreness, which can last for several days. In these cases, progression to the next stage should be delayed until persistent pain is eliminated.
- Minimal to no scapular substitution with active forward elevation, measured posteriorly, ensuring that the medial border of the scapula is symmetrical and remains protracted to the rib cage during shoulder flexion, and retracts/upwardly rotates appropriately during abduction.

Phase III (weeks 6 to 10)

Clinical Pearls

- As Phase III progresses to the initiation of sport-specific activity, it's not uncommon to have the athlete experience some pain in the surgical region.
- Careful monitoring of the intensity and provocative maneuver can lead to a more successful return.
- This is a good time to reassess scapular mechanics to ensure that scapular dyskinesis is not present. The Scapular Dyskinesis Test, which classifies scapula dyskinesis as either present or absent, is used to determine the presence of dyskinesis.[12,13] This system involves viewing of the scapula during humeral elevation to observe for "winging" (abnormal prominence of the medial and/or inferior boarder of the scapula) or dysrhythmia with grading of these findings as normal, subtle (mild, questionable, or inconsistent), and obvious (striking, clear, and consistent).

Goals

- Restore strength of the shoulder musculature
- Initiate return to sport training
- Unrestricted ADLS

Management of Pain and Swelling

- Careful monitoring of intensity and provocative movements with rehabilitation activities to allow adjustments to be made

Techniques for Progressive Increase in ROM

Manual Therapy Techniques

- Glenohumeral mobilization as needed

Soft Tissue Techniques

- Pectoralis minor stretching as needed

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Stretching/flexibility techniques for the musculotendinous unit: Posterior capsule/sleeper stretching as needed.

Other Therapeutic Exercises

- Continued conditioning and exercises described in Phase II
- Initiate upper extremity weight-bearing core stability exercises (plank, side plank, etc.)

Sensorimotor Exercises

- Continue upper extremity PNF patterns
- Continue rhythmic stabilization exercises
- Initiate mirroring exercise (Figure 7-16) utilizing matched motion in multiple planes of movement in a mirror to improve proprioception and control. The goal of this exercise is the have the athlete match the motion of the involved to the uninvolved side through repetitive synchronous movements

TIMELINE 7-2: **Postoperative Rehabilitation after Distal Clavicular Resection (DCE) (Mumford)** (Continued)

PHASE III (weeks 6 to 10)	PHASE IV (weeks 10 to 14)	PHASE V (weeks 14 to 24)
• ROM should be full • Mobilizations as needed • Scapular and rotator cuff musculature PRE • PNF exercise • Upper extremity plyometrics in supine (90-90 & overhead ball toss) at 10 weeks	• Scapular and rotator cuff musculature PRE • Blackburn exercises (Ts, Ys, and Is) • TAS—biceps/triceps PREs • Glenohumeral exercises –PREs • Rotator cuff exercises –PREs • Upper extremity core stability (plank, side plank) • PNF exercises • Upright 90-90 and overhead ball toss	• Throwing program • Modified bench and overhead press (≤50% of preop reps weight) • Glenohumeral exercises—PREs • Scapular and rotator cuff musculature PRE • PNF exercises • Sport-specific training



FIGURE 7-16. Mirror exercise. Patient works on position the postsurgical shoulder in the same position as the nonsurgical shoulder.

Techniques to Increase Muscle Strength, Power, and Endurance

- Multilevel cable column or tubing rows (Figure 7-17)
- Advanced strengthening such as Blackburn exercises[14] can be integrated after the patient has demonstrated the ability to complete Phase II exercises without pain or substitution.
- Cable column or tubing external rotation (ER) and internal rotation (IR)
- Scaption with a hand-held weight

Neuromuscular Dynamic Stability Exercises

- One-hand push up on wall with light ball (Figure 7-12)

Plyometrics

- Medicine ball chest pass
- Overhead supine ball toss (Figure 7-13*A*)
- 90-90 supine ball toss (Figure 7-13*B*)
- Repeat progression in standing once supine progression completed without pain or loss of control

Functional Exercises

- Continued lower extremity described in Phase II

Sport-Specific Exercises

- Lower extremity drills (shuttle runs, back pedal, lateral step, etc.)

Milestones for Progression to the Next Phase

- Pain-free motion
- Strong and painless rotator cuff strength at 0° ABD
- No scapular substitution with forward elevation or abduction as discussed earlier

Phase IV (weeks 10 to 14)

Clinical Pearls

- In the late phases of rehabilitation, it is essential that the athlete continue to work to correct any strength or flexibility deficits that have been identified during the rehabilitation process.
- It is not uncommon for patients to discontinue the exercise regimen prematurely and suffer a return of pain and a functional set back as a result.
- Frequent communication with the athlete reinforcing the need to continue with the program is critical.

Goals

- Full restoration of shoulder strength
- Appropriate return to sport program
- Throwing program at 12 weeks

Other Therapeutic Exercises

- Continue conditioning and exercise per Phase II and III.

Techniques to Increase Muscle Strength, Power, and Endurance

- Continue strengthening exercise for scapula and rotator cuff musculature
- Return to gym 12 to 14 weeks with focus on regaining appropriate exercise form and early training/hypertrophy phase
- Low-weight bench pressing. In our experience, bench press beginning at 50% or less than presurgical one repetition maximum
- Form changes to include narrower grip, avoid full lock out to minimize stress on healing tissues

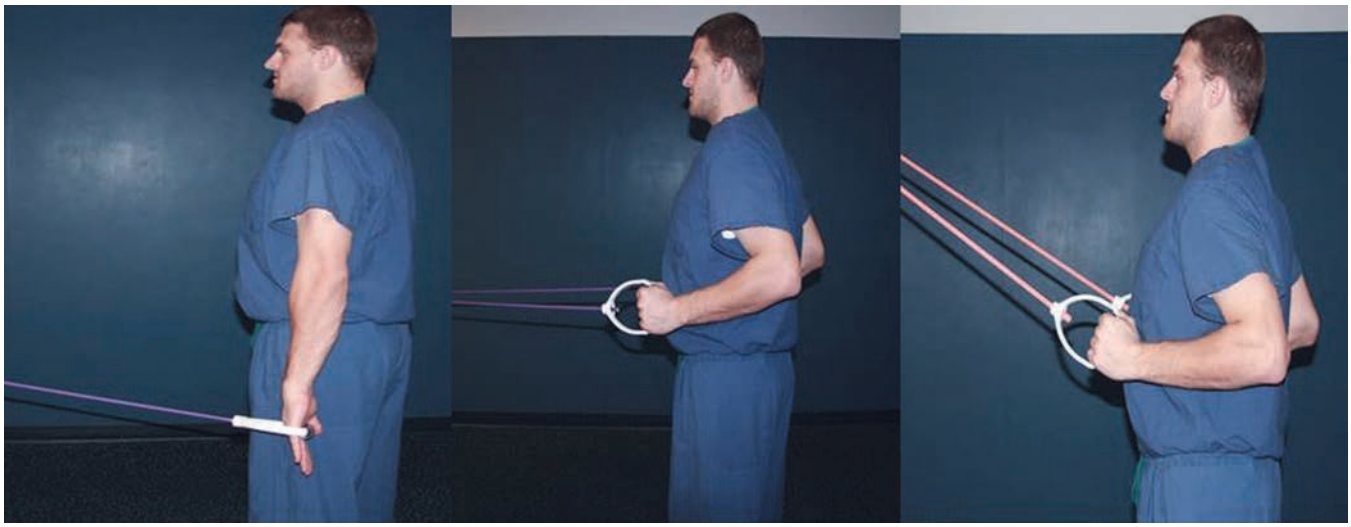

FIGURE 7-17. Multilevel rows.

- Low weight overhead press, in our experience beginning at 50% or less than presurgical one repetition maximum
- Form changes include avoiding full lock out at top and no behind neck presses
- Gradual return to previous level, progressing as tolerated

Neuromuscular Dynamic Stability Exercises

- One hand ball push up on wall progressing toward floor as athlete demonstrates appropriate form and control without pain in earlier phase exercises

Plyometrics

- Medicine ball chest pass
- Standing overhead ball toss
- Progress 90/90 ball toss to upright with rebounder

Functional Exercises

- Continue lower extremity exercises

Sport-Specific Exercises

- Progress lower extremity drills
- Initiate throwing program. Our throwing program is adopted and modified from review of previous published programs.[15-17] (See Table 7-1.)

Phase V (weeks 14 to 24)

Goals

- Successful or near completion of throwing program
- Sport-specific drills without complaints
- Discharge from formal care in preparation for return to sport

Sport-Specific Exercises

- Overhead throwing athletes may begin an interval-throwing program with short distance throws and frequent observation of proper throwing mechanics by the clinician. (Please see interval throwing program guidelines in Table 7-1.)
- General strength and conditioning of the UE may begin during this phase if the patient demonstrates full pain free AROM throughout all planes, and 5/5 strength throughout the affected UE, and no excessive soreness following rehabilitation exercises. Measurements of strength can be made using a hand-held dynamometer, which should reflect a 5% difference or less in strength in comparison to the uninvolved side. If a dynamometer is not available, 5/5 strength with manual muscle testing throughout the UE should be present.
- Exercises that the athlete will return to doing in the gym should be added on at this point at low intensity with close observation by clinician. All movements must also remain completely pain free.
- LE strength and agility exercises, combined with UE strengthening, may be incorporated at this stage for athletes in which UE function is dependent on LE stability and strength.
- Activities in this category may include box jumping with medicine ball, squat based kettle bell swings, or lateral shuttle run with intermittent medicine ball chest past between therapist and patient. These movements should be performed at low intensity for the purposes of improving endurance and technique rather than strength.
- Sport-specific drills at 24 weeks (football lineman-contact drills, light sled push, swimming maneuvers, wrestler-partner drills in quadruped, etc., basketball-lay up drills with partner to stimulate contact, racket sports-progressive swing/volley drills, etc.)

Criteria for Return to Sport

General

- Full active ROM without scapular dyskinesis as measured by the Scapular Dyskinesis Test.

- Full shoulder strength with handheld dynamometer or with manual muscle testing Successful completion of rehabilitation progression without residual soreness/pain
- Pain-free overhead activities
- Pain-free sport specific motions and maneuvers

Sport-Specific

- Thrower—successful completion of throwing program
- Contact athlete—contact without symptoms

After Return to Sport

- Focus on maintenance of parascapular strength
- Continuation of return to sport phase exercises for total body strength
- Return to team strength and conditioning program

Evidence

Charron KM, Schepsis AA, Voloshin I: Arthroscopic distal clavicle resection in athletes: a prospective comparison of the direct and indirect approach. *Am J Sports Med* 35:53–58, 2007.

Randomized controlled clinical trial comparing direct and indirect arthroscopic approaches for distal clavicle excision. Outcome scores were comparable at 2-year follow up in both groups, however athletes treated with the direct superior approach improved faster clinically and returned to sports earlier.[18] (Level II evidence)

Flatow EL, Duralde XA, Nicholson GP, et al: Arthroscopic resection of the distal clavicle with a superior approach. *J Shoulder Elbow Surg* 4(1 Pt 1):41–50, 1995.

Forty-one patients who underwent arthroscopic distal clavicle resection were followed for a minimum of 2 years postoperatively. At follow up 18 excellent, 16 good, and 7 poor results were found. High failure rate was associated with previous grade II acromioclavicular separations or acromioclavicular hypermobility.[4] (Level IV evidence)

Freedman BA, Javernick MA, O'Brien FP, et al: Arthroscopic versus open distal clavicle excision: comparative results at 6 months and 1 year from a randomized, prospective clinical trial. *J Shoulder Elbow Surg* 16:413–418, 2007.

Randomized, prospective clinical trial comparing the 6-month and 1-year outcomes between patients undergoing arthroscopic DCE to those undergoing open DCE. Both groups had comparable outcomes at 1 year. There was a trend for earlier improvement in the arthroscopic group.[7] (Level II evidence)

Kay SP, Dragoo JL, Lee R: Long-term results of arthroscopic resection of the distal clavicle with concomitant subacromial decompression. *Arthroscopy* 19:805–809, 2003.

Retrospective review of 20 patients followed for a mean of 6 years following combined arthroscopic DCE and subacromial decompression. Good to excellent scores on the Constant score and UCLA were observed in all 20 patients.[20] (Level IV evidence)

Robertson WJ, Griffith MH, Carroll K, et al: Arthroscopic versus open distal clavicle excision: a comparative assessment at intermediate-term follow-up. *Am J Sports Med* 39:2415–2420, 2011.

Comparison of 49 shoulders in 48 patients treated either with an open or arthroscopic approach. At 4-to 5-year follow-up, both groups had comparable outcome scores and were satisfied with the result of the procedure.[19] (Level III evidence)

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Multiple-Choice Questions

QUESTION 1. Pain is an important component in determining the progression of therapeutic activities. Which of the following is ***most*** important when making decisions regarding the pace of rehabilitation?

A. Sport played
B. Concomitant procedures
C. Operative approach
D. Mechanism of original injury

QUESTION 2. What is the described progression of ROM exercises in the postsurgical setting?

A. Start with exercises like the pulleys that elicit moderate amounts of muscle activity. If the patient can't tolerate this switch to exercises with the limb supported.
B. Active ROM can be initiated immediately. Only patients reporting high levels of pain need to start with active assistive motion exercises
C. ROM exercises should start with the limb supported as they produce low levels of muscle activity thereby allowing the patient to move in a tolerable range. As motion improves and pain subsides, active-assistive exercise such as the pulleys and open chain activities like reclined flexion that produce progressive amounts of muscle activity.
D. All of the above.

QUESTION 3. Which of the following exercises allow the patient to focus on scapular control and established movement patterns without creating excessive loads about the shoulder?

A. Scaption with a hand-held weight
B. Scapular clock
C. Active forward elevation
D. Cable column external rotation

Answer Key

QUESTION 1. Correct answer: **B** (see Factors that May Affect Rehabilitation)

QUESTION 2. Correct answer: **C** (see Phases I and II Under Increase Range of Motion)

QUESTION 3. Correct answer: **B** (see Phase II, Muscular Activation)

NONOPERATIVE REHABILITATION OF STERNOCLAVICULAR JOINT SPRAINS

Richard L. Romeyn, MD, and Becky Heinert, MS, PT, SCS

Introduction

Anatomy

- The structure of the sternoclavicular (SC) joint is unique. It is a saddle-type articulation of partially incongruent surfaces, but it essentially functions as a ball-and-socket joint. Virtually any motion of the upper extremity produces some degree of stress upon the SC joint. Because the medial clavicle's articular surface is much larger than that on the sternum (less than half of the medial clavicle actually articulates with it), a lack of bony stability means that SC joint stability is largely dependent upon the integrity of its investing soft tissue constraints to control rotation and resist displacement.
- The posterior capsule (posterior sternoclavicular ligament) and the costoclavicular ligaments are the strongest and most important.[1,2] Typically, 30° to 35° of upward elevation, 35° of combined anterior/posterior displacement, and 45° to 50° of rotation about the long axis of the clavicle are allowed.[3,4]
- The muscles that act upon the SC joint do so indirectly, and as with the AC joint, stresses upon it are significantly influenced by scapulothoracic (kinematics).
- Adjacent to the SC joint is the epiphysis (growth center) of the medial clavicle. That epiphysis is the last one to close as skeletal maturity is reached, and it generally remains patent until midway through the third decade of life.[5]

Symptoms

- SC joint pathology produces localized pain over the joint surfaces and adjacent capsule. Distant pathologies do not generally refer pain to the area of the SC joint, and SC joint pathologies generally do not produce pain referred to other locations.
- Because the SC joint is superficial, even in muscular or obese patients, swelling is usually visually evident, and discomfort and instability can be readily palpated.
- The SC joint can be difficult to assess with standard radiographic views. Cephalic tilt views may allow more sensitive images to be obtained, but the current standard of care, if significant pathology or injury is suspected, is an advanced imaging study such as a CT or MRI scan.[6,7]

Etiology of Symptoms

Acute sprain:

- The minimal and incongruous contact between the articular surfaces of the medial clavicle and sternum would suggest that the SC joint may be easily predisposed to instability. However, it actually is uncommonly injured. In one large series, SC joint trauma represented just 3% of all injuries to the shoulder girdle.[8]
- Ligamentous injury can occur due to a direct force applied to the anteromedial aspect of the clavicle—producing posterior subluxation or dislocation of the joint, or from an indirect force applied to the arm or

shoulder—which can result in either anterior or posterior instability.

- In approximately 75% of cases, the instability is anterior, and is produced when an abduction/external rotation force is applied to the ipsilateral shoulder.[3,9] As with all joints, ligamentous injury can be classified as mild (pain without instability), moderate (subluxation), or severe (complete disruption of all SC ligaments).[10]
- Although discomfort generally increases in proportion to the degree of injury, trauma producing anterior instability may be only minimally painful with the arm at rest.
- However, a position of provocation, such as the cocking motion in throwing, which levers the medial clavicle anteriorly, will generally reproduce and exacerbate the symptoms.
- Posterior dislocations typically produce far greater pain than injuries producing anterior instability, and because the displaced medial clavicle can compress the mediastinum, that injury may be associated with venous congestion of neck or upper extremity, cough or hoarseness, shortness of breath, and difficulty swallowing.[9,11]
- The deformity produced by a posterior dislocation may be obscured by swelling, but the edge of the sternum is palpable, and should provide confirmation during clinical examination. This injury may have life threatening consequences, generally requires prompt reduction in an operating room setting, and so must not be overlooked.
- Many "dislocations" of the SC joint are not ligamentous injuries at all, but represent traumatic separation of the adjacent epiphysis (growth center).[6,10,12] The epiphysis of the medial clavicle does not even appear on radiographs until the late teenage years, and is vulnerable into the mid-20s. Most of these injuries readily heal, will remodel with time, and require only initial supportive care.
- Initial treatment for acute ligamentous injuries of the SC joint consists of that typical of all joint sprains: ice and immobilization. The length and degree of protection required are dependent upon the degree of injury.
- Anterior dislocations tend to be unstable after reduction no matter what initial treatment is provided. Posterior dislocations are generally stable after reduction. Although the prominence of the medial clavicle often remains present after an anterior subluxation or dislocation has occurred, scaring about the joint capsule generally prevents symptomatic instability, and the majority of patients with chronic SC joint laxity may be expected to have, at most, minimal functional limitations.
- Although techniques for surgical reconstruction of anterior ligamentous laxity have been described, outcomes are not uniformly successful, and there is significant risk to operating on the SC joint due to its proximity to multiple large vessels.[8,7,13]

Spontaneous instability:

- This condition is most common in the late teen to early adulthood years in those individuals who have significant generalized ligamentous laxity (Figure 7-18). There is a moderate female preponderance.[14]
- The condition is characterized by painful popping localized to the SC joint with elevation of the arm, and (by definition) there is no history of trauma producing ligamentous compromise.
- Participation in overhead sports such as baseball, basketball, and volleyball, and swimming are often associated with this condition. Scapulothoracic dyskinesia and core stability deficits are often present.
- This is a self-limited condition, generally responding successfully to an appropriate rehabilitation algorithm; it should NOT be treated surgically.[14] In fact, operative intervention is associated with an increase in symptoms.



FIGURE 7-18. An athlete with spontaneous anterior instability of the right SC joint.

Arthritis:

- Systemic rheumatoid arthritis may affect the SC joint, and that articulation may upon occasion even represent the initial clinical manifestation.
- Localized osteoarthritis of the SC joint, and avascular necrosis of the medial clavicle may also occur; typical patients are middle aged or elderly, often with an employment history of repetitive overhead work.
- Although localization of arthritic symptoms to the SC joint is generally obvious clinically, confirmation requires appropriate radiographs. SC joint arthritis usually responds to treatment of the systemic condition when secondary to rheumatoid disease and its variants.
- Resection of the proximal clavicle for disabling osteoarthritis that is non-responsive to all other treatment has been reported as successful if the CS ligaments and capsule are intact.[4] Otherwise, intervention must also include ligamentous reconstruction. Multiple techniques have been described.[3,8,12,13]

Infection:

- In individuals at risk of recurrent bacteremia, such as those with HIV infection; and with drug addiction, alcoholism, and other chronic debilitating diseases, the SC joint may be a site of localized sepsis.[15]
- In addition to pain localized to the SC joint area, erythema, warmth, fluctuant exquisite tenderness to palpation, and other signs of joint infection and abscess are evident. Intravenous antibiotics and/or incision and drainage may be necessary.

GUIDING PRINCIPLES OF REHABILITATION

- Protect the SC joint to help minimize the likelihood of chronic subluxation.
- Correct any underlying scapulothoracic dyskinesia to allow normalized shoulder girdle biomechanics during arm elevation.
- Prevent chronic SC joint subluxation through strengthening of the shoulder and scapular stabilizers and improved flexibility of the sternocleidomastoid, upper trapezius, pectoralis major, and pectoralis minor muscles.

Phase I (weeks 0 to 4)

Goals

- The SC joint pathology can be divided into those caused by trauma and those of insidious onset.
- The acute sprain can be classified into grade I (mild), grade II (moderate) and grade III (severe). The duration of immobilization and progression through the rehabilitation program will be dependent on the degree of instability in the SC joint.
- A grade I SC joint sprain is symptom-limited with a fairly rapid return to activity based on resolution of symptoms within 7 to 10 days.
- The treatment of grade II and III SC joint sprain is identical except the period of immobilization. For grade III SC joint sprains, the timeline for the rehabilitation protocol provided will be delayed by approximately 2 weeks to help minimize the likelihood of chronic SC joint subluxation.
- For the rehabilitation of a non-traumatic SC joint injury it is recommended that provocative activities be avoided for 2 to 3 weeks and that local modalities such as ultrasound, interferential current and iontophoresis be utilized for inflammatory and pain control. Upon resolution of acute symptoms, the athlete can begin the rehabilitation protocol beginning with Phase II.

Protection

Grade I: 5 to 10 days in a sling
Grade II: 2 to 3 weeks using a sling for anterior instability and "figure of 8" brace for posterior instability
Grade III: 3 to 4 weeks using a sling for anterior instability and "figure of 8" brace for posterior instability

Management of Pain and Swelling

- Ice, Ultrasound, Interferential Current Electrical Stimulation

Techniques for Progressive Increase in Range of Motion

- PROM flexion and scaption:
  - 0° to 90° (week 1 to 2) to avoid excessive clavicular retraction, elevation, and posterior rotation on the thorax
  - 0° to 180° (week 2 to 3)
- AAROM 0° to 90° flexion and scaption (week 2 to 3)
- Pendulum exercises
- Active elbow and wrist ROM

Stretching and Flexibility Techniques for the Musculotendinous Unit

- TBS, Core, TLS as tolerated and recommended

Techniques to Increase Muscle Strength, Power, and Endurance

Week 2 to 3: Submaximal isometric flexion, abduction, IR, ER in neutral; progress to maximal isometric if pain-free
Week 2 to 3: Active scapular retraction and depression, scapular protraction, biceps curls, triceps extensions

Milestones for Progression to the Next Phase

- D/C sling or brace
- Visual analog scale (VAS) 0/10 at rest
- PROM 0° to 180° for flexion/scaption
- Pain-free maximal isometrics for shoulder flexion, abduction, IR, ER in neutral
- Correct sitting posture demonstrated

Phase II (weeks 4 to 8)

Protection

- Taping prn for anterior instability (Figure 7-19)



FIGURE 7-19. Utilization of kinesiotape for chronic anterior SC joint instability.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- For the anteriorly displaced AC joint, posterior SC joint mobilizations prn
- Thoracic anterior-posterior glides with overpressure prn to improve lower trapezius activation. Progression of range of motion is based on the absence of SC joint pain and instability
  - AAROM 0° to180° (week 3 to 4)
  - AROM 0° to 90° (week 3 to 4); 0° to 180° (week 4 to 6)

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Address cervicothoracic muscle imbalances through continued stretching of the SCM, upper trapezius and pectoralis muscles prn, and strengthening of middle and lower trapezius, rhomboids and deep cervical flexor muscle groups.

Other Therapeutic Exercises

- TBS, Core, TLS as tolerated and recommended

Sensorimotor Exercises

- Rhythmic stabilization, beginning in neutral with a progression to increasing degrees of arm elevation, decreasing upper extremity support, and greater intensity of perturbation placed distally on the extremity.
- PNF patterning in a pain-free ROM
- Body blade progression from neutral to 90°

Open and Closed Kinetic Chain Exercises

- Biodex VSRP for IR/ER from 60° to 180°/sec in neutral.
- Week 6 to 8: Initiate closed chain progression based on patient tolerance. A standard progression includes transitioning from a bilateral to unilateral activity with increasing weight bearing on the extremity.



FIGURE 7-20. Prone ball punches.

- One example may include press-ups, wall pushup with a plus, table pushup, 4-point weight shifts, prone on elbows, prone ball punches (Figure 7-20), standing ball punches with perturbations, modified pushups, partial ball walk-outs, full-walk-outs and full pushups.

Techniques to Increase Muscle Strength, Power, and Endurance

- Continue total arm strengthening, including bicep curls, triceps extensions

TIMELINE 7-3: **Nonoperative Rehabilitation of the Sternoclavicular Joint Sprain**

PHASE I (week 0 to 1)	PHASE II (weeks 2 to 4)
• Sling or "figure of 8" brace • PT modalities • PROM–flexion and scaption 0°–90° • Active ROM-elbow, wrist • Codman's exercises • TBS/TAS/TLS activities as recommended and tolerated	• D/C sling or "figure of 8" brace • PT modalities as needed • PROM–flexion and scaption 0°–180° • AAROM flexion and scaption 0°–90° (week 2–3) • AAROM flexion and scaption 0°–180° (week 3–4) • Submaximal to maximal isometrics for GH joint muscles • Biceps, triceps, and scapular exercises • SCM, UT, Pectoralis stretches • TBS/TAS/TLS activities as recommended and tolerated

- Progress strengthening of scapular stabilizers, posterior cuff, and glenohumeral muscles
  - Standing flexion, scaption 0° to 90°; increase ROM as strength and dynamic control improve
  - Prone rows
  - Prone GH extension
  - Supine protraction
  - Horizontal abduction with external rotation
  - Sidelying ER
  - TheraBand IR/ER

Plyometrics

- Week 6 to 8: Initiate a plyometric progression based on patient tolerance. A typical plyoback progression may begin with a two-handed chest level toss, progress to an overhead throw, and then to a single arm 90/90 step-throw.
- In addition, the base of support may be altered through the utilization of devices such as the BOSU ball or foam to increase the difficulty and engage more of the core muscles.

Milestones for Progression to the Next Phase

- VAS 0/10 with activities of daily living.
- Full AROM
- Manual muscle test 5/5 glenohumeral, scapular, and rotator cuff strength
- Isokinetic strength testing within 10% of the uninvolved shoulder for IR/ER in neutral at 60°/second, 180°/second and 300°/second
- Normal scapular assessment and/or normal scapular dyskinesis test

Phase III (weeks 8 to 12)

Protection

- Taping prn for anterior instability

Management of Pain and Swelling

- Ice, Ultrasound, Interferential Current Electrical Stimulation prn

Techniques for Progressive Increase in Range of Motion

Stretching and Flexibility Techniques for the Musculotendinous Unit

- As needed: Address cervicothoracic muscle imbalances through continued stretching of the SCM, upper trapezius and pectoralis muscles and strengthening of middle and lower trapezius, rhomboids and deep cervical flexor muscle groups.

Other Therapeutic Exercises

- TBS, Core, TLS as tolerated and recommended

Sensorimotor Exercises

- Incorporate exercises from 90° to the overhead position to improve dynamic control through the full arc of motion.
- Examples include wall dribbles (Figure 7-21), body blade in the overhead position or using PNF patterns, or 90/90 internal and external rotation using resistive tubing.

Open and Closed Kinetic Chain Exercises

- Progress to an isokinetic Velocity Spectrum Rehabilitation Protocol 180°/sec to 300°/sec in the 90/90 position.
- Continue to progress the CKC pushup activity by incorporating an unstable surface, an elevated position (box pushups), or unilateral support (Figures 7-22 and 7-23).

TIMELINE 7-3: **Nonoperative Rehabilitation of the Sternoclavicular Joint Sprain** (Continued)

PHASE III (weeks 4 to 8)	PHASE IV (weeks 8 to 12)
• Brace/taping prn • PT modalities as needed • AROM–full • Mobilizations (SC join, GH, thoracic spine) as needed • SCM, UT, pectoralis stretches prn • TBS/TAS/TLS activities as recommended and tolerated • Scapular exercises—PREs • TAS–biceps/triceps PREs • Glenohumeral exercises—PREs • Rotator cuff exercises–PREs • PNF exercises • Week 6–Plyometric progression (two-hand chest pass progressing to one-arm 90/90 step-throw) • Week 6–CKC progression (supported weight shift progressing to full pushup; bilateral progressing to unilateral)	• Brace/taping prn • PT modalities as needed • PROM–full • Mobilizations as needed • SCM, UT, Pectoralis stretching prn • TBS/TAS/TLS activities as recommended and tolerated • Scapular exercises–PREs • TAS–Biceps/Triceps PREs • Glenohumeral exercises–PREs • Rotator cuff exercises–PREs • Overhead strengthening exercises • PNF exercises • OKC rhythmic stabilization exercises • CKC exercises • Initiate sport-specific exercises • Return to sport program



FIGURE 7-21. Overhead wall dribbles.



FIGURE 7-22. Pushup with ball rolls.



FIGURE 7-23. Pushup with unilateral touches.



FIGURE 7-24. Prone Y exercise.



FIGURE 7-25. Prone T exercise.

Techniques to Increase Muscle Strength, Power, and Endurance

- Continue to increase resistance to the rotator cuff, scapular stabilizers and glenohumeral muscles. Utilize high repetition, low resistance for endurance training for the postural muscles such as the lower and middle trapezius muscle groups. Consider using a stability to engage more of the core muscles including:
  - Prone "Y"s (Figure 7-24)
  - Prone "T"s (Figure 7-25)
  - Prone goalpost (Figure 7-26)

Neuromuscular Dynamic Stability Exercises

- Integrate functional movement patterns, such as multi-directional lunges or squats with overhead press (Figures 7-27 and 7-28) that incorporated the entire upper and lower kinetic chain and require adequate core stability for proper completion.



FIGURE 7-26. Prone goalpost exercise.



FIGURE 7-27. Lunge with overhead press.

Sport-Specific Exercises

- A graduated return to throwing program prn (Table 7-1)

Milestones for Progression to Advanced Sport-Specific Training and Conditioning

- Successful completion of Phase III exercises, including closed kinetic chain, plyometric, functional movement pattern progressions, and return to throwing program with VAS 0-1/10 pain reported.



FIGURE 7-28. Squat with overhead press.

Criteria for Abandoning Nonoperative Treatment and Proceeding to Surgery or More Intensive Intervention

- Continued pain or instability interfering with upper extremity function

Performance Enhancement and Beyond Rehabilitation: Training/ Trainer and Optimization of Athletic Performance

- For an athlete returning to sport, a gradual transition is necessary to avoid excessive stress across the SC joint.
- The athlete with the goal of returning to a contact sport or one that requires overhead power may benefit from a biomechanical assessment by a physical therapist or athletic trainer, with the assistance of their positional coach to provide recommendations for technique modifications.

Specific Criteria for Return to Sports Participation: Tests and Measurements

- VAS 0-1/10 during sport-specific exercises
- Closed Kinetic Chain Upper Extremity Test scores within 10% of the uninvolved shoulder
- Isokinetic strength testing within 10% of the uninvolved shoulder for desired motions. IR/ER in 90/90

Table 7-1 High School and College Baseball Pitchers Interval Throwing

PHASE I Return to Throwing Throws at 50% effort	PHASE II Return to Pitching Throws at Effort Level Given	PHASE III Intensified Pitching
Step 1 Warm-up toss to 60 feet 15 throws at 30 feet 15 throws at 30 feet 15 throws at 30 feet 20 long tosses to 60 feet	**Step 8** 15 throws at 60 feet, 6 in (75%) 20 throws at 60 feet, 6 in (75%) 20 throws at 60 feet, 6 in (75%) 15 throws at 60 feet, 6 in (75%)	**Step 13** 25 fastballs (75%) 20 fastballs (100%) 10 fastballs (75%) 15 fastballs (100%) 25 fastballs (75%)
Step 2 Warm-up toss to 75 feet 15 throws at 45 feet 15 throws at 45 feet 15 throws at 45 feet 20 long tosses to 75 feet	**Step 9** 20 throws at 60 feet, 6 in (75%) 20 throws at 60 feet, 6 in (75%) 20 throws at 60 feet, 6 in (75%) 20 throws at 60 feet, 6 in (75%)	**Step 14 (Active Rest)** 20 throws at 80 feet 20 throws at 80 feet 20 throws at 80 feet 20 throws at 80 feet
Step 3 Warm-up toss to 90 feet 15 throws at 75 feet 15 throws at 75 feet 15 throws at 75 feet 20 long tosses to 90 feet	**Step 10** 20 fastballs (50%) 20 fastballs (50%) 20 fastballs (50%) 20 fastballs (50%) 25 throws at 60 feet, 6 in (75%)	**Step 15** 20 fastballs (75%) 20 fastballs (100%) 5 off speed pitches 15 fastballs (100%) 5 off speed pitches 20 fastballs (100%) 5 off speed pitches Field bunts and comebacks (Relievers and closing pitchers can go to step 21 on the next throwing day after completing this step)
Step 4 Warm-up toss to 105 feet 15 throws at 75 feet 15 throws at 75 feet 15 throws at 75 feet 20 long tosses to 105 feet	**Step 11** 20 fastballs (50%) 20 fastballs (75%) 20 fastballs (50%) 15 fastballs (75%) 25 throws at 60 feet, 6 in (75%)	**Step 16** 20 fastballs (100%) 15 fastballs (100%) 5 off speed pitches 5 pickoff throws to 1st 20 fastballs (100%) 5 off speed pitches 20 fastballs (100%) 5 off speed pitches
Step 5 Warm-up toss to 120 feet 15 throws at 90 feet 20 throws at 90 feet 15 throws at 90 feet 10 long tosses to 120 feet	**Step 12** 25 fastballs (50%) 20 fastballs (75%) 20 fastballs (75%) 20 fastballs (75%) 20 fastballs (75%)	**Step 17** 15 fastballs (100%) 5 off speed pitches 15 fastballs (100%) 3 pickoff throws to 1st 20 fastballs (100%) 5 off speed pitches 15 fastballs (100%) 3 pickoff throws to 2nd 15 fastballs (100%) 5 off speed pitches
Step 6 Warm-up toss to 120 feet 20 throws at 105 feet 20 throws at 105 feet 15 throws at 105 feet 20 long tosses at 120 feet		**Step 18 (Active rest)** Repeat step 14
Step 7 Warm-up toss to 120 feet 20 throws at 120 feet 20 throws at 120 feet 20 throws at 120 feet 20 long tosses at 120 feet		**Step 19** 20 fastballs (100%) 5 off speed pitches 20 fastballs (100%) 3 pickoff throws to 1st 20 fastballs (100%) 3 pickoff throws to 2nd 15 fastballs (100%) 5 off speed pitches 15 fastballs (100%) 5 off speed pitches
		Step 20 Batting practice 110 to120 pitches Field bunts and comebacks
		Step 21 Simulated game

(Courtesy of Gunderson Lutheran Sports Medicine.)

position at 60°/sec, 180°/sec, and 300°/ pain-free completion of a return to throwing program prn.

Evidence

Bontempo NA, Mazzocca AD: Biomechanics and treatment of acromioclavicular and sternoclavicular joint injuries. *Br J Sports Med* 44:361–369, 2010.

This descriptive article reviews the etiology, examination, and management of SC joint pathologies. (Level V evidence)

Cleland J, Selleck B, Stowell T, et al: Short term effects of thoracic manipulation on lower trapezius muscle strength. *J Manual Manipulative Ther* 12:82–90, 2004.

This randomized, controlled study evaluated the short-term effects of thoracic manipulation on lower trapezius muscle activation using a hand-held dynamometer. The subjects that received the thoracic manipulation demonstrated an increase of lower trapezius strength of 14% as compared with the control group which improved 3%. (Level I evidence)

Cools AM, Dewitte V, Lanszweert F, et al: Rehabilitation of scapular muscle balance; Which exercises to prescribe? *Am J Sports Med* 35:1744–1751, 2007.

This controlled laboratory study of 45 healthy subjects evaluated the electromyographic activity of the three trapezius parts during commonly used scapular stabilization exercises. The exercises of sidelying external rotation, sidelying forward flexion, prone horizontal abduction with external rotation and prone extension were found to be the most effective in promoting lower and middle trapezius muscle activity with minimal activation of the upper trapezius. (Level II evidence)

Jaggard MK, Gupte CM, Gulati V, et al: A comprehensive review of trauma and disruption to the sternoclavicular joint with the proposal of a new classification system. *J Trauma* 66:576–584, 2009.

This review article discusses the anatomy of the SC joint, classification of injuries, and the management of these injuries using primarily immobilization and physical therapy. (Level V evidence)

MacDonald PB, Lapointe P: Acromioclavicular and sternoclavicular joint injuries. *Orthop Clin North Am* 39:535–545, 2008.

This descriptive article briefly outlines the anatomy of the SC joint and the management of traumatic anterior and posterior dislocations. Recommendations regarding prolonged immobilization and a return to full activities within 12 to 16 weeks were included. (Level V evidence)

Neviaser JS: Injuries of the clavicle and its articulations. *Orthop Clin North Am* 11:233–237, 1980.

This brief commentary discusses the etiology and symptoms of SC joint injuries along with the conservative management of sprains using immobilization. (Level V evidence)

Robinson CM, Jenkins PJ, Markham PE, et al: Disorders of the sternoclavicular joint. *J Bone Joint Surg Br* 90:685–696, 2008.

This review article discusses the anatomy and pathophysiology of the SC joint, clinical presentation, and the conservative management of disorders involving the SC joint. (Level V evidence)

Rockwood CA, Odor JM: Spontaneous atraumatic anterior subluxation of the sternoclavicular joint. *J Bone Joint Surg Am* 71A:1280–1288, 1989.

This retrospective comparative study evaluates the outcomes of 37 patients treated for spontaneous atraumatic anterior subluxation of the SC joint with either conservative or surgical intervention. The authors recommend that this disorder be treated with a conservative approach that includes immobilization and reassurance of a full recovery. (Level IV evidence)

Tate AR, McClure P, Kareha S, et al: A clinical method for identifying scapular dyskinesis. Part 2: Validity. *J Athl Train* 44:165–173, 2009.

This validation study rated the scapular dyskinesia in 142 collegiate athletes performing weighted shoulder flexion and abduction. Athletes judged as having either normal motion or obvious dyskinesia underwent three-dimensional electromagnetic kinematic testing while performing the same movements. Shoulders visually judged as having dyskinesia showed significant differences in kinematic motion. (Level II evidence)

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Multiple-Choice Questions

QUESTION 1. The etiology of symptoms involving the sternoclavicular joint includes all of the following except:

A. Recurrent bacteremia (HIV infection, drug addiction, alcoholism)
B. Trauma to the anterior lateral clavicle
C. Referral pain from the cervical spine
D. Systemic rheumatoid arthritis

QUESTION 2. Which of the following is NOT a typical finding of a potential sternoclavicular joint pathology:

A. Painful popping in the SC joint region with arm elevation
B. Generalized multi-joint laxity
C. Shortness of breath
D. Abnormality obvious on standard plain x-ray views

QUESTION 3. A key component of Phase II of rehabilitation includes:

A. Immobilization of the joint to maximize healing and prevent chronic shoulder subluxation
B. Overhead strengthening
C. Return to sport program
D. Closed chain exercise progression

QUESTION 4. The timeline for return to sports is most closely related to:

A. Severity of the sprain
B. Location of pain
C. Direction of the sprain (anterior versus posterior)
D. Age of the athlete

Answer Key

QUESTION 1. Correct answer: **C** (see Introduction—Etiology of symptoms)

QUESTION 2. Correct answer: **D** (see Introduction)

QUESTION 3. Correct answer: **D** (see Phase II)

QUESTION 4. Correct answer: **A** (see Phase I)

POSTOPERATIVE REHABILITATION AFTER JOINT RECONSTRUCTION OF ACROMIOCLAVICULAR SEPARATIONS

Nathan A. Mall, MD, Amy Resler, PT, DPT, CSCS, Wendell M.R. Heard, MD, and Nikhil N. Verma, MD

Indications for Surgical Treatment

- Some acute Type III dislocations, mostly in elite athletes
- Type II and III dislocations that have continued pain or symptoms following conservative treatment
- Acute or chronic Type IV, V, VI dislocations
- Instability and pain following distal clavicle excision

Brief Summary of Surgical Treatment

Major Surgical Steps

- Hook plate (+/– ligament reconstruction)
  - Plate is hooked on undersurface of acromion and placed on superior surface of clavicle, secured with bicortical screws, thereby reducing the acromioclavicular (AC) joint
  - May be combined with ligament reconstruction
  - Plate is removed at 8 weeks postoperatively
- Coracoclavicular fixation (+/– ligament reconstruction)
  - Synthetic suture loops or screw fixation from clavicle around or into coracoid process (Figure 7-29)
  - May be combined with ligament reconstruction
  - Staged removal of coracoacromial screw
- Coracoacromial ligament transfer (Weaver-Dunn or equivalent)
  - Coracoacromial (CA) ligament is detached from inferior surface of acromion
    - May or may not be removed with chip of bone; some authors believe this improves healing
  - Transferred to clavicle to recreate coracoclavicular ligaments
  - Can be augmented with suture loop
  - Distal clavicle is excised to prevent AC arthritis as late pain generator
  - Can be performed arthroscopically
- Semitendinosus autograft or allograft (authors' preferred method)
  - If autograft used, harvest graft from proximal medial tibia at pes anserine insertion using tendon stripper.
  - Doubled semitendinosus graft can be secured into coracoid with a bone tunnel or can be looped around the coracoid base. Coracoid tunnel may predispose to coracoid fracture.
  - Clavicle drill holes in the location of the trapezoid and conoid ligaments (Figure 7-30) are made and the graft secured with interference screws.
  - +/– Distal clavicle resection—recent study demonstrated that maintaining AC joint (i.e., preserving the distal clavicle) leads to reduced contact forces and increased AC stability.
  - Remaining graft can be secured into distal acromion to recreate AC ligaments (Figures 7-31 and 7-32).
  - Figures 7-33 *A* and *B* demonstrate typical preoperative and postoperative radiographs showing anatomic reduction of the downward displacement of the acromion with respect to the clavicle using an anatomic reconstruction technique with autograft.

Factors That May Affect Rehabilitation

Anesthetic

- Preferred technique is general anesthesia with interscalene block for postoperative pain control.
- Interscalene block with sedation may be possible although entire operative field may not be covered.

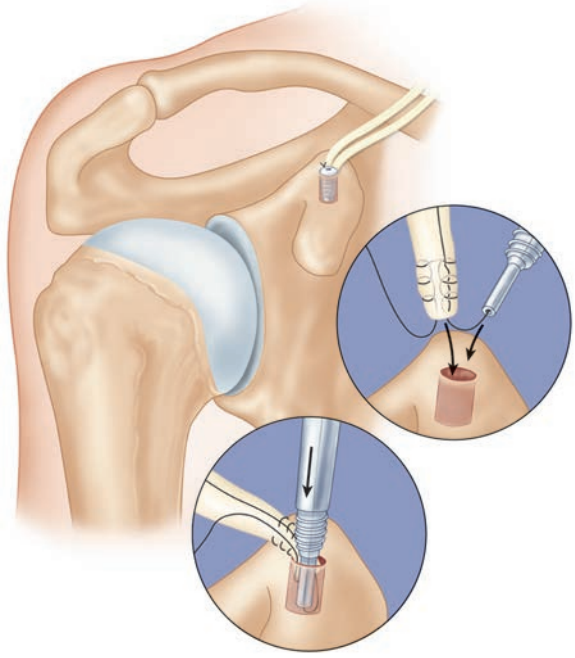

FIGURE 7-29. Coracoid bone repair—the sutures from the graft are tied together over the screw to provide dual functionality of the construct interference screw and suture anchor. *(From Provencher MT, LeClere LE, Mazzocca AD, et al: Acromioclavicular joint reconstruction. In Reider B, Terry MA, Provencher MT, editors: Operative techniques: sports medicine surgery, 2010, Elsevier.)*

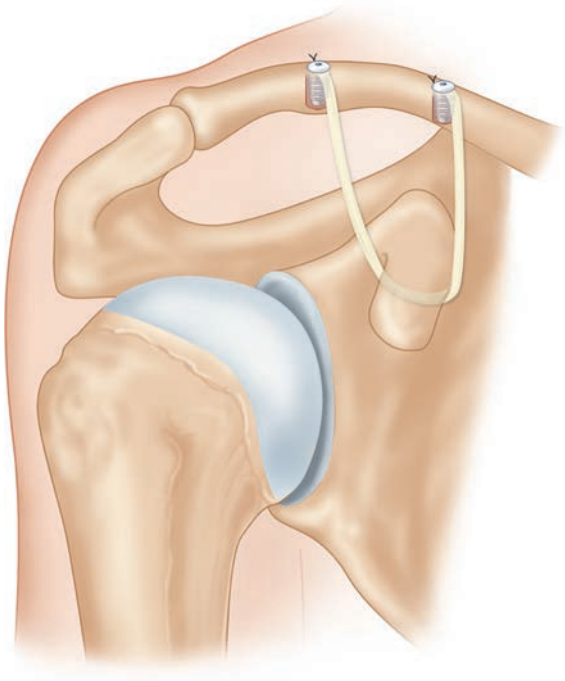

FIGURE 7-30. An alternative method of reconstruction involves passing a loop of the graft under the coracoid from lateral to medial. This is an excellent way to reconstruct the CC ligaments. *(From Provencher MT, LeClere LE, Mazzocca AD, et al: Acromioclavicular joint reconstruction. In Reider B, Terry MA, Provencher MT, editors: Operative techniques: sports medicine surgery, 2010, Elsevier.)*

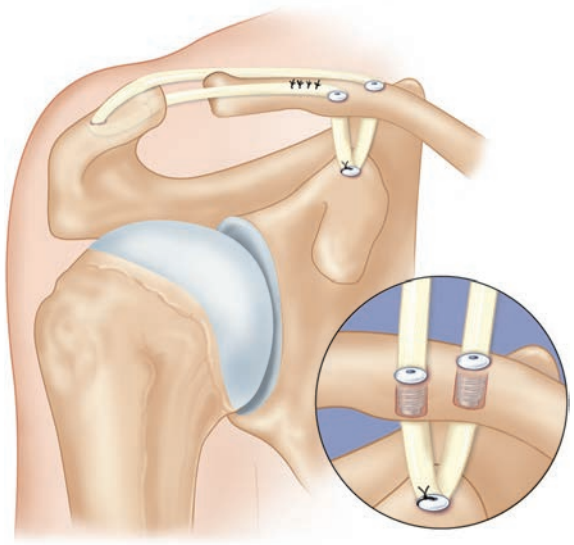

FIGURE 7-31. The tendon, driver, and screw are placed into the acromion bone tunnel and the screw is advanced. *(From Provencher MT, LeClere LE, Mazzocca AD, et al: Acromioclavicular joint reconstruction. In Reider B, Terry MA, Provencher MT, editors: Operative techniques: sports medicine surgery, 2010, Elsevier.)*

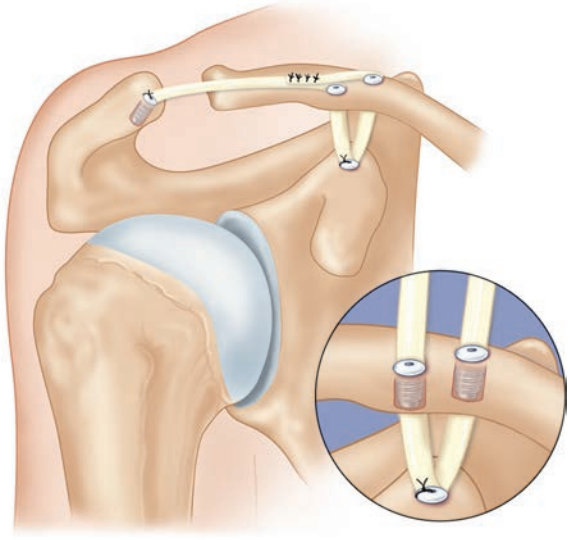

FIGURE 7-32. If both limbs of the graft can reach the acromion, then create two bone tunnels for interference screw insertion and security. *(From Provencher MT, LeClere LE, Mazzocca AD, et al: Acromioclavicular joint reconstruction. In Reider B, Terry MA, Provencher MT, editors: Operative techniques: sports medicine surgery, 2010, Elsevier.)*

Surgical

- CA ligament transfer only provides about 25% of the strength of an intact CC complex if not augmented with suture loop.
- Rockwood coracoclavicular screw has highest tensile strength and stiffness with lowest elasticity, which may predispose to screw cutout or breakage of the screw.
- Mazzocca et al.[1] found that an anatomic reconstruction using doubled semitendinosis through a coracoid

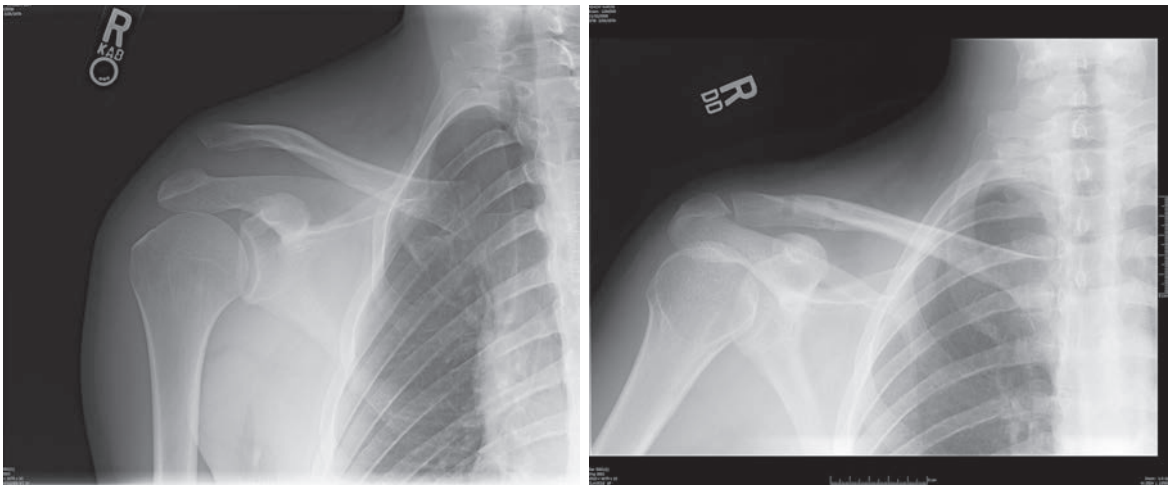

FIGURE 7-33. A, Preoperative radiographs demonstrating type III acromioclavicular dislocation. **B,** Postoperative radiographs following anatomic AC reconstruction.

bone tunnel provided similar resistance to anterior, posterior, and superior forces as the intact CC and AC ligament complex.

Other Surgical Techniques and Options

- The technique chosen for surgical fixation may depend on acuity of injury. Acute injuries may provide some opportunity for healing of the native CC ligament complex. In this case, fixation alone with screw of suture based construct may be considered.
- In chronic situations, healing of the CC ligaments is not expected. Augmentation with allograft or autograft tendon should be considered.
- Choice of surgical technique has minimal impact on postoperative rehabilitation. As all procedures are extraarticular, the risk of stiffness following surgery is limited, and the repair should be protected with support and limited range of motion. Graft or native ligament healing can be expected at 12 weeks at which time strengthening is initiated.
- Early return to play can result in graft stretching and loss of reduction, or in contact sports can lead to clavicle fracture (Figure 7-34).
  - Two drill holes of 5 to 6 mm in diameter are created in a bone that is typically 15 to 20 mm in diameter.



FIGURE 7-34. Clavicle fracture through a bone tunnel after anatomic AC reconstruction.

Before Surgery: Overview of Goals, Milestones, and Guidelines[2]

- Rehabilitation following AC joint reconstruction using tendon autograft or allograft is limited by the time to achieve tendon to bone healing, relying on fixation methods or supplementary suture loop until this time.
- A study by Rodeo et al.[2] found that tendon to bone healing occurs approximately 12 weeks following reconstruction in a dog model, however, allograft reconstruction may require even longer time to incorporate.
- Also, understanding the extremity motions that stress the AC joint is key to preventing stretching or failure of the graft. Forward elevation and abduction have been shown to produce rotational forces at the AC joint.
- Scapular protraction and retraction also produce significant forces at the AC joint and should be avoided until graft remodeling has occurred.
- In addition, the weight of the arm is suspended by the clavicle-scapular complex and early support of the arm is indicated to minimize stress on the graft.

[2]*Prehabilitation, if appropriate, is described in the Nonoperative Rehabilitation section of this chapter.*

GUIDING PRINCIPLES OF POSTOPERATIVE REHABILITATION

- Several studies have shown that translation at the AC joint may be corrected with reconstruction of the CC and AC ligaments, but still fail with less force than the intact ligaments.
- There is a significant difference in the force required to cause the reconstruction to fail depending on technique, and thus rehabilitation protocols may differ based on technique of reconstruction.
- The weight of the arm can produce a significant and constant force on the AC joint and thus sling immobilization is key to prevent downward displacement of the scapula and upper extremity with respect to the clavicle.
- Tendon to bone healing occurs at approximately 3 months, with allograft potentially taking slightly longer.
- AC reconstruction is an extraarticular procedure which decreases the risk of postoperative stiffness, therefore, therapy regimens can be less aggressive with delay of early motion compared with intra-articular shoulder procedures.

Phase I: Immediate Postoperative Period (days 0 to 14)

Clinical Pearls

- The weight of the upper extremity is often a source of pain and potential disruption of the surgically reconstructed AC joint if not sufficiently supported, in particular, during sleep or rest.
- To maintain a position of comfort with minimal stress to the repair, bolstering the extremity with pillows (as well as wearing the sling during rest and sleep) prevents the arm from falling into extension or adduction relative to the torso.
- Ensure that the sling is properly fitted and adjusted to eliminate any unnecessary traction across the AC joint, which will improve sling compliance as well.
- When patients perform elbow range of motion activities, we recommend doing so in the supine position with the elbow supported by a pillow to minimize the force of gravity on the repair.

Goals

- Minimize postoperative pain and swelling.
- Ensure patient understanding of the movements that stress the AC joint to avoid stretching the graft; emphasize the importance of sling compliance.
- Surgeon communication with therapist regarding type of repair, graft used, and any planned hardware removal.
- Protect distal clavicle and re-approximated ligaments/healing structures.

Protection

- Some authors recommend using a platform brace with no shoulder motion for 6 to 8 weeks after surgery.
  - The arm is immobilized in external rotation as this has been shown by some authors to reduce postbracing stiffness.
  - The platform is used to immobilize the AC joint, which is the only link between the thorax and the upper extremity.
- Others recommend a simple sling with wedge to provide some external rotation of the glenohumeral joint.
  - Sling immobilization is recommended by most for at least 2 weeks, others recommend 6 to 8 weeks, whereas some prefer sling immobilization for up to 3 months.
- The authors recommend sling with abduction pillow immobilization for 6 weeks. This provides immobilization of the shoulder with support of the arm.

Management of Pain and Swelling

- Multimodal pain management has been shown to decrease the amount of narcotics needed as well as the side effects of these medications.
- With the arm immobilized, pain medication typically is only required for 3 to 5 days after surgery.
- A combination of narcotic pain medication, short course of ketorolac, and ice are the mainstays of treatment.
  - A short course of ketorolac likely does not affect tendon to bone healing significantly.
  - Cold therapy is an effective pain control method as well as that it decreases swelling.
  - Some pain specialists recommend a scheduled dose of acetaminophen 1000 mg every 6 hours combined with a non-acetaminophen containing narcotic medication used as needed, stating this can reduce the overall amount of narcotic required.
- The physician must be very specific when discussing the patient's symptoms as many patients will verbally communicate muscle spasms as pain. Valium (diazepam) or flexeril can be added for patients experiencing spasm.
- Swelling can be a major source of discomfort for the patient and efforts to reduce swelling should be instituted. This includes a short course of ketorolac (2 to 3 days) if the patient has normal renal function, an ice pack or circulating ice machine (Figure 7-35), and sleeping slightly upright to elevate the shoulder.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- May begin active and passive range of motion of the wrist and hand immediately. Active and passive elbow



FIGURE 7-35. Cryotherapy with operative upper extremity supported.

flexion and extension is allowed without weight in the early postoperative period, and should be encouraged several times per day to prevent elbow stiffness.
- The authors recommend against shoulder ROM in the first 6 weeks following surgery. At this point shoulder ROM may be instituted with avoidance of motions that stress the AC joint, including: forward elevation and abduction (especially greater than 90°), cross-body adduction, and scapular protraction and retraction.

Soft Tissue Therapy Techniques

- Soft tissue techniques to cervical musculature (i.e., scalenes), torso, parascapular and shoulder girdle musculature

Stretching and Flexibility Techniques for the Musculotendinous Unit

- No stretching to the pectoralis minor or upper trapezius during this phase due to their attachments at the coracoid and clavicle respectively.

Other Therapeutic Exercises

- For the elite athlete, lower body strengthening can continue safely in the early postoperative period.
- Core strengthening can be performed with the arm in the sling.
- Stationary bicycle can be used for cardiovascular conditioning to prevent displacing forces on the AC joint caused by arm motion with running.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Deltoid and trapezius muscle activation is typically minimized until 6 weeks following reconstruction to minimize the pull on the components of the AC joint.
- Depending on the technique used for reconstruction, the coracoid process can be weakened by screws, bone tunnels or drill holes. Thus, the authors recommend against resisted elbow flexion with even minimal weight in the early postoperative period to prevent fracture of the coracoid process. This can safely be introduced approximately 8 weeks following surgery with light weights, and strengthening can begin at 12 weeks.

Sensorimotor Exercises

- Again, for the elite athlete these can begin several days following surgery in a supervised setting with the arm in a sling. This could include basic core and kinetic work that is supervised, with the arm in a sling. For most patients this would be restricted until at least 6 to 8 weeks to avoid falling or stumbling that may produce sudden movements with the operative extremity.

Open and Closed Kinetic Chain Exercises

- No AROM of the glenohumeral joint
- Supported or short lever Codmans (Figure 7-36) exercises during this phase, three times a day
- Ball squeeze for hand
- Wrist and gripping exercises

TIMELINE 7-4: **Postoperative Rehabilitation after AC Joint Reconstruction for AC Separations**

PHASE I (weeks 0 to 6)	PHASE II (weeks 6 to 10)
• Sling or platform brace • PT modalities • ROM elbow, wrist, hand • Week 2 begin TBS/TAS/TLS activities as recommended and tolerated	• DC sling • PT modalities as needed • PROM for GHJ to 90° advance to full after 8 weeks • Mobilizations as needed • Limit cross body adduction, scapular protraction/retraction, and end-range FE/ABD • TBS/TAS/TLS activities as recommended and tolerated



FIGURE 7-36. Supported Codman's.

Techniques to Increase Muscle Strength, Power, and Endurance

- Strengthening should be avoided until full passive and active motion have returned, which is likely at 10 to 12 weeks following AC reconstruction.

Neuromuscular Dynamic Stability Exercises

- Elite athletes may begin this in the next phase.

Plyometrics

- Lower extremity plyometrics can begin at 8 weeks following surgery.

Functional Exercises

- These can be incorporated at the same time as strengthening exercises begin, at about 10 to 12 weeks.

Sport-Specific Exercises

- These can be incorporated into the rehabilitation program once full passive and active motion of the glenohumeral joint has been achieved. Typically after 12 weeks.

Milestones for Progression to the Next Phase

- Minimal to no pain
- 100% sling/immobilizer compliance
- No signs or symptoms of compromise or failure of the repair

Phase II: Early Post-Operative Healing (weeks 2 to 6)

Clinical Pearls

- Again, the patient should be informed that the graft takes time to incorporate. The therapist and surgeon must remind the patient of the precautions and the anatomical and biomechanical reasons for these precautions to avoid non-compliance.
- As pain improves, the patient will naturally attempt more activities and allowed activity should be reiterated.

Goals

- Prevent loss of motion of hand, wrist, and elbow.
- Protect the reconstruction.
- Prevent loosening or migration of fixation.
- Eliminate residual postoperative pain and swelling.

Protection

- Some authors recommend using a platform brace with no shoulder motion for 6 to 8 weeks after surgery.

TIMELINE 7-4: Postoperative Rehabilitation after AC Joint Reconstruction for AC Separations (Continued)

PHASE III (weeks 10 to 14)	PHASE IV (weeks 14 to 24)	PHASE V (weeks 24 to 52)
• PT modalities as needed • PROM-full • Mobilizations as needed • Begin AAROM/AROM when full PROM • Week 12 begin ABIR, ABER stretch • TBS/TAS/TLS activities as recommended and tolerated • Scapular exercises—PREs • TAS—Biceps/Triceps – PREs • Glenohumeral exercises—PREs • Rotator cuff exercises—PREs • PNF exercises • OKC Rhythmic stabilization exercises • CKC exercises	• PROM—maintain full motion • Mobilizations as needed • TBS/TAS/TLS activities as recommended and tolerated • Scapular exercises—PREs • TAS—biceps/triceps PREs • Glenohumeral exercises—PREs • Rotator cuff exercises—PREs • PNF exercises • OKC rhythmic stabilization exercises • CKC exercises • CKC manual perturbation exercises • Sport-specific exercises begin • Overhead throwing athletes can begin an easy interval throwing program	• SEE non-operative AC joint injury chapter • Maintenance Program • PROM-maintain full motion • Mobilizations as needed • TBS/TAS/TLS activities as recommended and tolerated • Scapular exercises—PREs • TAS—biceps/triceps—PREs • Glenohumeral exercises—PREs • Rotator cuff exercises—PREs • IR/ER exercises at 90° • Thrower's Ten progress intensity • PNF exercises • OKC rhythmic stabilization exercises • CKC exercises • CKC manual perturbation exercises • Sport-specific exercises progressed • Overhead throwing athletes progress through an interval throwing program

  - The arm is immobilized in external rotation as this has been shown by some authors to reduce postbracing stiffness.
  - The platform is used to immobilize the AC joint, which is the only link between the thorax and the upper extremity.
- Others recommend a simple sling with wedge to provide some external rotation of the glenohumeral joint.
  - Sling immobilization is recommended by most for at least 2 weeks, others recommend 6 to 8 weeks, whereas some prefer sling immobilization for up to 3 months.
- The authors recommend sling with abduction pillow immobilization for 6 weeks. This provides immobilization of the shoulder with support of the arm.

Management of Pain and Swelling

- The patient should require very little in terms of pain medication at this time; acetaminophen may be all that is needed.
- Cold therapy is not only an effective method at reducing swelling but it also improves pain control.

Techniques for Progressive Increase in Range of Motion

Soft Tissue Techniques

- Continue soft tissue mobilization to muscles discussed in Phase 1. Begin scar mobilization when incisions are sufficiently closed.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- No stretching to the pectoralis minor or upper trapezius during this phase due to their attachments at the coracoid and clavicle respectively.

Other Therapeutic Exercises

- Stationary bike at weeks 3 to 4 while wearing sling.
- Isometrics exercises for the transverse abdominals, gluteals, and uninvolved muscle groups

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- No glenohumeral AROM during this phase.
- Isometrics within the sling may be initiated.

Sensorimotor Exercises

- Elite athletes may begin LE unilateral balance (Figure 7-37) and proprioceptive exercises.
- Single limb LE balance with head movements, including neck flexion and extension, lateral tilt to the right and left, cervical rotation and combine motions such as looking over shoulder and sport-specific head/neck movement patterns. This can improve vestibular and neck proprioceptive input and improve balance.



FIGURE 7-37. Lower extremity unilateral balance.

Open and Closed Kinetic Chain Exercises

- May begin trunk or thoracic rotation while wearing sling.

Functional Exercises

- Functional 1/3 squats (wearing sling) for elite athletes
- Steps ups/step downs
- Stationary lunges for elite athletes

Milestones for Progression to the Next Phase

- No postoperative swelling or pain
- Elbow, wrist and hand ROM equal to the contralateral extremity
- No signs or symptoms of compromise or failure of the repair

Phase III: Mobilization (weeks 6 to 10)

Clinical Pearls

- Pain during this phase is often generated from mild glenohumeral stiffness or from the subacromial space. This may occur upon initiating PROM of the glenohumeral joint.
- Clinically, we have had success eliminating pain during this phase with soft tissue mobilization techniques to the supraspinatus tendon while the GH joint is in the loose pack position.
- In addition, gentle Grades 1 to 2 joint mobilization to the GH joint (generally, posterior glides due to ROM limitations) may be applied to improve arthrokinematics that may be contributing to subtle rotator cuff impingement due to stiffness and faulty mechanics.

Goals

- Pain-free glenohumeral (GH) joint PROM and progression to AROM within postoperative restrictions to prevent stiffness.
- Limit motions that increase stress on the AC joint-Internal rotation behind the back, cross-body adduction, abduction, scapular protraction and retraction, and end-range forward elevation.
- If coracoclavicular screw was used, this is typically removed at 8 weeks at which point patients may progress to full active and passive motion.
- Prevent fixation failure before 8 weeks by limiting motion to below shoulder level and lifting to less than 5 pounds.

Protection

- Discontinue sling after week 6; may continue use until week 8 for comfort until motion returns.

Management of Pain and Swelling

- Continue or initiate pain modalities as needed.
- Apply moist heat to the AC joint for stiffness.
- Continue cryotherapy following physical therapy.
- Ice the rotator cuff/ subacromial space if indicated.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- No active GH joint ROM. PROM only for the GHJ to 90° of flexion in the scapular plane. Continue PROM to the wrist and elbow. Grades 1 to 2 joint mobilization to the GH joint (no AC joint mobilization) to facilitate PROM. Primarily, mobilization of the GH joint in the anterior to posterior direction is applied during this phase.

Soft Tissue Techniques

- Continue scar mobilization and soft tissue mobilization as described in previous phases.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Begin very gentle stretching of levator and pectoralis at weeks 8 to 10.

Other Therapeutic Exercises

- LE gym weights and machines; light resistance
- Elliptical using LEs only; no UEs
- Stationary bike with increased resistance

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- May begin AAROM and AROM when PROM returns to within approximately 75% of full ROM
- Dowel or pulley for AAROM flexion, scaption, ER/IR beginning in supine, progressing to upright position as the patient advances (Figure 7-38)



FIGURE 7-38. Active assisted range of motion in supine with dowel.



FIGURE 7-39. Lower extremity proprioceptive exercise on BOSU ball.

Sensorimotor Exercises

- Elite athletes may begin LE unilateral balance and proprioceptive exercises (Figure 7-39).
- Single limb LE balance with head movements, including cervical rotation, flexion/extension and combine movements.

Open and Closed Kinetic Chain Exercises

- Closed chain range of motion exercises are used such as table or wall slides, and have been shown to limit the activation of shoulder musculature.
- Supine flexion or pulleys can be used to improve forward elevation, keeping the upper extremity below shoulder level (less than 90° of flexion).
- Closed chain scapular exercises and kinetic chain exercises begin at 8 weeks, allowing the patient to improve scapular kinetics. These can include shoulder shrugs, shoulder rolls, rows, stability ball wall circles and push-ups. Scapular clocks, scapular depression, and

closed chain protraction can also improve scapular kinetics.

Techniques to Increase Muscle Strength, Power, and Endurance

- Seated small arc scapular depression at weeks 8 to10.
- Seated scapular retraction at weeks 8 to 10.
- Biceps and triceps strength with no weight > 5 lbs at weeks 8 to 10.

Neuromuscular Dynamic Stability Exercises

- Scapula PNF in sidelying; repeated isometric progressing to slow reversals (Figure 7-40)
- Elbow PNF
- Begin with rhythmic stabilization in supine with GH joint flexed to 90°
- Body blade at side weeks 8 to 10

Plyometrics

- LE low impact plyometrics at week 8 for elite athletes

Sport-Specific Exercises

- LE sport-specific agility drills for elite athletes

Milestones for Progression to the Next Phase

- GH joint: 90° of PROM flexion in the scapular plane
- No postsurgical pain or swelling
- Repair intact

Phase IV: Strengthening (weeks 10 to 14)

Clinical Pearls

- As the patient begins AROM, clinically we have observed the patient exhibiting signs and symptoms consistent with impingement. Continue soft tissue mobilization to the supraspinatus or posterior RC if tender and painful during this phase.
- Restore scapulohumeral rhythm with manual cueing to further improve faulty arthrokinematics.



FIGURE 7-40. Scapula PNF in sidelying.

Goals

- Restore scapulohumeral rhythm
- Optimize strength of UE and parascapular musculature
- Full pain-free AROM by week 14

Protection

- May apply postural tape, kinesiotape to cue or facilitate parascapular muscles.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Continue joint mobilization, manually facilitate scapulohumeral rhythm. This is performed by guiding the scapula through rotation, abduction, and depression during active glenohumeral flexion and abduction. The therapist's hand placement can vary, but standing behind the patient with one hand just superior to the spine of the scapula and the other at the inferior medial scapular border is a comfortable and effective positioning. Continue PROM and AAROM to full ROM by week 12.
- Low-load long-duration capsular stretch if lacking end-range combined ABIR or ABER.

Soft Tissue Techniques

- Continue scar mobilization and soft tissue mobilization as described in previous phases.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Hold relax stretching of pectoralis major, minor, latissumus dorsi, levator scapula as needed.

Other Therapeutic Exercises

- Upper body ergometer (Figure 7-41)
- LE gym weighs and machines; increase resistance

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Full can to 90° only for nonthrowers with light weights
- Shoulder raises (flexion, abduction) to 90° with light weights
- Biceps curls; begin with supported preacher curl

Sensorimotor Exercises

- Hand on baps board in partial UE weightbearing
- Increase UE weightbearing on unstable surface (i.e., ½ kneeling UE balance on BOSU ball)
- Progress UE resistance band exercises with decrease base of support (unilateral balance or on unstable surface)

Open and Closed Kinetic Chain Exercises

- Scapular clocks (Figure 7-42)
- Wall protraction at weeks 9 to 10 with Bilateral UEs, progressing to Unilateral UE



FIGURE 7-41. Upper body ergometer.

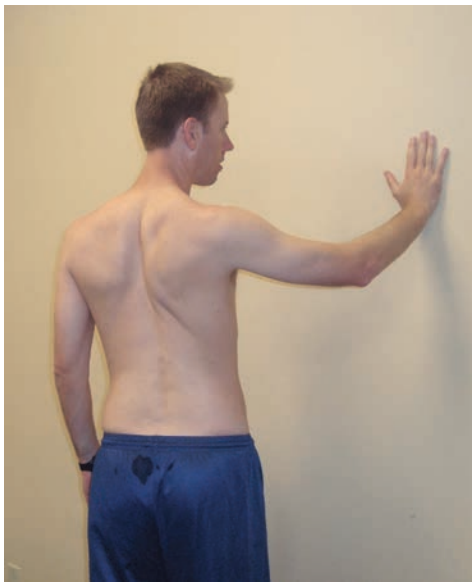

FIGURE 7-42. Scapular clocks.

- AAROM using towel for IR
- AAROM using with wand or dowel for flexion, abduction, ER.

Techniques to Increase Muscle Strength, Power, and Endurance

- Sidelying ER with no resistance
- Prone "I" scapular 3-step exercise at weeks 10 to 12. (The patient is positioned prone with arms at the sides. There are three distinct movements emphasized: (1) scapular depression, followed by (2) scapular retraction and finally (3) glenohumeral extension.)
- Isometric ER, IR, flexion, extension and abduction at week 10
- Progress to light resistance band for rotator cuff strength, in neutral at week 12
- Progress to scapular depression and rows with light resistance band at week 12

Neuromuscular Dynamic Stability Exercises

- GH joint PNF in supine position; rhythmic stabilization progressing to slow reversals
- Progress to seated GH joint PNF
- Body blade at varying flexion, abduction and scaption angles (Figure 7-43)

Plyometrics

- Progress LE plyometrics (i.e., hopping, jumping, box jumps)

Functional Exercises

- Lawnmowers. Utilizing a bench, with one leg kneeling, one standing, a dumbbell weight is used in a simulated lawnmower starting (i.e., pulling the rope to start a lawnmower engine) while the core is stabilized
- Russian dead lifts (RDLs) a "stiff-legged" deadlift, often performed unilaterally with dumbbell
- Begin jogging at week 12

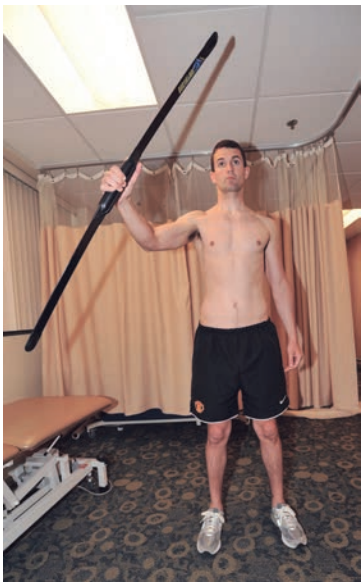

FIGURE 7-43. Body blade dynamic stability.

Sport-Specific Exercises

- LE sport-specific agility drills for elite athletes

Milestones for Progression to the Next Phase

- Full PROM, AROM GH joint compared with the nonoperative side or if this has a prior or concurrent injury, then compared to normative values
- Strength of UE at least 4+/5 using manual muscle testing (MMT)
- No pain or swelling noted by observation or palpation
- Repair intact

Phase V: Functional Recovery and Initial Return to Sport (weeks 14 to 24)

Clinical Pearls

- Surgical technique should be taken into consideration. If graft reconstruction was performed, graft incorporation and remodeling will continue for 6 months or more, and delayed integration may occur with allograft tissue.
- Patient and therapist should understand the biologic phases of graft incorporation and remodeling and the implications to return to sport.
- If continued pain at the subacromial space (SAS) or rotator cuff during this phase, assess pectoralis minor length and formally assess lower and middle trapezius during this phase using manual muscle testing.
- If flexibility or strength is impaired, emphasize correction of these deficits during this phase. ACJ mobilization may be considered during the latter part of this phase as well.

Goals

- Continue strengthening, focusing on scapular stabilizing muscles and core strengthening
- Initiate sports specific exercises
- Maximize muscular strength, flexibility and endurance

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Continue Grades 3 to 4 GH joint mobilization, with scapulothoracic joint mobilization as needed.

Soft Tissue Techniques

- Continue scar mobilization and soft tissue mobilization as described in previous phases.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Continue stretching of pectoralis major, minor, latissimus dorsi, levator scapula as needed.

Other Therapeutic Exercises

- Sit ups
- Add bent over low row with light weight
- Progress to low and mid row machine (low resistance)
- Begin plank progression (start with half planks or pillars)

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Full can with increased weights
- Shoulder raises (flexion, abduction) with increased weight
- Biceps curls, unsupported with dumbbell or bar
- Triceps press or extensions with dumbbell in neutral (not overhead)
- Kettlebell low row mid phase
- Chest press; begin seated with machine
- Seated short arc machine flys and progress to cable flys later in this phase

Sensorimotor Exercises

- Hand-eye coordination drills for racquet or overhead athletes.

Open and Closed Kinetic Chain Exercises

- Increase resistance to rotator cuff, middle, lower trapezius and serratus anterior strength
- Protraction progression: unilateral at wall, bilateral at table, bilateral half kneeling unstable surface

Techniques to Increase Muscle Strength, Power, and Endurance

- Add PNF patterns with resistance bands.
- Perform Prone T and Y exercises (Figures 7-44 and 7-45).
- Begin isokinetics of shoulder girdle/upper extremity musculature (i.e., rotator cuff, biceps, triceps).
- Do wall push up progression (i.e., leaning on wall to leaning on bench to ½ or kneeling pushups to full pushups).
- Late phase: add "endurance" sets to all PREs.



FIGURE 7-44. Prone scapular strength "T" exercise.



FIGURE 7-45. Prone scapular strength "Y" exercise.

- Transition from hypertrophic (lower weight, higher volume and repetition maximum) to strength load (heavier load and lower repetition maximum with failure at 8 to 12 repetitions).

Neuromuscular Dynamic Stability Exercises

- Progress UE weight on unstable surface (i.e., unilateral wall ball perturbations)
- Body blade in end range positions and varying planes

Plyometrics

- Begin UE plyometrics (i.e., dribble on floor, progress to wall dribble)
- PlyoBall/medicine ball rebound and pass (Figure 7-46)

Functional Exercises

- Begin swimming at week 16.

Sport-Specific Exercises

- Overhead athletes begin throwing program (Figure 7-47): Thrower's Ten and interval throwing program
- Thrower's Ten[3]



FIGURE 7-46. Upper extremity plyometric weighted ball toss.



FIGURE 7-47. Resistance band overhead throwing exercise.

- UE agility exercises later in this phase (i.e., dribbling drills on floor and overhead onto wall, timed volleyball setting frills against wall)

Milestones for Progression to the Next Phase

- Strength 5/5 including RC, middle and lower trapezius and serratus anterior on manual muscle testing
- No pain or limitation with throwing program (for overhead athletes)

Phase VI: Advanced Functional Recovery and Return to Sport (weeks 24 to 52)

Goals

- Return to sport when full ROM and strength at 90% of contralateral extremity.
- Perform maintenance scapular stabilizing exercises and core strengthening
- Prevent future injury/AC joint preservation by constructing a maintenance program that parallels treatment of non-surgical AC joint disruption.
- Refer to the nonsurgical treatment section of this chapter.

Criteria for Return to Sport

General

- No pain with sport-specific movements
- Full active and passive shoulder ROM without pain as compared to the opposite extremity
- Strength greater than or equal to 90% of the contralateral extremity using manual muscle testing or Cybex

Sport-Specific

- Overhead (Racquet) athlete: Achieve GHJ ROM symmetrical as well as ROM of C/S and T/S within normal limits as measured with a goniometer.
- Overhead (throwing) athlete: Will require gradual return to throwing with structured throwing program. Close attention to restoring abduction, external rotation and eliminating glenohumeral internal rotation deficit is recommended. Scapular strength including serratus anterior, lower and middle trapezius, as well as hip rotator strength symmetrical on manual muscle testing.
- Contact sports: Pain-free loaded adduction symmetrical. Minimum 6 months before return to contact activities recommended for graft reconstruction.

Continuing Fitness or Rehabilitation Exercises

- Cardiovascular program, and cross training to avoid repetitive strain

- Interval training to include varying speeds and plyometrics
- Comprehensive balanced strength/weight training program for extremities and core
- Sport-specific agility drill program
- Progressive strengthening should be continued after return to sport (Maximum strength recovery occurs at approximately one year postoperatively.)

Exercises and Other Techniques for Prevention of Recurrent Injury

- No specific exercise may prevent risk of recurrence
- Risk is associated with activity level and type of activities being performed
- Taping to stabilize the AC joint, proper fitting footwear, uniform, shoulder padding and bracing
- Proper pregame warm-up program
- Maintenance stretching program
- No good evidence demonstrating the ability of these exercises and techniques to help prevent recurrence

Evidence

Cote M, Wojcik K, Gomlinski G, et al: Rehabilitation or acromioclavicular joint separations: operative and nonoperative considerations. *Clin Sports Med* 29:213–228, 2010.

This manuscript reviews the relevant literature on nonoperative and postoperative rehabilitation for AC joint injuries and recommends a treatment protocol. The rehabilitation protocol following AC joint reconstruction described is similar to that described in this chapter with prolonged immobilization based on the healing of the soft tissue graft to bone.

Culp L, Romani W: Physical therapist examination, evaluation, and intervention following the surgical reconstruction of a grade III acromioclavicular joint separation. *Phys Ther* 86:857–869, 2006.

This was a case report of a 34-year-old male who underwent an AC reconstruction. The patient was able to return to preinjury levels of function at 5 months from surgery. (Level V evidence)

Mazzocca AD, Santangelo SA, Johnson ST, et al: A biomechanical evaluation of an anatomical coracoclavicular ligament reconstruction. *Am J Sports Med* 34:236–246, 2006.

This study compared 42 cadaveric AC reconstructions randomly assigned to three groups: arthroscopic reconstruction, anatomic coracoclavicular reconstruction, and a modified Weaver-Dunn procedure. The Weaver-Dunn procedure was significantly more lax than the other two procedures, and the anatomic reconstruction had significantly less anterior and posterior translation.

Rios CG, Arciero CA, Mazzocca AD: Anatomy of the clavicle and coracoid process for the reconstruction of the coracoclavicular ligaments. *Am J Sports Med* 35:811–817, 2007.

This cadaveric study evaluated the osteology of the clavicle and coracoid as well as the anatomic location of the insertions of the coracoclavicular ligaments. The aim of this study was to develop an anatomical coracoclavicular reconstruction technique.

Rodeo SA, Arnoczky SP, Torzilli PA, et al: Tendon-healing in a bone tunnel. A biomechanical and histological study in the dog. *J Bone Joint Surg Am* 75:1795–1803, 1993.

This study evaluated the time for tendon to bone healing in a dog model. This group demonstrated that, after 12 weeks, tendons began failing due to intersubstance tearing rather than at the tendon bone interface, indicating the tendon had healed within the bone tunnel.

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1. Mazzocca AD, Santangelo SA, Johnson ST, et al: A biomechanical evaluation of an anatomical coracoclavicular ligament reconstruction. *Am J Sports Med* 34:236–246, 2006.
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3. Wilk KE, et al: The Advanced Thrower's Ten Exercise Program: A new exercise series for enhanced dynamic shoulder control in the overhead throwing athlete. *Phys Sportsmed* 39:90–97, 2011.

Multiple Choice Questions

QUESTION 1. What is the appropriate duration of postoperative immobilization following ACJR?

A. 3 weeks
B. 3 months
C. 4 weeks
D. 6 weeks

QUESTION 2. During the initial 6 weeks of postoperative rehabilitation, the ROM allowed is:

A. AROM to 90° flexion after 2 weeks of no GHJ ROM
B. PROM GHJ flexion to 90° in the scapular plane only after 2 weeks of no GHJ ROM
C. No PROM of GHJ until week 6
D. PROM flexion to 120° at week 4 and elbow AROM beginning postop day 1

QUESTION 3. Which of the following is a known complication following anatomic AC joint reconstruction?

A. axillary nerve palsy
B. short head of the biceps tendon rupture
C. clavicle fracture
D. proximal humerus fracture

QUESTION 4. What is the rate limiting step in terms of preventing failure following AC reconstruction and how long does this take?

A. soft tissue to bone healing, 6 weeks
B. soft tissue to bone healing, 3 months
C. biocomposite screw absorption, 6 months
D. graft remodeling, 4 weeks

QUESTION 5. What of the listed complications is not a theoretical or known complication of using a coracoid screw for temporary or permanent fixation?

A. potential musculocutaneous nerve injury
B. coracoid fracture
C. screw pull-out
D. acromial fracture

Answer Key

QUESTION 1. Correct answer: **D** (see Phase I, Protection)

QUESTION 2. Correct answer: **B** (see Phase I, Manual Therapy Techniques)

QUESTION 3. Correct answer: **C** (See Other Surgical Techniques and Options)

QUESTION 4. Correct answer: **B** (See Overview of Goals, Milestones and Guidelines)

QUESTION 5. Correct answer: **D** (See acromial fracture (D)

BEYOND BASIC REHABILITATION: RETURN TO ICE HOCKEY AFTER ACROMIOCLAVICULAR INJURY

Amy Resler, PT, DPT, CSCS, Wendell M.R. Heard, MD, Nathan A. Mall, MD, and Nikhil N. Verma, MD

Introduction

ASPECTS OF HOCKEY THAT REQUIRE SPECIAL ATTENTION IN REHABILITATION*

- In the case of acromioclavicular joint injuries in ice hockey, several intrinsic characteristics of the sport itself must be taken into account while rehabilitating an athlete to return to play.
- The contact sport routinely involves direct blows, checking opposing players, and frequent falls.
- In addition, the low friction surface of ice provides an unstable platform for players while shooting, propelling, and checking.
- The high anaerobic requirements of hockey must also be considered when determining whether a player is sufficiently fit to return.

*The same criteria and procedures are employed to return a patient back to weightlifting.

- It has been shown that in men's collegiate hockey in the United States, collisions with an opponent can cause as many as 32.8% of injuries, whereas collisions with the boards account for 18.6% of all injuries.[1]
- Overall the injury rate in hockey is 4.9 per 1000 athletic exposures, with an athletic exposure being defined as a single player participating in a single game or practice.[1] In this study, acromioclavicular joint injuries were the third most common injury behind concussion and medial collateral ligament sprains.[1]
- Another study of 77 hockey players by Norfray[2] demonstrated that 45% had asymptomatic x-ray abnormalities, which included osteolysis of the acromioclavicular joint and callus from united and nonunited distal clavical fractures.
- Despite these injuries, Pettersson and Lorentzon showed that only one in four players with acromioclavicular joint separation were shown to miss more than 1 week of practice or games.[3]
- Gladstone et al.[4] have provided the current rehabilitation program for athletes suffering an AC joint injury. Phase I consists of ice and short-term immobilization with sling use of up to 2 weeks. Pain and inflammation reduction with subsequent range of motion exercises are the goals. Active assisted motion is advanced in the pain-free patient.
- Phase II begins when 75% of motion is regained, AC joint palpation produces minimal pain, and there is 4/5 manual muscle testing for the deltoid and upper trapezius. Phase II concentrates on advancing to full pain-free motion and increasing isotonic strength. Strengthening of the deltoid, trapezius, and rotator cuff is emphasized. Once full, painless range of motion is achieved with no tenderness to palpation of the AC joint and muscle strength 75% of the contralateral side, Phase III is begun.
- Phase III strengthens the shoulder and increases power and endurance using plyometric drills and isotonic exercises. When isokinetic strength is equal to the other side.
- Phase IV is started and concentrates on sport-specific drills.

Phase I: Advanced Strength and Conditioning Programs

Periodization

- Rehabilitation of the immediate postoperative patient must be separated from the postinjury patient.
- In patients undergoing nonoperative treatment, Phase I can begin once the patient has adequate pain control. The total rehabilitation time in such a case is 6 to 8 weeks.
- The postoperative patient, however, should be strictly immobilized for the first 6 weeks after injury. During this time, range of motion of the wrist, hand, and fingers can be performed. To protect the repair from having to support the entire weight of the arm, elbow range of motion exercise should only be performed in the supine position with a pillow under the elbow for support.

- After this initial 6-week period of immobilization, the Phase I regimen can be started.
- Phase I begins following the initial postoperative or postinjury period during the athlete's off-season.
- This mesocycle occurs for approximately 6 to 8 weeks in the postoperative patient.
- The nonoperative patient will be in Phase I until 75% of motion is regained, AC joint palpation produces minimal pain, and there is 4/5 manual muscle testing of the deltoid and upper trapezius.

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- Flexibility/joint mobility for joint stability
- Sensorimotor and balance training
- Training for optimum muscle balance
- Neuromuscular dynamic stability exercises
- Functional training

Training Principles Used in the Design of the Program

- Principle of progression
- Principle of overload

Application of Acute Training Variables

- Phase I is the hypertrophy or endurance phase. The focus is on balancing muscle groups, in particular the shoulder girdle, in order to stabilize the acromioclavicular (AC) joint. This phase is particularly important for reconditioning following an injury or surgery, as well as for prevention of injury, re-injury, or surgical failure.
- It has been proposed that capillarization occurs during this time, which is necessary for strength optimization in the later training phases.
- Phase I training regimens involve high repetitions of low loads performed to isolate opposing muscle groups. These are carried out at low intensity with the focus on body mechanics and avoiding compensatory strategies.
  - Repetitions: 12 to 25
  - Sets: 2 to 4
  - Rest interval: 1 minute
  - Intensity: low
  - Repetition tempo: slow, progressing to moderate as approaching next phase
  - Training frequency: 2 to 4 days per week
  - Training duration: 30 to 60 minutes
  - Training volume: sum of all repetitions performed during one session
  - Specific exercises used in the training
    - Shoulder girdle
- Three-way shoulder raise
- Chest press
- Seated rows
- One-arm dumbbell row and latissimus dorsi row
- Latissimus dorsi pulls
- Bent-over row
- Chest fly
- Rotator cuff program with pulleys
  - Elbow
- Triceps press
- Biceps curl
  - Forearms
- Wrist curls
- Pronation

TIMELINE 7-5: **Returning to Hockey After AC Joint Injury: Nonoperative Treatment**

PHASE I (weeks 1 to 6)	PHASE II (weeks 4 to 8)	PHASE III (weeks 6 to 12)
• Time of injury until 75% of motion is regained. AC joint is minimally tender to palpation, and there is 4/5 manual muscle strength of deltoid and upper trapezius. • Repetitions: 12 to 25 • Sets: 2 to 4 • Rest Interval: 1 min • Intensity: low • Rep tempo: slow to moderate • Duration: 3 to 60 min • Frequency: 2 to 4 days/week • Shoulder: shoulder raises, chest press/fly, rows, lat pull, rotator cuff • Elbow: triceps press, biceps curl • Forearm: wrist curl, pronation, supination • Legs/hip: leg press, squats, glute press, hamstring curl, glute/calf raise • Vestibular/balance: posturography, unstable surgace progression • Functional: fitter, side-to-side slide board, thoracic spine ROM • CV: rowing machine, jogging, stationary cycling, skating • Flex/stretch: shoulder girdle, adductors, quads	• Begins with 75% of motion is regained, AC joint is minimally tender to palpation, and there is 4/5 manual muscle strength of deltoid and upper trapezius. Phase II will continue until full painless range of motion is achieved, there is no tenderness to palpation of the AC joint, and strength is 75% of the contralateral side. • Repetitions: 8 to 12 • Sets: 3 to 5 • Rest interval: 1 min • Intensity: moderate • Rep tempo: slow to moderate • Duration: 3 to 60 min • Frequency: 3 to 4 days/week • Shoulder: bench press, incline, decline, dumbbells • LE: multi-planar lunge, step-ups, kettlebell lawnmowers, cable pulleys, diagonals, crossovers • Vestibular/balance: perturbation on unstable surface • Functional: push-ups, planks, unstable surface planks, abdominals • CV: increase intensity, rowing, running, cycling, elliptical, skating	• Begins when full painless range of motion is achieved, there is no tenderness to palpation of the AC joint, and strength is 75% of the contralateral side. Phase III will continue until isokinetic strength is equal to the other side. • Repetitions: 3 to 6 (max) • Sets: 3 to 5 • Rest interval: 3 to 5 min • Intensity: moderate-high • Rep tempo: moderate-high • Duration: 30 to 90 min • Frequency: 1 to 3 days/week • Add power load to strength exercises • Olympic lifts: snatch, power clean • Plyometrics: PlyoBall sit-ups, drop-catch push-ups, medicine ball plyopass, LE bounding • Sprints, drills, agility, running with resistance • Obstacles, cutting, punching bag, "check" drills • Falls and "checks: strategies • Low level skating/shooting drills • Focus on recover, stretching, flexibility • Adequate nutrition, hydration • Injury prevention: shoulder pads, taping

- Supination
  - Legs/hip Girdle
- Unilateral leg press
- Squats using Smith machine
- Four-way hip machine
- Glute press
- Hamstring curls
- Calf raises
- Glute-hamstring raise
  - Vestibular and balance training
- Posturography
  - Lui and colleagues[5] found that use of a sling for immobilization following shoulder injury affects balance and decompensates the vestibular system. They used computerized dynamic posturography (CDP). CDP makes an objective assessment of balance and postural stability by providing a dynamic test condition.
  - In addition, Alpini and colleagues[6] propose that the vestibular systems of ice hockey players are particularly stressed due to the brisk movements of the game. The proprioceptive input to the vestibular system from the ice as a stable surface is not reliable. This is another challenge to the motor control and balance of the ice hockey athlete.
  - This equipment, commonly known as the Equitest is used for evaluation and training or rehabilitation purposes in rehabilitation, physical therapy and athletic training centers. The authors feel that the addition of posturography training would be an excellent adjunct in the rehabilitation program for return to hockey following sling use.
- Unstable surface balance—B LE to U LE progression
  - Functional exercises
- Fitter
- Side-to-side slide board
- Thoracic spine range of motion exercises
  - Cardiovascular training
- Rowing machine
- Jogging
- Stationary cycling
- Upper body ergometer
- Skating

Application of Chronic Training Variables

- Cardiovascular conditioning is performed during this phase, though at low intensity, and for moderate to long duration.
- Flexibility and stretching—in particular across the shoulder girdle (to focus on the pectoralis major, pectoralis minor, and levator scapulae), adductors, and quadriceps—are integrated into the training program.

Phase II: Performance Enhancement Training Techniques

Periodization

- Phase II is initiated at about 12 weeks after surgery for the postoperative patient.
- The nonoperatively treated patient will begin Phase II when 75% of motion is regained, AC joint palpation produces minimal pain, and there is 4/5 manual muscle testing for the deltoid and upper trapezius.
- Phase II will continue until full, painless range of motion is achieved, with no AC joint tenderness and muscle strength at 75% of the contralateral side.

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- Core training
- Cardiorespiratory training
- Multi-planar training activities
- Training for optimum muscle functional strength
- Training for optimum muscle functional power
- Training for speed, agility, quickness (SAQ)
- Sport-specific training

Training Principles Used in the Design of the Program

- Principle of progression
- Principle of overload
- Principle of variation
- Principles of specificity—specific adaptation to imposed demands (SAID)

Application of Acute Training Variables

- Phase II is the strength phase. The goal here is to maximize strength at varying speeds and joint angles, with a decreased base of support, taking measures not to use compensatory muscles or re-injure the AC joint. Compared to the previous phase, Phase II calls for an increase in load, with an accordant decrease in the number of repetitions.
- Repetitions: 8 to 12
- Sets: 3 to 5
- Rest interval: 1 minute
- Intensity: moderate
- Repetition tempo: low to moderate
- Training frequency: 3 to 4 days per week (alternating days, no consecutive days of same muscle group)
- Training duration: 30 to 60 minutes
- Training volume: the amount lifted or number of repetitions per the training session
- Specific exercises used in the training
  - Continue Phase I shoulder girdle, elbow, wrist, and lower extremity exercises, incorporating modified acute training variables (increased load and intensity; decreased number of repetitions)
  - Advance chest press to bench press, incline, and decline; progress from using bar to using dumbbells
  - Add multi-planar lunging, step-ups, kettle bell lawnmowers, cable pulleys, diagonals, and crossovers
  - Vestibular and Balance training: include perturbation on unstable surfaces
  - Functional exercises: pushups, planks, unstable surface planks, abdominals
  - Cardiovascular training: increase intensity of rowing, cycling, running, elliptical, and skating
  - Body blade

Phase III: Sport-Specific Training

Periodization

- Phase III takes place during weeks 20 to 26 of the rehabilitation program in the postoperative patient.
- The nonoperatively treated patient will progress to Phase III when full, painless range of motion is achieved with no AC joint tenderness and muscle strength 75% of the contralateral side.
- Phase III will continue until isokinetic strength is equal to the other side.

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- Cardiorespiratory training
- Multi-planar training activities
- Training for optimum muscle functional power
- Neuromuscular dynamic stability exercises
- Training for speed, agility, quickness (SAQ)
- Plyometric training
- Sport-specific training

Olympic Lifts Used in the Training Program

- Snatch
- Power clean

Training Principles Used in the Design of the Program[7]

- Principle of progression
- Principle of overload
- Principle of variation
- Principle of individualization
- Principles of specificity—Specific Adaptation to Imposed Demands (SAID)

Application of Acute Training Variables

This mesocycle is the power phase. The load is high, a 3 to 6 repetition maximum and the repetitions are decreased. Olympic lifts will be incorporated in this phase.

- Repetitions: 3 to 6
- Sets: 3 to 5
- Rest interval: 3 to 5 minutes
- Intensity: moderate to high
- Repetition tempo: moderate to high
- Training frequency: 1 to 3 times per week
- Training duration: 30 to 90 minutes
- Training volume: number of repetitions or amount lifted per duration of session
- Specific exercises used in the training
  - Add power load to strengthening exercises
  - Add Olympic lifts (snatch, power clean)
  - Add plyometrics: PlyoBall sit ups, drop-catch pushups, medicine ball plyopass, LE bounding
  - Sprints, drills, agility, running with resistance cords or weighted sled
  - Integrate plyometrics and agility to interval training drills
  - Obstacles, cutting, punching bag, "check" drills
  - Falls and "checks" strategies (i.e., rolling, protect shoulder and AC joint)
  - Low-level skating drills
  - Low-level shooting drills
    - Wrist shot
    - Slap shot
    - Work on upper body/trunk rotation
    - Upper trunk rotation in quadruped
    - Alternate medicine ball pass rotating to partner behind

Application of Chronic Training Variables

- Given that exertion in hockey is 2/3 anaerobic and 1/3 aerobic, interval and cardiovascular training must match this ratio. It is important to maximize functional training and sport-specific training during Phase III to include scrimmages.
- Power training or plyometrics should not be performed on the same day as scrimmage, or on the days before or after; the training schedule will thus need to be appropriately manipulated.
- Recovery is especially important during Phase III, as is an awareness of adequate nutrition and hydration.

TIMELINE 7-6: **Returning to Hockey after AC Joint Injury: Operative Treatment**

PHASE I (weeks 1 to 6)	PHASE II (weeks 6 to 12)
• Strict sling immobilization; no shoulder range of motion • Finger, hand, wrist range of motion • Elbow range of motion in the supine position with the elbow supported	• Repetitions: 12 to 25 • Sets: 2 to 4 • Rest interval: 1 min • Intensity: low • Rep tempo: slow to moderate • Duration: 30 to 60 minutes • Frequency: 2 to 4 days/week • Shoulder: shoulder raises, chest press/fly, rows, lat pull, rotator cuff • Elbow: triceps press, biceps curl • Forearm: wrist curl, pronation, supination • Legs/Hip: leg press, squats, glute press, hamstring curl, glute/calf raise • Vestibular/Balance: posturography, unstable surface progression • Functional: fitter, side-to-side slide board, thoracic spine ROM • CV: rowing machine, jogging, stationary cycling, skating • Flex/stretch: shoulder girdle, adductors, quads

- There is an emphasis on stretching and flexibility during this phase, as increased muscle soreness is expected secondary to plyometrics. In addition to shoulder girdle stretching, the adductors and quadriceps should be stretched, as adductor and patellar tendinopathies are common hockey injuries.
- Prevention from re-injury is equally important, and as such, proper equipment, including special shoulder pads, should be worn during practice and scrimmage to protect the AC joint. For hockey players a doughnut or spider pad can be used to protect the area and reduce the pain of a repeated impact.[8]
- Taping techniques can be applied to stabilize the joint as well. It is important to remember that with an anatomic surgical reconstruction of the AC joint, drill holes are made in the clavicle. Athletes should be made aware that there is a risk of fracture through these drill holes even after they have completed the rehabilitation protocol and returned to hockey.

Phase IV: Return to Sport or Performance Readiness Testing

Recommended Ongoing Exercises

- Recommend ongoing training programs as described in Phase II and III

Sports Performance Testing

General Information

- General history
- Subjective questionnaires
- Medical history—including history of tobacco use
- Sports injury history—assess prior injuries or new injuries that may have been sustained during off-season, preseason training, or scrimmage
- Surgical history—assess prior surgeries or recent unrelated surgeries that may have been performed during the off-season

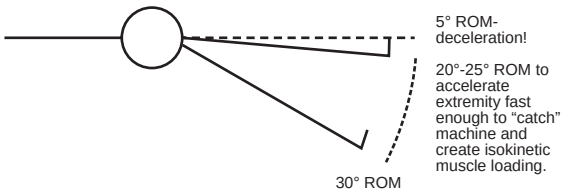

FIGURE 7-48. Acceleration and deceleration range of motion (ROM) with short-arc isokinetic exercise. *(Reprinted with permission from A Compendium of Isokinetics in Clinical Usage and Rehabilitation Techniques. 4th edition. Copyright 1992, S&S Publishers.)*

- Chronic conditions/medication—assess for respiratory condition, cardiac condition, head injuries, concussions, vestibular disease, systemic diseases

Specific Criteria for Progression to the Next Stage to Determine Readiness for Hockey

- Objective tests
  - VO_2 max/submax test when the athlete has history of "ice hockey" lung or recent respiratory illness
  - Side to side symmetry in ROM, strength, and mechanics of involved and uninvolved UE
- Objective questionnaires.
  - DASH.

Specific Criteria for Release to Unsupervised Complete Participation in Hockey

- Although the Kerlan-Jobe Orthopedic Clinic (KJOC) Shoulder and Elbow Questionaire[9] is a sensitive subjective measurement for detection of upper extremity dysfunction, it is generally applied to the overhead athlete. In addition, it is not a functional screen for return to sport. There is a lack of validated functional tests to assess readiness for return to sport following shoulder injury.
- Ellenbecker and Davies[10] propose functional tests and an isokinetic testing algorithm as a measure for readiness and successful return to sport. Davies Closed Kinetic Chain Upper Extremity Stability Test (Figure 7-48) has been found to be a highly reliable clinical tool.

TIMELINE 7-6: **Returning to Hockey after AC Joint Injury: Operative Treatment** (Continued)

PHASE III (weeks 12 to 20)	PHASE IV (weeks 20 to 26)
• Repetitions: 8 to 12 • Sets: 3 to 5 • Rest interval: 1 min • Intensity: moderate • Rep tempo: slow to moderate • Duration: 30 to 60 min • Frequency: 3 to 4 days/week • Shoulder: bench press, incline, decline, dumbells • LE: multi-planar lunge, step-ups, kettlebell, lawnmowers, cable pulleys, diagonals, crossovers • Vestibular/balance: perturbation on unstable surface • Functional: push-ups, planks, unstable surface planks, abdominals • CF: increase intensity, rowing, running, cycling, elliptical, skating	• Repetitions: 3 to 6 (max) • Sets: 3 to 5 • Rest interval: 3 to 5 min • Intensity: moderate-high • Rep tempo: moderate-high • Duration: 30 to 90 min • Frequency: 1 to 3 days/week • Add power load to strength exercises • Olympic lifts: snatch, power clean • Plyometrics: PlyoBall sit-ups, drop-catch push-ups, medicine ball, plyopass, LE bounding • Sprints, drills, agility, running with resistance • Obstacles, cutting, punching bag, "check" drills • Falls and "check" strategies • Low level skating/shooting drills • Focus on recovery, stretching, flexibility • Adequate nutrition, hydration • Injury prevention: shoulder pads, taping

Evidence

Alpini D, Hahn A, Riva D: Static and dynamic postural control adaptations induced by playing ice hockey. *Sport Sci Health* 2:85–92, 2008.

In this study among elite and amateur hockey players and healthy controls, the authors performed sensory organization, head stabilization stance and step testing. They concluded that ice hockey practice induces modifications in static and dynamic postural control. (Level II evidence)

Bradley JP, Elkousy H: Decision making: operative versus nonoperative treatment of acromioclavicular joint injuries. *Clin Sports Med* 22:277–290, 2003.

This review discusses the types of AC joint injuries as described in the classification system of Allman and Tossy (revised by Rockwood). The authors acknowledge the controversy over management of Type III AC joint injuries and agree with the consensus regarding initial conservative treatment of these injuries.

Flik K, Lyman S, Marx RG: American collegiate men's ice hockey: An analysis of injuries. *Am J Sports Med* 33:183–187, 2005.

In this prospective cohort study among Division I men's collegiate hockey, the authors found the following statistics regarding injuries: Collision with an opponent (32.8%) or the boards (18.6%) caused more than half of all injuries. Concussion (18.6%) was the most common injury, followed by MCL sprains, acromioclavicular joint injuries, and ankle sprains. (Level II evidence)

Lui DF, Mermon A, Kwan S, et al: Computerized dynamic posturography analysis of balance in individuals with a shoulder stabilization sling. *Eur J Trauma Emerg Surg* Published online. 28, June 2013.

The authors conclude that sling immobilization affects balance. Computerized dynamic posturography (CDP) was applied as a valid measure to objectify the balance decompensation. They suggest that sling use is important for healing shoulder injuries, however, when early range of motion without a sling can be promoted, it may potentially limit falls related to balance disturbance from the use of a sling. (Level II evidence)

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Multiple-Choice Questions

QUESTION 1. What is the typical rehabilitation time for AC joint injuries that are treated nonoperatively?

A. 2 to 4 weeks
B. 6 to 8 weeks
C. 12 to 14 weeks
D. 16 to 18 weeks

QUESTION 2. After surgical reconstruction of the AC joint, for how long should the extremity be immobilized?

A. 2 weeks
B. 4 weeks
C. 6 weeks
D. 8 weeks

QUESTION 3. Which phase of the rehabilitation protocol is the first to use plyometric training and Olympic lifts?

A. Phase I
B. Phase II
C. Phase III
D. Phase IV

QUESTION 4. At what point does the nonoperatively treated patient progress from Phase III to Phase IV?

A. When palpation of the AC joint is not painful
B. When VO_2 testing is normal
C. When range of motion is equal to the opposite side
D. When isokinetic strength is equal to the opposite side

QUESTION 5. Patients who undergo anatomic reconstruction of the AC joint are at a theoretical increased risk for which of the following?

A. Sternoclavicular joint dislocation
B. Rotator cuff tear
C. Clavicle fracture
D. Biceps tendon rupture

Answer Key

QUESTION 1. Correct answer: **B** (see Phase I: Advanced Strength and Conditioning Programs)

QUESTION 2. Correct answer: **C** (see Phase I: Periodization)

QUESTION 3. Correct answer: **C** (see Phase III: Application of Acute Training Variables)

QUESTION 4. Correct answer: **D** (see Phase III: Periodization)

QUESTION 5. Correct answer: **C** (see Phase III: Application of Chronic Training Variables)

NONOPERATIVE REHABILITATION OF CLAVICLE FRACTURES

Theresa A. Chiaia, PT, DPT, Miho J. Tanaka, MD, and Christopher S. Ahmed, MD

GUIDING PRINICPLES OF NONOPERATIVE REHABILITATION

- Understand the healing rates of clavicular fractures
- Avoid positions and movements that place the most stress on fracture stability and healing
- Avoid painful ROM and/or strengthening exercises
- Avoid placing stress on the clavicle until radiographic union
- Achieve painless full range of motion and nearly symmetrical strength before return to play

Introduction

- Clavicle fractures (Figure 7-49) had historically been treated with figure-of-eight bracing, hoping that it would aid in maintaining the alignment and length of the clavicle.
- However, studies have shown that treatment of clavicle fractures in a simple sling have had comparable results with fewer complications. Therefore, nonoperative management of clavicle fractures is generally performed with a simple sling (Figure 7-50).

Phase I (weeks 0 to 6)

Goals

- Protect the healing fracture
  - Sling immobilization
- Promote patient compliance through patient education with:
  - Activity modification (axial load, distractive/traction forces, active arm elevation, and ROM above shoulder height)
  - Use of sling

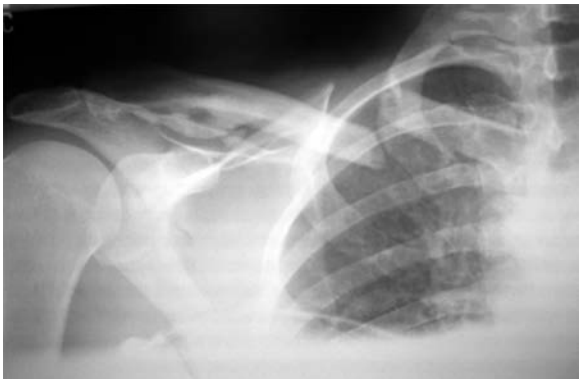

FIGURE 7-49. Clavicle fractures without significant shortening or displacement can be treated nonoperatively.



FIGURE 7-50. The injured extremity is immobilized in a sling.

- Minimize rotator cuff inhibition
- Ensure proper balance and gait while wearing a sling
- Maintain conditioning (exercise bike, ambulation)
- Check for glenohumeral stiffness and consider early gentle ROM exercises (limited to <90° abduction and forward flexion) if necessary
- Maintain scapular mobility

Protection

- Sling immobilization at all times.
- Resting positions: lying supine with pillow support; lying on the contralateral side with pillow support; lying on the ipsilateral side, as well as, without pillow support on the opposite side, is contraindicated

Management of Pain and Swelling

- Oral pain medications
- Resting positions: UE positioned on a pillow with the arm supported in the scapular plane.
- Education in activity modification and importance of sling immobilization
- Therapeutic modalities:
  - Cryotherapy
  - Transcutaneous electrical nerve stimulation (TENS)

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Initiate manual therapy techniques for IR and ER in the plane of the scapula

Soft Tissue Techniques

- Myofascial release for pectorals, trapezius
- Stretching/flexibility techniques for the musculotendinous unit:
- AROM wrist extension/flexion; pronation/supination; elbow flexion/extension with arm at side; gripping exercises

Stretching and Flexibility Techniques for the Musculotendinous Unit

TBS

- Can be incorporated early while wearing the sling
- Exercises that challenge the individual's balance are discouraged
- Stationary cycling and elliptical trainer

Core stability

- Lower abdominals; hip musculature (seated machines)

TLS

- The patient can perform exercises that do not stress the repair site, or present the risk of falling, such as ball squats, seated LE machines for hamstrings, quads, and hip musculature
- Contraindication:
  - Leg press with shoulder pads
  - Carrying weights which create distractive forces.

Activation of Primary Muscles Involved

- Muscle activation of the primary muscles (pectorals, anterior deltoid, upper trapezius, SCM) is not indicated during this healing phase
- Postural retraining (Figure 7-51)
- Submaximal rotator cuff isometrics in the plane of the scapula (PoS).

Techniques to Increase Muscle Strength, Power, and Endurance

- Postural exercises such as scapular retraction to neutral and lower trapezius isometrics may be initiated
  Neuromuscular Dynamic Stability Exercises



FIGURE 7-51. Postural training is initiated to avoid forward shoulder posture.

- Pain-free, submaximal IR/ER rhythmic stabilization exercises in the plane of the scapula may be initiated in this phase if adequate ROM is present (30° ER)

Milestones for Progression to the Next Phase

- No pain at rest
- Pain and swelling controlled
- Radiographic evidence of union

Phase II (weeks 6 to 10)

Goals

- Discontinue sling
- Limit ROM to 90° abduction and forward flexion
- Begin progressive ROM when signs of radiographic healing

TIMELINE 7-7: **Rehabilitation After Clavicle Fracture**

PHASE I (weeks 1 to 6)	PHASE II (weeks 6 to 10)
• Sling immobilization • Patient education: sling, activity modification • PT modalities, prn • AROM of elbow, wrist, hand • AAROM of shoulder for plane of scapula IR/ER • Myofascial release for pectorals • Postural retraining • Codman's exercises • Isometric rotator cuff strengthening as tolerated • TBS/TAS/TLS activities as recommended and tolerated	• Discontinue sling • PT modalities, prn; moist heat, cryotherapy • Patient education: activity modification, carrying heavy weights • ROM—Start scapular plane elevation, PROM, AAROM • Manual therapy, evaluation-based: joint mobilization • Soft-tissue techniques, evaluation-based: pectorals, subscapularis, latissimus, trapezii. • Pendulums • Isometric strengthening of deltoid, trapezius • Rotator cuff strengthening: PREs • Periscapular strengthening exercises • Hydrotherapy • Upper body ergometry, limited arc • CKC physioball stabilization • Rhythmic stabilization • PROM limited to <90° of abduction • TBS/TAS/TLS activities as recommended and tolerated

- Avoid pain with ADLs, exercise
- Avoid distractive forces
- Minimize rotator cuff inhibition
- Compliance with home exercise program
- Normalized scapulohumeral rhythm to 90° scapular plane elevation to shoulder height

Protection

- Discontinue sling.
- Limit active abduction/flexion to 90°.
- Pillow support for sleeping will be used to avoid deleterious positions such as side lying on ipsilateral side and unsupported lying on the contralateral side.

Management of Pain and Swelling

- Oral pain medications, prn; however, pain should be controlled without meds through safe progression of therapeutic exercise and introduction of activities into daily life
- Cryotherapy
- Patient education in:
  - UE positioning
  - Activity modification

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- ROM exercises: passive-to-active assistive-ROM of shoulder flexion/abduction, ER at 90° abduction, IR, scapular mobility in sidelying.
- Evaluation based glenohumeral, sternoclavicular, and acromioclavicular joint mobilization

Soft Tissue Techniques

- Scapular mobilization to maintain mobility
- Therapeutic massage for the pectorals, subscapularis, posterior cuff, latissimus, trapezii



FIGURE 7-52. After signs of healing, flexion ROM exercises in the plane of the scapula can be performed to maintain glenohumeral motion.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Passive-AAROM exercises for shoulder flexion are performed in sitting or standing with the arm positioned in the plane of the scapula (Figure 7-52). ROM exercises for shoulder IR and ER may be performed in supine in the plane of the scapula.
- Increase ER at 90° abduction with cane/stick.
- Pulleys can be initiated with adequate humeral head control and ROM of approximately 130°.
- Can begin doorway or corner stretch for pectorals (major and minor).
- Supine "T towel" positioning, with a towel roll positioned along the spine, and a second along the base of the head, is recommended to promote thoracic extension, and to allow the anterior positioned humeral head to sit back.
- Pendulum exercises

TIMELINE 7-7: **Rehabilitation after Clavicle Fracture** (Continued)

PHASE III (weeks 10 to 14)	PHASE IV (weeks 15 to 20)
• PT modalities, prn • Pulleys • Upper body ergometry • ROM: evaluation-based • Manual therapy: evaluation-based • Doorway stretch • Achieve full ROM • Rotator cuff PREs • Periscapular strengthening PREs: advance to prone exercises • TBS/TAS/TLS activities as recommended and tolerated	• PT modalities, prn: cryotherapy • RO: evaluation-based • Rotator cuff PREs: 90/90 position • Advanced periscapular strengthening • PNF diagonal patterns • Sport-specific exercises • RTP may differ by sport, hand dominance • TBS/TAS/TLS activities as recommended and tolerated

Other Therapeutic Exercises

TBS

- Stationary cycling, elliptical, and in latter phase, begin pain-free utilization of upper body with c-v equipment.

Core

- Lower abdominals, bridging, gluteals

TAS

- Avoid carrying heavy weights and traction forces with training program.
- Perform pain-free exercise within the available ROM such as biceps curls, triceps curls, scapular retraction, scapular protraction, extension.
- Latter phase: Upper body ergometry; use of arms in c-v equipment (elliptical, bicycle) pain-free.

TLS

- Emphasize sports specific training exercises including:
- Squats, RDLs, knee extension, knee flexion.
- Machines for hip abd/add, gluteals.

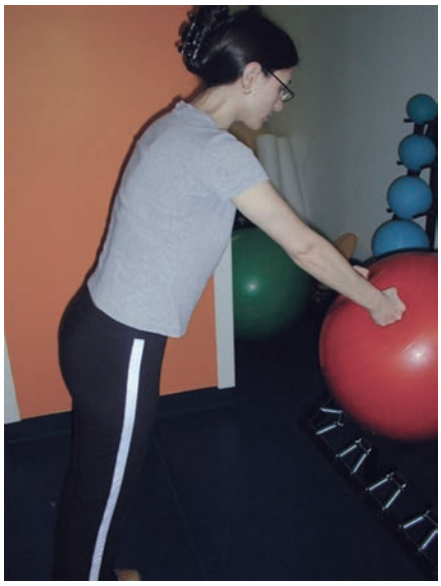

FIGURE 7-53. CKC physioball scapular stabilization exercises below horizontal are initiated with double arm support.

Activation of Primary Muscles Involved

- Scapular stabilization exercises beginning in supported sidelying position and progressing to manual strengthening, then to resisted exercises such as shrugs, forward flexion in the plane of the scapula, and in latter phase, begin supine bench press with light weights (arms below shoulder height).

Sensorimotor Exercises

- Hydrotherapy
- Rhythmic stabilization
- Physioball scapular stabilization, CKC.

Open and Closed Kinetic Chain Exercises

- CKC exercises such as physioball scapular stabilization exercises below horizontal are initiated with double arm support (Figure 7-53)

Techniques to Increase Muscle Strength, Power, and Endurance

- Progressive strengthening of the scapular musculature such as rhomboids, serratus anterior, lower trapezius to begin to address force couple involved in shoulder flexion/abduction.
- Rotator cuff strengthening is progressed from submaximal isometrics to isotonics (ER in side lying position to elastic bands).
- Forward elevation in the plane of the scapula—full can—is initiated with evidence of good scapulohumeral rhythm
- Hydrotherapy exercises are utilized for its buoyancy and hydrostatic properties
- In latter phase, begin pain-free, upper body ergometry may be initiated at this time.

Neuromuscular Dynamic Stability Exercises

- Continue with rhythmic stabilization exercises, progressing to more challenging positions, such as greater angles of ER, without towel roll support, and at shoulder height) (Figure 7-54)
- Perturbation in latter phase with adequate strength base with arm close to side



FIGURE 7-54. Rhythmic stabilization exercises below horizontal are imitated with double arm support.

Functional Exercises

- Begin scapula plane elevation—full can position—to shoulder height when good, pain-free scapulohumeral rhythm is evident (no shrug).
- Hydrotherapy may be used initially to provide environment for active-assistive exercise.

Milestones for Progression to the Next Phase

- Normal ER ROM in the plane of the scapula
- Shoulder flexion/abduction PROM to >90°

- Normal scapulo-humeral rhythm with PoS shoulder flexion to shoulder height
- 0/10 pain with exercise progression, and ADLs
- Compliance with home exercise program

Phase III (weeks 10 to 14)

Goals

- Achieve full range of motion
- Begin progressive overhead activities
- Progressive shoulder strengthening

Management of Pain and Swelling

- Pain should be controlled without medication

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Evaluation based SC, AC, GH joint mobilization, as necessary
- ROM exercises for flexion, abduction, ER at 90° abduction, IR
- Scapular mobility in side lying position

Soft Tissue Techniques

- Therapeutic massage for the pectorals, subscapularis, trapezii, posterior cuff, latissiumus

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Increase ER at 90° with cane/stick.
- Pulleys can be initiated with adequate humeral head control and ROM of approximately 130°
- Doorway or corner stretch for pectorals (major and minor)
- Evaluation-based posterior cuff, posterior capsule, as necessary
- Evaluation-based ROM exercises, as necessary

Other Therapeutic Exercises

TBS

- Stationary cycling, elliptical, utilization of upper body with c-v equipment, pain-free

Core

- Lower abdominals, bridging, gluteals

TAS

- Avoid carrying heavy weights and traction forces with training program.
- Perform pain-free exercise within the available ROM such as biceps curls, triceps curls, scapular retraction, scapular protraction, extension (dumbbell row).
- Upper body ergometry; use of arms in c-v equipment (row, elliptical, bicycle) progresses pain-free.

TLS

- Emphasize sports-specific training exercises including:
  - Squats, RDLs, knee extension, knee flexion, side lying hip abduction
  - Machines for hip abd/add, gluteals

Activation of Primary Muscles Involved

- Scapular stabilization exercise progression
- Forward flexion in plane of scapula—full can position (Figure 7-55)
- Supine chest press with light weights, arms below shoulder height

Sensorimotor Exercises

- Hydrotherapy
- Rhythmic stabilization
- Physioball stabilization
- PNF diagonal patterns, D2 flexion/extension in supine

Open and Closed Kinetic Chain Exercises

- CKC exercises such as physioball scapular stabilization exercises can progress to single arm as tolerated
- Pushup progression, arms below shoulder height
- Quadruped position

Techniques to Increase Muscle Strength, Power, and Endurance

- Progressive, advanced periscapular strengthening such as prone exercises for lower trapezius, middle trapezius, latissimus to continue to address force couple involved in shoulder flexion/abduction.
- PREs for the rotator cuff, progressing from side lying to elastic band exercises.
- Forward flexion in the plane of the scapula
- Upper body ergometry, cycle, Airdyne

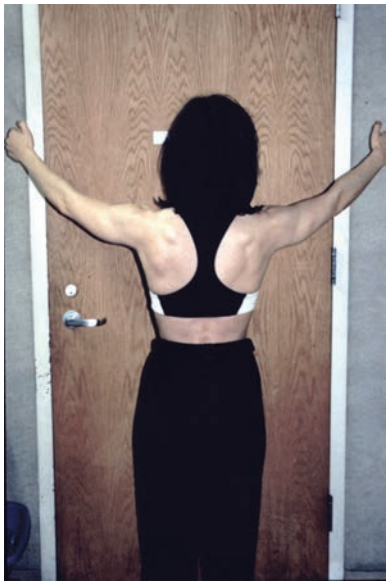

FIGURE 7-55. Forward flexion in plan of scapula—full can position.

Neuromuscular Dynamic Stability Exercises

- Continue with rhythmic stabilization exercises
- Perturbation in later phase with adequate strength base with arm close to side

Functional Exercises

- Shoulder flexion in the PoS
- Pushing activities such as wall push-ups

Milestones for Progression to the Next Phase

- Normal scapulo-humeral rhythm above shoulder
- ROM WNLs
- 0/10 pain with exercise progression and ADLs

Phase IV (weeks 15 to 20)

Management of Pain and Swelling

- Safe exercise progression
- Monitor for swelling

Techniques for Progressive Increase in Range of Motion

- Maintain ROM or if not FROM, please refer to Phase III

Other Therapeutic Exercises

- Without restriction

Activation of Primary Muscles Involved

- Chest press
- Shrugs
- Push-ups

Sensorimotor Exercises

- PNF diagonal pattern progressions to D1 flexion/extension
- Upright posture with elastic bands

Open and Closed Kinetic Chain Exercises

- Progress to single arm ball stabilization
- Pushup progression

Techniques to Increase Muscle Strength, Power, and Endurance

- Advanced periscapular strengthening
- Rotator cuff strengthening in 90/90 position

Neuromuscular Dynamic Stability Exercises

- Body blade
- Ball stabilization exercises (single arm)
- PNF diagonal patterns

Plyometrics

- Activity-specific plyos
- Ball tosses: chest pass, overhead pass
  Functional Exercises
- PNF diagonal pattern progressions

Sport-Specific Exercises

- Throwing program

Milestones for Progression to Advanced Sport-Specific Training and Conditioning

- Radiographic signs of fracture union
- Full, painless range of motion of affected shoulder
- Near symmetric strength in shoulders

Criteria for Abandoning Nonoperative Treatment and Proceeding to Surgery or More Intensive Intervention

- Increased fracture shortening or displacement
- Signs of malunion
- Signs of nonunion

Tips and Guidelines for Transitioning to Performance Enhancement

- Transition to performance will begin in the latter phases (phase III and IV) with regard to training the upper extremity.
- When the patient has achieved the phase II milestones, transition to performance can be made.
- Core exercises and lower body transition to performance can be ongoing from the early phases. This will help keep the athlete engaged.
- As always, communication between the physical therapist and performance specialist must be ongoing.

Performance Enhancement and Beyond Rehabilitation: Training/Trainer and Optimization of Athletic Performance

- Maintaining a solid foundation of strength is important for safe progression of functional exercises.
- Care is taken to monitor ROM and flexibility throughout to ensure proper shoulder mechanics.
- Lower extremity and trunk strength and mobility will take stress off the shoulder.
- Adequate core strength will transfer power from the lower extremities to the upper extremities.

- Adequate rest is incorporated into upper extremity training program so as not to flare the joint.
- Close attention is paid to the volume of exercise. The performance specialist must recognize signs and symptoms of inflammation such as pain, loss of motion, and a decrease in strength, and readily communicate with the physical therapist. The athlete will not be pushed through pain and inflammation to avoid setbacks.

Specific Criteria for Return to Sports Participation: Tests and Measurements

- Radiographic signs of fracture union
- Full, painless range of motion of affected shoulder
- Near symmetric strength in shoulders

Evidence

Canadian Orthopaedic Trauma Society: Nonoperative treatment compared with plate fixation of displaced mid-shaft clavicular fractures. A multicenter, randomized clinical trial. *J Bone Joint Surg Am* 89:1–10, 2007.

The authors performed a prospective study on outcomes and complication rates following nonoperative vs. plate fixation of displaced mid-shaft clavicle fractures. A total of 132 patients were randomized to treatment and outcomes were assessed using the Constant score, DASH score, and radiographs. The mean time to radiographic union was 16.4 weeks in the group with plate fixation, versus 28.4 weeks in the nonoperative group. Nine symptomatic malunions and seven nonunions were noted in the nonoperative group, versus two nonunions and no malunions in those with plate fixation. The operative group showed higher satisfaction rates than the nonoperative group at 1 year. (Level XX evidence)

Judd DB, Pallis MP, Smith E, et al: Acute operative stabilization versus nonoperative management of clavicle fractures. *Am J Orthop (Belle Mead NJ)* 38:341–345, 2009.

This was a prospective, randomized study of 57 subjects with midshaft clavicle fractures which were either treated nonoperatively (28 subjects) or with intramedullary fixation (29 subjects) with a modified Hagie pin. The authors reported that one subject in each group sustained a refracture within 1 year of the original injury. (Level XX evidence)

McKee MD, Pedersen EM, Jones C, et al: Deficits following nonoperative treatment of displaced mid-shaft clavicular fractures. *J Bone Joint Surg Am* 88:35–40, 2006.

The authors identified 30 patients (22 male, 8 female) who were treated nonoperatively for a displaced mid-shaft clavicle fracture. Their functional outcomes were measured using the Constant Score and the DASH (Disabilities of the Arm, Shoulder and Hand) Score, and objective muscle testing was performed using the Baltimore Therapeutic Equipment Work Simulator. The authors found that these patients had residual deficits in shoulder strength and endurance, with strength testing of the injured shoulder at 81% for maximum flexion compared to the uninjured side, 81% and 85% for maximum external and internal rotation, respectively, and 82% and 78% for endurance of external rotation and internal rotation, respectively. The mean Constant Score was 71, and the mean DASH score was 24.6. Range of motion appeared to be well preserved and averaged 170° +/– 20°, with abduction averaging 165°+/– 25°. (Comparative study, Level XX evidence)

Morgan RJ, Bankston LS, Jr, Hoenig MP, et al: Evolving management of middle-third clavicle fractures in the National Football League. *Am J Sports Med* 38:2092–2096, 2010.

Of 13 100% displaced mid-shaft clavicle fractures in the National Football League, 6 underwent open reduction internal fixation with plating and 7 were treated nonoperatively. Of those treated operatively, players returned to play within the same season, whereas 4 of the 7 treated nonoperatively sustained refracture of their clavicle within 1 year and missed an average of 1.5 seasons. (Level XX evidence)

Robinson CM, Court-Brown CM, McQueen MM, et al: Estimating the risk of nonunion following nonoperative treatment of a clavicular fracture. *J Bone Joint Surg Am* 86-A(7):1359–1365, 2004.

The authors performed a prospective, observational cohort study of 868 patients with a clavicle fracture over 51 months. Median age was 29.5 years. At 24 weeks, 6.2% showed signs of nonunion, with 8.3%, 4.5% and 11.5% in the medial, mid-shaft and lateral clavicle fractures, respectively. Risk of nonunion was increased by increased age, female gender, fracture displacement and presence of comminution. (Level XX evidence)

Multiple-Choice Questions

QUESTION 1. In the first 2 weeks after injury, physical therapy may include all of the following EXCEPT:

A. Pendulum exercises
B. Isometric strengthening of RTC
C. Isometric strengthening of deltoid
D. Passive ROM to 120 degrees of abduction

QUESTION 2. In the first 6 weeks after injury, exercises of the rotator cuff and deltoid should involve:

A. Unlimited passive ROM
B. Resisted strengthening
C. Isometric strengthening
D. Strict immobilization

QUESTION 3. Unlimited range of motion exercises should typically begin after signs of clinical or radiographic union, typically after:

A. 2 weeks
B. 4 weeks
C. 6 weeks
D. 12 weeks

Answer Key

QUESTION 1. Correct answer: **D** (see Phase I: Weeks 0 to 6)

QUESTION 2. Correct answer: **C** (see Phase I: Weeks 0 to 6)

QUESTION 3. Correct answer: **C** (see Phase III: Weeks 10 to 14)

POSTOPERATIVE REHABILITATION AFTER REPAIR OF CLAVICLE FRACTURE

Miho J. Tanaka, MD, Theresa A. Chiaia, PT, DPT, and Christopher S. Ahmed, MD

Indications for Surgical Treatment

- Significant fracture displacement, shortening or comminution (Figure 7-49)
- Tenting of skin, impending skin necrosis
- Neurovascular compromise
- Open fracture
- Polytrauma and need for early mobilization
- Inability to tolerate immobilization
- Nonunion, symptomatic malunion or failed nonoperative treatment

Brief Summary of Surgical Treatment

Major Surgical Steps

Major steps in technique for plate fixation

- Beachchair positioning with fluoroscopic unit used to obtain AP and 45° cephalad views
- Exposure of fracture, and avoiding supraclavicular nerve
- Preparation of fracture site
- Reduction of fracture, with restoration of length and rotation
- Fixation with lag screw if appropriate fracture pattern
- Selection of appropriate size and position of plate
- Plate fixation with minimum three screws (six cortices) on each side of fracture
- Closure with soft tissue coverage of plate
- Postoperative sling

Major steps in technique for intramedullary fixation

- Beachchair positioning with fluoroscopic unit used to obtain AP and 45° cephalad views
- Exposure of fracture, and avoiding supraclavicular nerve
- Preparation of fracture site
- Insertion of intramedullary device, with radiographic confirmation of restoration of length and rotation
- Closure with care to minimize soft tissue trauma
- Postoperative sling

Other Surgical Techniques and Options

- Major differences in other surgical techniques:
  - Midshaft clavicle fractures can be fixed with plate fixation (Figure 7-56) or intramedullary fixation (Figure 7-57), as described above, depending on the surgeon's preference.
  - Several types of plate fixation may be used, including precontoured locking plates, noncontoured plates, dynamic compression plates, and limited contact dynamic compression plates. These plates can be placed superiorly (Figure 7-56), anterior-inferiorly (Figure 7-58), or with 90° dual plate fixation (Figure 7-59).
  - No significant differences in postoperative rehabilitation exist between these methods of fixation.
  - Lateral clavicle fractures are challenging and difficult to stabilize. Use of the precontoured plates or hook plate has been described in the treatment of lateral clavicle fractures (Figure 7-60).



FIGURE 7-56. Superior plating is a common technique in the plate fixation of midshaft clavicle fractures.

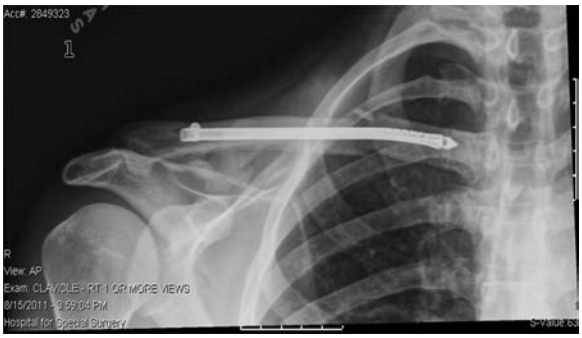

FIGURE 7-57. Intramedullary fixation is gaining popularity in the fixation of midshaft clavicle fractures due to its low profile nature.

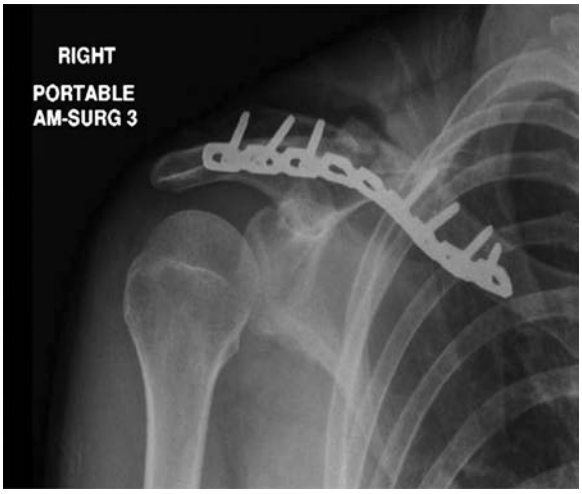

FIGURE 7-58. Anteroinferior plating is an alternative method of plate positioning in open reduction and fixation of clavicle fractures.

- However, it is important to note that the lateral portion of the hook plate lies in the subacromial space and may cause impingement with abduction and external rotation of the shoulder.
- Early removal of the hook plate is recommended to prevent complications such as impingement and acromial fractures.

Before Surgery: Overview of Goals, Milestones, and Guidelines[3]

GUIDING PRINCIPLES OF POSTOPERATIVE REHABILITATION

- Understand the healing rates of clavicular fractures.
- Avoid positions and movements that place excessive stress on fracture fixation and healing until radiographic confirmation of healing is observed.
- Avoid painful ROM.
- Achieve painless full range of motion and nearly symmetrical strength before return to play.
- Achievement of phase-specific goals will determine advancement.

Phase I: Immediate Postoperative Period (days 0 to 14)

Clinical Pearls

- Compliance with the use of the sling will assist with activity modification as well as avoidance of movements and forces that will interfere with healing. Patient education regarding the injury and healing constraints will help foster compliance.

[3]*Prehabilitation, if appropriate, is described in the Nonoperative Rehabilitation section of this chapter.*



FIGURE 7-59. Dual plate fixation is another method described for the use of clavicle fractures *(Image courtesy of Sabrina Strickland MD).*

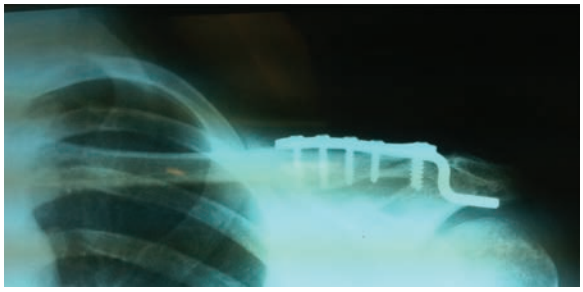

FIGURE 7-60. The hook plate can be used to fix distal clavicle fractures, however, the implant may cause impingement in shoulder abduction or acromion fractures if not removed.

Goals

- Protect surgical repair
- Control postoperative pain and swelling
- Educate the patient (regarding posture, resting positions)
- Ensure proper balance and gait while wearing a sling
- Obtain patient compliance with:
  - Activity modification (axial load, distractive/traction forces, active arm elevation, and ROM above shoulder height)
  - Immobilization
- Independence in a home exercise program to include distal ROM and grip strength
- Minimize rotator cuff inhibition

Protection

- Sling immobilization at all times
- Resting position: Supine lying with pillow support. Lying on the ipsilateral side is contraindicated

Management of Pain and Swelling

- Oral pain medications
- Positioning of the UE on a pillow with the arm supported in the scapular plane to allow the patient to rest comfortably without stressing the repair
- Patient education:
  - Activity modification will provide the patient with an understanding of how to manage pain
  - Sling immobilization
- Therapeutic modalities
  - Cryotherapy
  - Transcutaneous Electrical Nerve Stimulation (TENS)
- Activity modification
- Cryotherapy.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- ROM: Physiologic movements—IR and ER in the plane of the scapula (PoS)

Soft Tissue Techniques

- Therapeutic massage for myofascial release for pectorals, trapezii

Stretching and Flexibility Techniques for the Musculotendinous Unit

- AROM wrist extension/flexion; pronation/supination; elbow flexion/extension with arm at side; gripping exercises

Other Therapeutic Exercises

TBS

- Can be incorporated early while wearing the sling
- Exercises that challenge the individual's balance are also discouraged
- Light stationary cycling, however, perspiration is discouraged to protect the healing wound

Core stability

- Lower abdominals; hip musculature (seated machines)

TLS

- The patient can perform exercises that do not stress the repair site, or present the risk of falling, such as ball squats, seated LE machines for hamstrings, quads, and hip musculature.
- Contraindication:
  - Leg press with shoulder pads is not encouraged
  - Carrying weights which create distractive forces.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Muscle activation of the primary muscles (pectorals, anterior deltoid, trapezius, SCM) is not indicated during this immediate postoperative phase.
- Postural retraining
- Exercises for the distal extremity may be performed such as gripping, wrist extension/flexion, forearm pronation/supination, elbow flexion/extension.

Techniques to Increase Muscle Strength, Power, and Endurance

- Postural exercises such as scapular retraction to neutral and lower trapezius isometrics may be initiated

Neuromuscular Dynamic Stability Exercises

- Pain-free, submaximal IR/ER rhythmic stabilization exercises in the plane of the scapula (PoS) may be initiated in this phase with adequate available ROM (30° ER).

Milestones for Progression to the Next Phase

- Pain and swelling is controlled.
- Abolish rest pain.
- Obtain compliance with activity modification.
- Minimize rotator cuff inhibition.

TIMELINE 7-8: **Postoperative Rehabilitation After Repair of Clavicle Fracture**

PHASE I (weeks 1 to 2)	PHASE II (weeks 3 to 6)	PHASE III (weeks 6 to 10)
• Sling immobilization • PT modalities, prn: cryotherapy, TENS • AROM of distal joints: elbow, forearm, wrist, hand • AAROM of shoulder for plane of scapula IR/ER • Myofascial release for pectorals • Patient education: activity modification, sling • Postural retraining (avoid forward shoulder posture) • TBS/TAS/TLS activities as recommended & tolerated: avoid perspiring to protect the healing wound	• Sling immobilization • PT modalities, prn: moist heat, cryotherapy, TENS • ROM: PROM for scapular plane shoulder elevation, AAROM to 90° in sitting position • Manual therapy evaluation-based: joint mobilization for shoulder flexion/abduction; IR/ER. Manual therapy, evaluation-based: for shoulder flexion PoS; ER/IR • Soft tissue techniques—evaluation-based—for pectorals, subscapularis • Submaximal isometric strengthening: deltoid, lower trapezius • RC strengthening: progress from scapular plane submaximal isometrics to ER in side lying • Scapular mobility • Pendulums • Periscapular PREs in latter phase, progressing from supported side lying to manual resistance • Rhythmic stabilization for IR/ER in PoS • TBS/TAS/TLS activities as recommended & tolerated	• PT modalities, prn (moist heat, cryotherapy) • AAROM exercises without restriction and to tolerance: pulleys; can ER at 90° abduction, cane forward flexion • Manual therapy: joint mobilizations, evaluation-based • Soft tissue techniques—evaluation-based • Upper extremity ergometry • Flexibility exercises: evaluation-based for pectorals, posterior rotator cuff, latissimus • Periscapular PREs • CKC exercises progressing from double to single support • Hydrotherapy • Rotator cuff PREs progressing from side lying to elastic band resistance • Pushup progression: wall pushup • Neuromuscular training: Bodyblade at neutral; rhythmic stabilization, increasingly challenging positions • TBS/TAS/TLS activities as recommended & tolerated

Phase II (weeks 2 to 6)

Clinical Pearls

- ROM exercises should be pain-free. If the individual experiences pain with supine flexion in the plane of the scapula (PoS), one may consider ROM exercises in the sitting position to allow the scapula to move. The patient's body weight in the supine position will limit movement at the scapula, thereby increasing the movement at the clavicle.
- Passive-AAROM exercises for flexion/abduction may be performed in the sitting or standing position to allow for scapular movement.
- Continued use of the sling will assist with activity modification, and avoid movements and forces that will interfere with healing.

Goals

- Protect surgical repair.
- Emphasize postural awareness (avoid forward shoulder posture).
- Obtain patient compliance with:
  - Activity modification (axial load, distractive/traction forces, active arm elevation, and ROM above shoulder height)
  - Immobilization
- Minimize rotator cuff inhibition.
- Avoid pain with exercises, ADLs.
- ROM to ≤90° flexion/abduction.
- Avoid horizontal adduction beyond neutral.
- Normal ER ROM in the plane of the scapula.
- Provide independent home exercise program.

Protection

- Sling immobilization
- Limit active abduction/flexion to ≤90°
- Pillow support for sleeping will be used for proper positioning and to avoid deleterious positions such as side-lying on ipsilateral side and unsupported contralateral side lying

Management of Pain and Swelling

- Oral pain medications
- Cryotherapy
- Patient education (UE positioning, and activity modification)
- Cryotherapy
- Activity modification

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- ROM: Physiologic movements—passive-to active assistive—ROM of shoulder flexion/abduction; IR and ER in the plane of the scapula (PoS)
- Joint mobilization in the posterior direction, inferior direction
- Scapular mobilization

Soft Tissue Techniques

- Therapeutic massage for myofascial release for pectorals, subscapularis, trapezii

TIMELINE 7-8: **Postoperative Rehabilitation After Repair of Clavicle Fracture** (Continued)

PHASE IV (weeks 10 to 14)	PHASE V (weeks 14 to 24)	PHASE VI (weeks 24 to 52)
• PT modalities, prn • ROM: evaluation-based • Manual therapy: evaluation-based • Flexibility: evaluation-based • UE ergometry • Advanced periscapular strengthening: prone-lying middle traps, lower traps, • RC strengthening progression to 90/90 position • Plyometrics • PNF diagonals progression • Throwing program • Swimming • Progressive neuromuscular training • TBS/TAS/TLS activities as recommended & tolerated	• RTP may differ by sport • TBS/TAS/TLS activities as recommended & tolerated	• Possible hardware removal if indicated • Postoperatively: Limit overhead strengthening and heavy lifting for a minimum of 6 weeks

Stretching and Flexibility Techniques for the Musculotendinous Unit

- AROM wrist extension/flexion; pronation/supination; elbow flexion/extension with arm at side; gripping exercises
- P-AAROM exercises for shoulder flexion are performed in sitting or standing with the arm positioned in the plane of the scapula (Figure 7-50); ROM exercises for PoS shoulder IR and ER may be performed in supine
- Supine "T towel" positioning, with a towel roll positioned along the spine, and a second along the base of the head, is recommended to promote thoracic extension, and to allow the anterior positioned humeral head to sit back.
- Pendulum exercises

Other Therapeutic Exercises

TBS

- Once the wound is healed, patient can perform exercises such as stationary cycling and elliptical trainer for cardiovascular fitness. The sling is worn during these activities.

Core stability

- Lower abdominals; hip musculature (seated machines)

TLS

- The patient can perform exercises that do not stress the repair site, or present the risk of falling, such as ball squats, seated LE machines for hamstrings, quads, and hip musculature.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Rotator cuff isometrics
- In latter part of this phase
- Self AAROM exercises in sitting will begin to activate the anterior deltoid.
- Scapular elevation can be initiated in a supported side lying position.

Sensorimotor Exercises

- Hydrotherapy

Techniques to Increase Muscle Strength, Power, and Endurance

- Scapular strengthening is initiated in this phase to include scapular retraction, lower trapezius to neutral.
- RC strengthening is progressed from submaximal isometrics to isotonics (ER in side lying).

Neuromuscular Dynamic Stability Exercises

- Rhythmic stabilization exercises performed for PoS IR/ER

Functional Exercises

- Hydrotherapy may be used initially to provide environment for active-assistive exercise.

Sport-Specific Exercises

- N/A with the exception of progressive ROM exercises
- Incorporating exercises for core, TBS, TAS, TLS is encouraged, keeping in mind the limitations/precautions associated with the involved shoulder

Milestones for Progression to the Next Phase

- Normal ER ROM in the plane of the scapula
- PROM shoulder flexion/abduction to 90°
- Pain and swelling is controlled
- Compliance with activity modification
- Compliance with home exercise program

Phase III (weeks 6 to 10)

Clinical Pearls

- As restrictions are lifted after fracture union, activity levels should be increased gradually in order to optimize muscular fitness and avoid aggravating the joint.
- Patients should be monitored for signs and symptoms of progressing too quickly.
- Scapular strengthening is initiated and progressed so that an adequate strength base is developed for more advanced exercises.
- Again, care is taken to follow a functional progression.
- For physical therapists, communication with the physician regarding the healing progress is imperative for appropriate progression.
- If healing is delayed, the progression of therapy should be postponed accordingly.

Goals

- Discontinue sling
- Pain free with ADLs and exercise
- Compliance with activity modification and precautions
- When signs of radiographic union, begin progressive ROM and strengthening
- Normalized scapulohumeral rhythm to 90° scapular plane shoulder elevation
- Avoid distractive forces

Protection

- The sling is discontinued.

Management of Pain and Swelling

- Pain to be controlled without medication
- A safe progression of therapeutic exercise and introduction of activities into daily life will control pain
- Patient education

- Activity modification
- Cryotherapy
- Activity modification
- Progressive ADLs, and therapeutic exercise

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Evaluation-based joint mobilization include: sternoclavicular, acromioclavicular, and glenohumeral (posteriorly and inferiorly directed) joints, as needed
- ROM exercises for physiologic movements: flexion, abduction, ER at 90° abduction, IR
- Scapular mobility in side lying

Soft Tissue Techniques

- Pectorals, subscapularis, posterior cuff, trapezii

Stretching and Flexibility Techniques for the Musculotendinous Unit

- ROM exercises with cane for ER at 90° abduction, forward flexion.
- Pulleys can be initiated with adequate humeral head control and ROM of approximately 130° flexion.
- Initiate doorway or corner stretch for pectorals (major and minor).

Other Therapeutic Exercises

- Stationary cycling, elliptical, utilization of upper body with c-v equipment, pain-free

Core

- Lower abdominals, bridging, gluteals

TAS

- Avoid carrying heavy weights and traction forces with training program.
- Perform pain-free exercise within the available ROM such as biceps curls, triceps curls, scapular retraction, scapular protraction, extension (dumbbell row).
- Upper body ergometry, use of arms in c-v equipment (row, elliptical, bicycle) progresses pain-free.

TLS

- Emphasize sports specific training exercises including:
  - Squats, RDLs, knee extension, knee flexion, side lying hip abduction.
  - Machines for hip abduction/adduction, gluteals.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Scapular stabilization exercises beginning with manual strengthening, progressing to resisted exercises such as shrugs, forward flexion in the plane of the scapula, supine bench press with light weights (arms below shoulder height)

Sensorimotor Exercises

- Hydrotherapy
- Rhythmic stabilization
- Physioball scapular stabilization, CKC.

Open and Closed Kinetic Chain Exercises

- CKC exercises such as physioball scapular stabilization exercises below horizontal are initiated with double arm support and progress to single arm support.

Techniques to Increase Muscle Strength, Power, and Endurance

- Progressive strengthening of the scapular musculature such as rhomboids, serratus anterior, lower trapezius to begin to address force couple involved in shoulder flexion/abduction.
- PREs for the rotator cuff, progressing from side lying to elastic band exercises.
- Forward elevation in the plane of the scapula—full can—is initiated with evidence of good scapulohumeral rhythm.
- Hydrotherapy exercises are utilized for its buoyancy and hydrostatic properties.
- Upper body ergometry.

Neuromuscular Dynamic Stability Exercises

- Continue with rhythmic stabilization exercises, progressing to more challenging positions such as at shoulder height
- Perturbation in latter phase with adequate strength base with arm close to side

Functional Exercises

- Begin scapula plane elevation—full can position—to shoulder height when good, pain-free scapulohumeral rhythm is evident (no shrug)
- Hydrotherapy may be used initially to provide environment for active-assistive exercise
- Pushing activities such as wall pushups

Sport-Specific Exercises

- Introduced based on the demands of the sport that the athlete is returning to

Milestones for Progression to the Next Phase

- Normal scapulo-humeral rhythm with PoS shoulder flexion to shoulder height and to 120° of flexion
- ROM WNLs
- 0/10 pain with exercise progression, and ADLs
- Compliance with home exercise program

Phase IV (weeks 10 to 14)

Clinical Pearls

- At this point, communication with the physician to ensure that healing is complete is important.
- The patient should be monitored for symptoms of pain and should be progressing.
- An adequate strength base is required for progression to plyometrics.

Goals

- Achieve full range of motion
- Normal S-H rhythm throughout full ROM
- Overhead activities with adequate strength base, and normal shoulder mechanics
- Avoid pain with exercise: progressive shoulder strengthening
- Monitor for increase in symptoms

Management of Pain and Swelling

- Avoid pain with exercise
- Activity modification
- Cryotherapy
- Monitor for swelling

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Evaluation-based, treat as needed

Soft Tissue Techniques

- Evaluation-based, treat as needed

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Evaluation-based, treat as needed
- Monitor flexibility of posterior cuff and posterior capsule and address accordingly.

Other Therapeutic Exercises

- Stationary cycling, elliptical, utilization of upper body with c-v equipment, pain-free

Core

- Lower abdominals, bridging, gluteals

TAS

- Avoid carrying heavy weights and traction forces with training program.
- Perform pain-free exercise within the available ROM such as biceps curls, triceps curls, scapular retraction, scapular protraction, extension (dumbbell row).
- Upper body ergometry, use of arms in c-v equipment (row, elliptical, bicycle) progresses pain-free.

TLS

- Emphasize sports specific training exercises including:
- Squats, RDLs, knee extension, knee flexion, side lying hip abduction.
- Machines for hip abduction/adduction, gluteals.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Chest press/bench press/pushups
- Forward flexion in the plane of the scapula, full can position

Sensorimotor Exercises

- PNF diagonal pattern progressions from supine to standing; from no resistance to manual resistance and resistance with elastic bands

Open and Closed Kinetic Chain Exercises

- Rotator cuff full Can exercise with progression to single arm ball stabilization
- Push up progressions
- Quadruped position

Techniques to Increase Muscle Strength, Power, and Endurance

- Progressive rotator cuff strengthening from modified neutral to 90/90 position
- Advanced periscapular strengthening: prone exercises for middle trapezius, lower trapezius, latissimus
- Upper body ergometry, use of arms in c-v equipment (row, elliptical, bicycle)
- Isokinetic training

Neuromuscular Dynamic Stability Exercises

- Body blade©
- Ball stabilization
- Manual
- Quadruped position
- PNF diagonal pattern progression

Plyometrics

- Activity-specific plyometrics, ball tosses: chest pass, overhead pass;
- Progress from double arm to single arm

Functional Exercises

- PNF diagonal pattern progressions

Sport-Specific Exercises

- These are introduced based on the demands of the sport that the athlete is returning to and arm dominance: throwing, catching, swimming, and stability.
- Throwing program

Milestones for Progression to the Next Phase

- 2:3 ER:IR strength ratio
- Strength 85% of non-involved extremity
- ROM WNLs
- Normal scapulohumeral rhythm above shoulder height

Phase V (weeks 14 to 24)

Clinical Pearls

- Overhead athletes with involvement of their dominant arm in overhead athletes may require more time before returning to sport.
- Caution should be taken in early return to play, as refracture has been reported.
- Return to play criteria can vary by the athlete's sport.
- Hardware removal can be performed at **12 to 16 weeks**, after confirmation of radiographic union.
- Reasons for hardware removal:
  - Painful or prominent hardware
  - Cosmesis or patient preference
  - Prevention of impingement on the rotator cuff and acromial fractures (for distal clavicle hook plates)
- After removal of hardware (Figure 7-61), the clavicle is susceptible to refracture
- Rehabilitation guidelines after hardware removal are as follows:
  - Sling immobilization for 1 week
  - Isometric strengthening of rotator cuff, deltoid, biceps, triceps
  - Progressive ROM exercises
  - No contact sports or heavy lifting for a minimum of 6 weeks

Criteria for Return to Sport

General

- Radiographic signs of fracture union
- Full, painless range of motion of involved shoulder
- 85% strength of contralateral shoulder
- Normal scapulohumeral rhythm above shoulder height

Sport-Specific

- Football and contact sports
- Baseball and overhead throwing athletes
- Swimming and overhead athletes



FIGURE 7-61. Removal of implants can weaken the healed clavicle. Lifting and overhead restrictions are recommended after hardware removal.

After Return to Sport

Continuing Fitness or Rehabilitation Exercises

- Maintain symmetry in strength and ROM and flexibility

Exercises and Other Techniques for Prevention of Recurrent Injury

- Donut pads or fiberglass shoulder shell can be used to protect the healing clavicle during participation in contact sports
- If applicable, educate the athlete in proper falling, landing techniques

Evidence

Canadian Orthopaedic Trauma Society: Nonoperative treatment compared with plate fixation of displaced midshaft clavicular fractures. A multicenter, randomized clinical trial. *J Bone Joint Surg Am* 89:1–10, 2007.

The authors performed a prospective study on outcomes and complication rates following nonoperative vs. plate fixation of displaced midshaft clavicle fractures. A total of 132 patients were randomized to treatment and outcomes were assessed using the Constant score, DASH score, and radiographs. The mean time to radiographic union was 16.4 weeks in the group with plate fixation, versus 28.4 weeks in the nonoperative group. Nine symptomatic malunions and seven nonunions were noted in the nonoperative group, versus two nonunions and no malunions in those with plate fixation. The operative group showed higher satisfaction rates than the nonoperative group at one year.

Golish SR, Oliviero JA, Francke EI, et al: A biomechanical study of plate versus intramedullary devices for midshaft clavicle fixation. *J Orthop Surg* 3:28, 2008.

The authors performed a biomechanical study comparing the biomechanical performance of plate versus intramedullary fixation under cyclic bending forces in eight sets of matched cadaveric clavicles. A midshaft clavicle osteotomy was fixed with a 3.5 mm dynamic compression plate or a 3.8 or 4.5 mm intramedullary device and increasingly loaded for 3000 cycles. The plate constructs showed less displacement at fixed loads. The authors concluded that plate fixation may provide a stronger construct for early rehab protocols with repetitive motions.

Iannotti MR, Crosby LA, Stafford P, et al: Effects of plate location and selection on the stability of midshaft clavicle osteotomies: a biomechanical study. *J Shoulder Elbow Surg* 11:457–462, 2002.

The authors reported the effects of plate location and selection on the stability of midshaft clavicle fractures using 30 matched pairs of cadaver clavicles. Midshaft osteotomies were fixed with 3.5 mm reconstruction, 3.5 mm limited contact dynamic compression (LCDC) or 2.7 mm dynamic compression (DC) plates and loaded to failure in compression. They found that superior plating constructs had greater fracture rigidity and mean retained stiffness than the anterior location. They also found that LCDC plate constructs were superior to DC plates constructs in torsional rigidity and to reconstruction plates in compressive load.

Judd DB, Pallis MP, Smith E, et al: Acute operative stabilization versus nonoperative management of clavicle fractures. *Am J Orthop* 38:341–345, 2009.

This was prospective, randomized study of 57 subjects with midshaft clavicle fractures which were either treated nonoperatively (28 subjects) or with intramedullary fixation (29 subjects) with a modified Hagie pin. The authors reported that one subject in each group sustained a refracture within one year of the original injury.

Liu HH, Chang CH, Chia WT, et al: Comparison of plates versus intramedullary nails for fixation of displaced midshaft clavicular fractures. *J Trauma* 69:E82–E87, 2010.

The authors performed a retrospective review of 110 patients who underwent plate fixation (59 patients) or intramedullary nail fixation (51 patients) who were similar in demographics and fracture characteristics. They found that there was no significant difference in operative time, time to union, restoration of mobility, functional scores, or occurrence of complications such as malunion, nonunion, infection and need for hardware removal.

Morgan RJ, Bankston LS, Jr, Hoenig MP, et al: Evolving management of middle-third clavicle fractures in the National Football League. *Am J Sports Med* 38:2092–2096, 2010.

Of 13 100% displaced midshaft clavicle fractures in the National Football League, six underwent open reduction internal fixation with plating and seven were treated nonoperatively. Of those treated operatively, players returned to play within the same season, whereas four of the seven treated nonoperatively sustained refracture of their clavicle within 1 year and missed an average of 1.5 seasons.

Verborgt O, Pittoors K, Van Glabbeek F, et al: Plate fixation of middle-third fractures of the clavicle in the semi-professional athlete. *Acta Orthop Belg* 71:17–21, 2005.

The authors reported on their study of 39 semiprofessional athletes in various sports (mountain bike racers, soccer players, swimmers, cyclists) with displaced midshaft clavicle fractures that were treated with open reduction and plating with a 3.5 mm LCDC plate. Five percent had a complication with refracture due to new trauma while the hardware in place. The authors reported that these were treated with revision fixation and grafting with good results. The authors also reported that the most common complication was wound infection (18%).

Multiple-Choice Questions

QUESTION 1. In the first 6 weeks postoperatively after clavicle ORIF, limitations in rehabilitation should include

A. Strict immobilization
B. No strengthening
C. No limitations
D. <90° of abduction

QUESTION 2. In the first 6 weeks after surgery, exercises of the rotator cuff and deltoid should involve:

A. Unlimited passive ROM
B. Resisted strengthening
C. Isometric strengthening
D. Strict immobilization

QUESTION 3. Unlimited range of motion exercises should typically begin after signs of clinical or radiographic union, typically after:

A. 2 weeks
B. 4 weeks
C. 6 weeks
D. 12 weeks

QUESTION 4. Following removal of hardware:

A. there are no precautions
B. there are no risks for fracture
C. overhead strengthening may begin immediately
D. overhead strengthening may begin at 6 weeks, evaluation-based

Answer Key

QUESTION 1. Correct answer: **D** (see Phase II)

QUESTION 2. Correct answer: **C** (see Phase II)

QUESTION 3. Correct answer: **C** (see Phase III)

QUESTION 4. Correct answer: **D** (see Phase V)

BEYOND BASIC REHABILITATION: RETURN TO MOTOCROSS AFTER CLAVICLE FRACTURE

Kahl Goldfarb, PT, DPT, OCS, OMT, CSCS, and Paul C. Murphy, MD

Introduction

ASPECTS OF MOTOCROSS THAT REQUIRE SPECIAL ATTENTION IN REHABILITATION

- Clavicle fractures are common injuries and represent 4% to 10% of all adult fractures and 35% to 40% of all fractures of the shoulder girdle area. The most frequent location for a clavicular fracture is the middle one-third which accounts for 72% to 80% of all clavicle fractures.[1]
- The literature regarding nonoperative versus operative treatment has been extensive over the years, and there is much written about complications and functional results with both forms of treatment. Current literature has now determined that surgical management may indeed be more effective than previously thought, especially in displaced fractures.[2,3,4] Therefore, we are focusing on the surgical management and rehabilitation of clavicle fractures in this chapter.
- Returning to motocross after surgery can be challenging if not properly implemented. The treatment of these fractures should be determined by the clinical judgment of the treating surgeon and the athlete. Once surgery has been determined to be the treatment of choice, rehabilitation should be tailored to the athlete's fracture and its surgical stability. It is imperative that the fracture have rigid fixation in order to progress with early aggressive physical therapy treatments.
- Motocross riders are unique athletes. They require not only upper body strength and athleticism, but also lower extremity balance and aerobic fitness, as they can have three or four consecutive motos of 20 minutes or longer. Clavicle fractures in these athletes create a special set of circumstances for the surgeon and therapist in that the physical requirements of these athletes are not only strength, but very sport-specific proprioceptive demands that are required. Therefore, the rehabilitation of these athletes must not only focus on the shoulder clavicle fracture, but also incorporate core body fitness and aerobic capacity simultaneously.

- Motocross requires an inordinate need for functional postural endurance and aerobic fitness.
- The athlete must also demonstrate explosive strength of the upper extremity (UE) and lower extremity (LE) to control the bike (Figure 7-62).



FIGURE 7-62. Significant upper body requirements for controlling the bike in midair.

- Spinal motor control and extremity proprioception for afferent and efferent feedback are of utmost importance in order to control the bike under precarious circumstances during events and trainings.

Phase I: Advanced Strength and Conditioning Programs

Periodization

- Phase I of this periodization program for the postoperative patient will take approximately 6 weeks.[5]
- This mesocycle will utilize a linear design.
- The rehabilitation timeline is outlined in detail at the end of this chapter and describes the progression through this 6-week protocol. Pain and radiology findings are always the guide in progressing the athlete to the next stage.
- Typically we would rehabilitate our athletes in proper postural position with regard to glenohumeral and scapulothoracic position, but with these athletes, exercises should be performed in a postural position that mimics the riding position that these athletes must maintain for prolonged periods of time. Flexibility and joint mobility are not critical as compared to joint stability. Multi-planer exercises are needed to mimic motocross activities.

TIMELINE 7-9: Advanced Postoperative Rehabilitation for Clavicle Fracture with Internal Fixation for the Motocross Athlete

PHASE I (weeks 0 to 6)

- Repetitions: 15–30
- Sets: two to three
- Rest interval: 30 seconds
- Intensity: low
- Repetition tempo: slow with control
- Training frequency: 3–5 days per week
- Training duration: 30–60 minutes

Week 1

- Sling worn at all times except when exercising
- PT modalities and cryotherapy for controlling, pain and swelling
- No Continuous Passive Motion device (CPM) because there is a rare incidence of frozen shoulders post clavicle ORIF (Open Reduction Internal Fixation)
- Active assistive Codman's exercises
- Range of Motion(ROM)-scapular plane elevation to 90°
- Ball squeeze
- Resisted tricep and bicep TheraBand(TB) exercises
- Active assisted ROM below 90° of flexion and abduction
- Isometric shoulder external rotation(ER), internal rotation(IR), extension, abduction, adduction at side pain-free: early exercise can assist in muscular activity to avoid neuromuscular functional delay
- Manual therapy; mobilize soft tissue (pectoralis major and minor, upper trapezius, sternocleidomastoid, subclavius) decrease lymphedema, decrease trauma from surgery

Week 2

- Progressive weight bearing onto hands in riding position-weight shifting: use pain as guide
- PT Modalities as needed
- Active assisted range of motion (AAROM) 90° flexion and abduction
- Pulley flexion and scaption
- Proprioceptive Neuromuscular Facilitation(PNF): elbow, wrist, and periscapular exercises
- TB shoulder IR/ER at 0° abduction
- TB elbow and wrist flexion, extension, supination, pronation, radial and ulnar deviation
- Wall plank progress to standing table plank
- Scapular clocks against wall progress to standing at a table
- Isometric wall Ts (scapular retraction with arms at 90° of abduction), and Ms (scapular retraction with arms at sides)* Radiographs must indicate rigid internal fixation without loosening of the screws or movement of the plates in order to progress to week 3.
- At week 2–4 theoretically there could be some stress shielding on superior cortex and therefore repetitive load on the fixation and this type of load may need to be monitored with X-rays.

Week 3

- Discharge sling
- Closed chain activity is stressed due to functional needs. ROM needed for riding is 30° to 120° of flexion, extension 30°, ER 30°, IR 60°, horizontal abd 30°, horizontal add 30° (all stabilization exercises will encompass the above ROM. We are not training in a correct postural position because we want to mimic the riding posture during exercise)
- Towel wall active range of motion(AROM) within 120° of flexion with wall pressure
- Use TB around elbows during wall clocks with wall pressure
- Floor planks on knees and elbows progress as tolerated to normal plank position
- Floor plank clocks on knees and elbows
- Floor serratus punch on knees (quadruped)
- TB serratus punch
- TB/pulley IR/ER at 45° to 90° flexion, 0° abduction
- TB or TRX Ms, Ts rows
- PNF exercises
- Rhythmic stabilization exercises
- Closed Kinetic Chain manual perturbation exercises

WEEK 4–6

- Plank
- Plank with shoulder ER
- Physioball plank with perturbations: therapist tries to move ball, bouncing to simulate riding
- Lat pull down (avoiding ROM > 160* of flexion)
- Pushups (for endurance and control without pain)
- Ball toss to ground and up
- Horizontal adduction ball toss into trampoline
- Ball self catch at 90° of abduction moving in all ranges of horizontal adduction and abduction
- IR/ER at 90° abduction all ranges of horizontal adduction and abduction
- Body blade in all functional ranges

*Perform alternating sets with eyes open and then closed

TIMELINE 7-9: **Advanced Postoperative Rehabilitation for Clavicle Fracture with Internal Fixation for the Motocross Athlete** (Continued)

PHASE II (weeks 6 to 12)

- Repetitions: at least 30 but push until fatigue
- Sets: One set before training runs in order to prepare the athlete for the sport from a neuromuscular control standpoint, and then three sets greater than 30 repetitions each after they complete the training run in order to improve endurance.
- Rest interval: 30 seconds in order to stress the cardio respiratory system
- Intensity: moderate
- Repetition tempo: moderate to high
- Training frequency: 3–4 days per week (alternating days)
- Training duration: 60 minutes
  - Prone physioball LE on ball (LE curl up/pike and oblique curl up)
  - Supine physioball LE curl up (progress from full foot touch to just heel touch and from UE support to arms across chest)
  - UE step ups onto step
  - Humeral head depression dips

PHASE III (weeks 4 to 6 in preseason)

- Repetitions: 3–6 for Olympic lifts and 8–12 for all other exercises
- Sets: 3–5
- Rest interval: 60 seconds
- Intensity: moderate to high
- Repetition tempo: moderate to high
- Training frequency: 2 times per week with 2 day break
- Training duration: 30–80 minutes
- Training volume: total amount of repetitions and sets performed during one session
- Olympic lift (power clean)
- Plyometrics: double leg box jumps, single leg box jumps, drop-catch pushups, medicine ball plyopass from chest and progress to above head and incorporate rotation
- Bosu ball dumbell deadlifts
- Bear crawl exercise
- Three or four consecutive motos for >20 minutes each

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- Training with optimum posture (functional riding position)
- Core training
- Multiplanar training activities
- Sensorimotor and balance training
- Training for optimum muscle balance
- Neuromuscular dynamic stability exercises
- Functional training

Training Principles Used in the Design of the Program

- Principle of progression

Application of Acute Training Variables

Phase I is the range of motion and stabilization phase. The focus is on regaining full range of motion (ROM), stabilizing the scapulothoracic and glenohumeral joints, and then functional strengthening exercises that mimic the angle and force that is required to perform motocross activities.

- Repetitions: 15 to 30
- Sets: 2 to 3
- Rest interval: 30 seconds
- Intensity: low
- Repetition tempo: slow with control
- Training frequency: 3 to 5 days per week
- Training duration: 30 to 60 minutes
- Training volume: total amount of repetitions and sets performed during one session
- Specific exercises used in the training:
  - Shoulder girdle and core
  - Active assisted ROM in flexion, abduction and scaption within permissible range
  - Passive pulley flexion and scaption ROM within pain-free range.
  - Isometrics for rotator cuff: internal rotation (IR) and external rotation (ER) at 0° and progressing to 90° of shoulder flexion and abduction,
  - Isometrics shoulder flexion, extension and abduction within pain-free range. Scapula stabilizers Ms (scapular retraction with arms at sides) and Ts (scapular retraction with arms at 90° of abduction)
  - Progressive weight bearing onto upper extremity (UE) with weight shifting and clocks
  - TheraBand (TB) internal rotation (IR) and external rotation (ER) at 0° and progressing to 90° of shoulder flexion and abduction; TB resisted extension
  - Wall towel slides with progressive resistance; pushing body weight into the wall not to exceed 120° of flexion
  - TB or TRX (Total body Resistance eXercise suspension system) Ts and Ms and serratus punch and wall clocks with TB around elbows
  - Proprioceptive neuromuscular facilitation (PNF) and rhythmic stabilization exercises
  - Plank progressions from the wall to a table to the ground. Progress on the ground from knees and elbows to normal plank. Then add variations such as shoulder ER and/or physioball under elbows with perterbations
  - Pushups (for endurance and control without pain)
  - Latismus dorsi pull downs (avoiding ROM > 160° of flexion)[6]
  - Ball tossing to ground and up
  - Self catching the ball at 90° of flexion and in all ranges of horizontal abduction and adduction.
  - Body blade in all functional ranges
  - Elbow/wrist/hand
  - TB elbow and wrist flexion and extension pronation and supination, radial and ulnar deviation
  - PNF in all directions
  - Ball squeezes

Application of Chronic Training Variables

At this stage in the rehabilitation process, intensity level will be low but total volume will be performed at a high level.

In order to progress to Phase II and to ride on flat surfaces, the following criteria must be met:

- Radiographic and clinical healing
  - Radiographs must indicate rigid internal fixation without loosening of the screws or movement of the plates. Minimal periosteal healing must be present unless under the age of 18 years old.
  - At weeks 2 to 4 theoretically there could be some stress shielding on superior cortex and therefore repetitive load on the fixation, and this type of load may need to be monitored with X-rays.
- Pushups: Able to perform 80% of the maximum amount of pushups without pain that the athlete was able to achieve prior to injury
- Laser pointer test: Able to perform 80% of the maximum time to maintain the laser beam within a 2-inch radius circle as compared to the uninvolved extremity during the laser pointer test (Figure 7-63). The athlete must be asymptomatic during this exercise in order to progress to Phase II.[7]
- Plank Proprioception Testing: Able to perform 80% of the maximum amount of UE reaches with uninvolved extremity as involved extremity without pain (Figures 7-64 and 7-65).

If the athlete is unable to pass all four criteria listed above, he/she will continue with the Phase 1 program and be reassessed by the surgeon until criteria is passed.

Phase II: Performance Enhancement Training Techniques

Periodization

- After our athlete progresses successfully through the Phase I rehabilitation program, and after the athlete passes all of the objective tests discussed, an advanced training and conditioning program is initiated. Phase II is initiated at about 6 weeks after surgery. This mesocycle will utilize a linear design.
- Careful monitoring of healing: weekly radiographs monitoring internal fixation until week 9 and then the final X-ray at week 12.

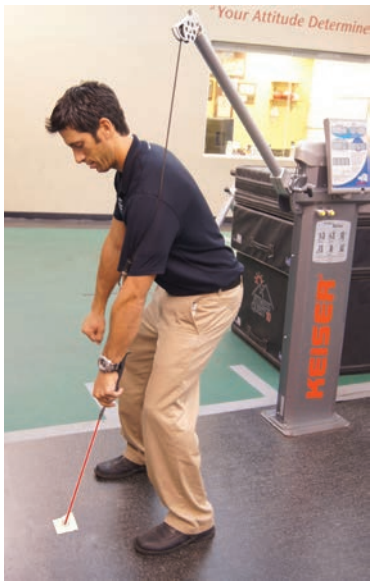

FIGURE 7-63. Laser Pointer test: Stand in a position that mimics the riding position and place the pulley and a laser in the uninvolved hand so the force is directed up through the arm and into the shoulder and thorax. Choose a weight on the pulley stack that mimics flat riding to test endurance. Attempt to keep the laser beam inside of a 2-inch radius circle on a sticky note. Time how long it takes until the subject can no longer isometrically maintain the laser in the 2 inch radius circle and then test the involved extremity in same manner. Subject must be able to keep the laser within the 2-inch circle 80% of the time in order to be cleared to ride on flat surfaces and 100% of the time in order to return to competition. The athlete must be asymptomatic in this exercise in order to progress forward.



FIGURE 7-64. Plank Proprioceptive Testing Level 1: In a plank position, weight bear through the involved extremity as seen with the red arrow. Slowly move the other extremity forward and back and to the side, as seen with the black arrow, while being sure to keep the body still through the entire motion. This test demonstrates stability of the shoulder in the riding position without dynamic stress (i.e., bumps and hills).

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

All of the specific exercises listed below are sports specific and can be performed with minimal equipment and without supervision. They incorporate all of the training variables listed.

- Core training
- Cardiorespiratory training



FIGURE 7-65. Plank Proprioceptive Testing level 2: similar to level 1 except with the uninvolved extremity on a slider (or using a towel) reach as far as possible away from the body in all directions. This time try to move the body over the involved shoulder during the maximal reach in order to stress the involved shoulder in different positions mimicking shoulder motions during dynamic riding (bumps, hills, etc.).

- Multi-planar training activities
- Training for optimum muscle functional strength
- Training for speed, agility, quickness (SAQ)
- Sport-specific training
- Neuromuscular dynamic stability
- Sensorimotor and balance training

Training Principles Used in the Design of the Program

- Principle of progression
- Principle of individualization

Application of Acute Training Variables

Phase II is a combination of the endurance phase with a progressive strengthening component to mimic the needs of a motocross athlete. The load is increased as compared to Phase I and the volume is increased to enhance the fatigue threshold.

- Repetitions: at least 30, but push until fatigue results
- Sets: 1 set before training runs in order to prepare the athlete for the sport from a neuromuscular control standpoint, and then 3 sets greater than 30 repetitions each after they complete the training run in order to improve endurance.
- Rest interval: 30 seconds in order to stress the cardio respiratory system
- Intensity: moderate
- Repetition tempo: moderate to high
- Training frequency: 3 to 4 days per week (alternating days)
- Training duration: 60 to 90 minutes
- Training volume: training volume varies but should be documented in order to improve the repetitions and or time/endurance
- Specific exercises used in the training
  - Prone physioball LE on ball (LE curl up/pike and oblique curl up) (Figures 7-66 and 7-67). This exercise mimics the coordination, strength (core, UE and LE) and endurance needed to control the bike when riding over bumps or when airborne. Slowly increase



FIGURE 7-66. Pike on Ball: With hands placed on ground and toes on ball, simultaneously pull your upper body and lower body together to reach a final pike position.



FIGURE 7-67. Physioball oblique curl up: With hands on the ground and toes on the ball begin to pull your upper and lower body together but curl to one side so to incorporate rotation and repeat on both sides.

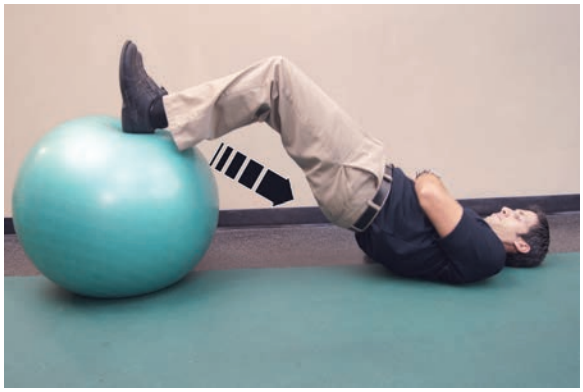

FIGURE 7-68. Supine bridge physioball hamstring curl up. Level 1. Place both feet on the ball so the entire sole is touching the ball, place hands on the floor at your sides to increase stability, and bridge body into the air. Slowly raise and lower your body but do not touch the ground until fatigue or control is an issue. Progression: Progress so heels only touch the ball and final progression is to place arms across chest to increase demand.



FIGURE 7-69. Upper extremity step ups: Put as much weight as comfortable through the involved extremity and slowly step opposite hand onto step. Then elevate involved extremity onto step and then slowly control the opposite arm during its descent down from the step. Make sure that shoulder blade does not wing.

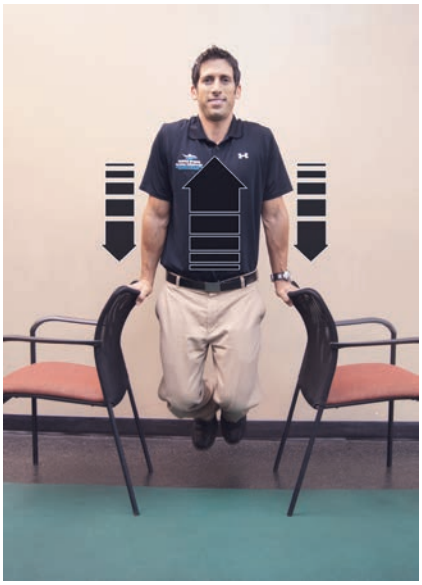

FIGURE 7-70. Humeral head depression dips: Using two chairs that are placed shoulder width apart, hold your full body weight in the air and then elevate your body higher by pressing your shoulders down toward the ground. Slowly lower your body until your shoulders reach your chin and then elevate your body up again. Repeat until fatigue or control is compromised.

speed to focus on speed, agility, and quickness and to stress the cardio respiratory system.

- Supine physioball bridge hamstring curl (progress from full foot touch to just heel touch and from UE support to arms across chest) (Figure 7-68). This activity directly stresses the posterior chain, which is essential in kickstarting and controlling the bike. This exercise assists in training for optimum muscle functional strength and sensorimotor and balance systems.
- UE step ups onto step (Figure 7-69), which utilizes scapular stability and shoulder girdle strength in order to mimic the force attenuated by the UE during riding and during bumpy rides. These exercises incorporate sport-specific training and neuromuscular dynamic stability
- Humeral head depression dips (Figure 7-70) focus on rotator cuff dynamic stability and scapular strength in order to provide the ability for the shoulder and UE to control the bike during rough rides.

Application of Chronic Training Variables

- Chronic training variables are manipulated over the mesocycle with a continued increase in volume and intensity as per the athlete's maximal ability and endurance allows.
- In contrast to most team sports where a trainer, strength coach, and physical therapist, as well as a training room are readily available, motocross athletes do not have access to these privileges. In our experience, once the rider returns to full competition, the rider often does not continue with rehab or neuromuscular reeducation and strength training under supervision. Therefore, the program that we prescribe can be completed in any location, as it only requires a physioball, two chairs, and 12 feet by 12 feet open space. This simple program will help with patient compliance. The exercises are performed once before a training run and again three times after the run is complete in order to improve functional capacity, strength, motor control and endurance. For optimal recovery and performance, it is recommended that the athlete continue with a supervised sports-specific training program. If the athlete complies, we then progress them to Phase III.

Phase III: Sport-Specific Training

Periodization

- Phase III takes place during the preseason and would stress the development of maximum aerobic capacity, strength/motor control and flexibility. Training will be a linear. Periodization for the length of one mesocycle (approximately 4 to 6 weeks).

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- Flexibility/joint mobility for joint stability
- Core training
- Cardiorespiratory training
- Multiplanar training activities
- Training for optimum muscle functional strength
- Neuromuscular dynamic stability exercises
- Training for speed, agility, quickness
- Plyometric training
- Functional training
- Sport-specific training

Olympic Lifts Used in the Training Program

- Power clean: In a power clean, the athlete pulls the barbell from shin level and must receive it on the shoulders and stop moving downward before sinking past a parallel squat.

Training Principles Used in the Design of the Program

- Principle of progression
- Principle of overload
- Principle of variation
- Principle of individualization
- Principles of specificity–specific adaptation to imposed demands (SAID)

Application of Acute Training Variables

This mesocycle is a strength phase. If the athlete does not have a strength coach or appropriate supervision to assure that form is correct, we recommend omitting power lifting. The power clean should be done with heavy weights so that the athlete can perform a maximum of 3 to 6 repetitions. Plyometrics should follow power cleans after a 60-second rest time and should be done 8 to 12 times.

Repetitions: three to six for Olympic lifts and eight to twelve for all other exercises

- Sets: three to five
- Rest interval: 60 seconds
- Intensity: moderate to high (athlete should only be able to speak in short phrases, should be sweating, and breathing is deep and rapid due to exercise intensity)
- Repetition tempo: moderate to high
- Training frequency: two times per week with a 2-day break
- Training duration: 30 to 90 minutes
- Training volume: total amount of repetitions and sets performed during one session
- Specific exercises used in the training:
  - Olympic lift (Power Clean) which will assist in the force production needed to push the bike off of terrain and utilizes training for optimum muscle functional strength
  - Plyometrics: double leg box jumps, single leg box jumps, drop-catch pushups, medicine ball plyopass from chest and progress to above head and incorporate rotation. These plyometric exercises incorporate core training, cardiorespiratory training and multiplanar training activities to reproduce the forces that the UE and LE must absorb during riding.
  - Dumbell deadlifts on BOSU ball to stress the neuromuscular dynamic stability system while strengthening the posterior chain eccentrically.
  - Bear crawl exercise (crawling on hands and feet with pelvis as low to the ground as possible without allowing knees to touch the ground). This multiplanar and core exercise assists in functional strengthening of the shoulders and hips during spinal stabilization.
  - Three or four consecutive motos for > 20 minutes each.

Application of Chronic Training Variables

- Power is generally not a primary focus for motocross athletes. The primary muscles that are worked for power are the posterior chain muscles such as hamstrings and gluteals which are used to kick start and push off the bike. Back muscular strength is needed in the form of neuromuscular control and movement patterns to control the weight of the bike. Shoulder and chest motor control is needed to manipulate the bike. We recommend that the athlete perform this exercise program 2 days per week. Day 1 would consist of this

exercise program, Day 2 would consist of functional riding for sports specific training and Day 3 should be the HEP from phase II. Day 4 would be a rest day and then the entire cycle would be repeated.

Sports Performance Testing

General Information

- General history
- Subjective questionnaires
- Medical history
- Sports injury history
- Surgical history—history of related or unrelated surgeries
- Chronic conditions/medication—check for respiratory and cardiac condition, head injuries, concussions, vestibular disorders, systemic diseases

Objective Tests

- Radiographic healing
- Laser pointer test for endurance and control (see Figure 7-63)
- Plank proprioceptive testing PPT 1 and 2 (see Figures 7-64 and 7-65)
- Body weight tests: pushups
- Balance and proprioception (eyes open vs closed with HEP)
- Objective questionnaires: DASH.

Specific Criteria for Progression to the Next Stage to Determine Readiness for Motocross

- There must be rigid internal fixation (no movement of the screws or the plate) and minimal periosteal healing in order to progress to week 3.
- In order to progress to week 4, patient must pass the laser pointer test. Athlete must be able to keep laser within the two-inch radius circle 80% of the time as compared to uninvolved side. The athlete must be asymptomatic during this exercise.
- In order to ride on flats (approximately week 4), the athlete must pass the Plank Proprioception Test 1: In the plank position, slowly move the other extremity forward, back, and to the side, while being sure to keep the body still through the entire motion. Able to perform 80% of the maximum amount of UE reaches with uninvolved extremity as involved extremity without pain.
- In order to be cleared to ride on flat surfaces (approximately week 4), the athlete must perform 80% of the maximum amount of pushups without pain that the athlete was able to achieve prior to injury.

Specific Criteria for Release to Unsupervised Complete Participation in Motocross

- Radiographic and clinical healing (athletes under the age of 18 may present with periosteal callus which would not indicate an issue with fixation):
  - Fracture line is no longer present.
  - Periosteal healing is minimal.
  - Endosteal healing is clearly visible; sclerosis of the fracture line in the medullary canal.
  - Internal fixation is rigid without any movement of the screws or plate.
- Athlete must perform 100% of the maximum amount of pushups (pain free) that the athlete was able to achieve prior to injury.
- Athlete must pass the laser pointer test: Able to perform 100% of the maximum time to maintain the laser beam within a 2-inch radius circle as compared to the uninvolved extremity during the laser pointer test.
- Athlete must pass the Plank Proprioception Test 2: Able to perform 100% of the maximum amount of UE reaches with uninvolved extremity as involved extremity (pain-free)
- Careful monitoring of healing: weekly radiographs monitoring internal fixation until week 9, and then final x-ray at week 12.

Recommended Ongoing Exercises

- The authors recommend that the athlete continue with the Phase II program indefinitely.

Evidence

There are no evidence-based trials to support techniques to return patients to motocross after clavicle fracture.

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Multiple-Choice Questions

QUESTION 1. At what week do we increase flexion ROM past 90°?

A. Week 1
B. Week 2
C. Week 3
D. Week 4

QUESTION 2. What is the functional criteria in order to progress to (non-competitive) riding?

A. Perform 10 pushups without pain and 20 pull-ups without pain
B. Pain-free full ROM and pain-free with putting weight through arms in a pushup position
C. Able to perform 20 pushups with pain and perform 30 serratus punches with 20 lbs per arm without pain
D. Perform 80% of the maximum amount of pushups (pain-free) that the athlete was able to achieve prior to injury.

QUESTION 3. Which Olympic lift is most appropriate for motocross athletes?

A. Clean and jerk
B. Snatch
C. Power clean
D. Dead lift

QUESTION 4. In order to perform advanced rehabilitation on a patient with a clavicle fracture who has had internal fixation, what is the most critical objective factor in determining when the athlete can begin rehab?

A. Motivated athlete
B. Main free with all movements
C. Rigid internal fixation via radiograph
D. Pain-free with weight lifting

QUESTION 5. Which of the following is a part of Phase II training?

A. Olympic lifting
B. Physioball dynamic exercises
C. Plyometrics
D. Isometrics

Answer Key

QUESTION 1. Correct answer: **C** (Week 3, as long as bony healing is occurring)

QUESTION 2. Correct answer: **D** (Perform 80% of the maximum number of pushups)

QUESTION 3. Correct answer: **C** (Power clean)

QUESTION 4. Correct answer: **C** (Rigid internal fixation via radiograph)

QUESTION 5. Correct answer: **B** (Physioball dynamic exercises)

Chapter 8



Adhesive Capsulitis and Glenohumeral Arthritis

INTRODUCTION

Jo A. Hannafin, MD, PhD, Theresa A. Chiaia, PT, DPT, and A. Simone Maybin, BS, NSCA-CPT

Epidemiology

- Primary adhesive capsulitis affects 2% to 5% of the general population
- Patient age, 40 to 65 years old
- Incidence, higher in females than in males
- Nondominant arm is more frequently involved
- Athletes (not sport specific) and nonathletes equally affected

Pathophysiology

Intrinsic Factors

- The following intrinsic factors may play a role in the development of primary adhesive capsulitis:
  - Angiogenesis and synovitis consistent with inflammation
- Secondary adhesive capsulitis and restriction of glenohumeral range of motion may result from:
  - Rotator cuff tendonitis
  - Rotator cuff tears
  - Calcific tendonitis
  - Contracture of the rotator cuff interval
  - Subacromial scarring
  - Inflammation of the long head of the biceps tendon and its synovial sheath

Extrinsic Factors

- Trauma is the only known extrinsic factor implicated in the development of adhesive capsulitis.
- Patients with diabetes mellitus are at greater risk of developing adhesive capsulitis, with a prevalence between 10% and 20%[1-3]
- Although more rare, both thyroid dysfunction and Parkinson disease are also associated with the development of adhesive capsulitis[4-6]

Classic Pathological Findings

- General pathological findings are synovial hyperplasia and capsular fibrosis[7] further characterized by:
  - Elevated cytokine expression in shoulder capsule including transforming growth factor-β (TGF-β), platelet-derived growth factor, and hepatocyte growth factor[7]
  - Excess accumulation and propagation of fibroblasts (Type I and II collagen)[7,8]
- Specific pathological findings vary dependent upon the current stage of the patient. These are further described in Table 8-1.[9,10]

Table 8-1 Stages of Adhesive Capsulitis

	Arthroscopic Appearance	Biopsy
Stage 1 (Preadhesive)	Fibrinous synovial inflammatory reaction No adhesions or capsular contracture	Rare inflammatory cell infiltrate Hypervascular, hypertrophic synovitis Normal capsular tissue
Stage 2 (Freezing)	Christmas tree synovitis Some loss of axillary fold	Hypertrophic, hypervascular synovitis Perivascular, subsynovial capsular scar
Stage 3 (Frozen)	Complete loss of axillary fold Minimal synovitis	Hypercellular, collagenous tissue with a thin synovial layer Similar features to other fibrosing conditions
Stage 4 (Thawing)	Fully mature adhesions Identification of intraarticular structures difficult	Not reported

Clinical Presentation

History

- Insidious onset without a definitive action or event causing symptoms
- Progressive increase in pain with development of sleep-disturbing night pain
- Deep achy pain at rest with acute intense pain associated with quick motion or rapid stretch
- ROM is initially limited by pain, not capsular contracture. It then progresses to global stiffness shoulder.
- Initial loss of external and internal rotation
- Passive and active motions are more restricted owing to pain at or before end range secondary to muscle guarding.

Physical Examination

Abnormal Findings

- Patients with adhesive capsulitis will differ in motion limitations dependent upon their current stage (1 through 4) (Table 8-2).

Pertinent Normal Findings

- Strength deficits are generally not present, in contrast to impingement and rotator cuff disease.
- No significant muscle atrophy

Imaging

- Plain radiographs (X-rays) are routinely performed to rule out calcific tendinitis or glenohumeral arthritis.
- Osteopenia is a common radiographic finding.
- Magnetic resonance imaging (MRI) is not essential for diagnosis but can rule out confounding pathology.
- Hallmark of adhesive capsulitis on MRI is thickening and loss of volume of the axillary pouch.
- MRI in stages 1 and 2 demonstrates increased signal in capsule and synovium consistent with hyperemia and synovitis.
- MRI in stages 3 and 4 demonstrates low signal capsule with increased capsular thickness in anterior capsule, posterior capsule, and axillary pouch.
- One-third of stage 2 adhesive capsulitis patients show some form of supraspinatus pathology on magnetic resonance arthrography.[11] The clinical significance is unknown but should be correlated with physical examination.
- Axillary recess thickening up to 1.3 cm or more compared with normal measurement of less than 4 mm[11]
- Rotator interval thickening[12]
- Glenohumeral ligament thickening[12]

Differential Diagnosis

- Shoulder stiffness is a common symptom of many glenohumeral joint conditions. It is critical to distinguish

Table 8-2 Clinical Signs and Symptoms of Adhesive Capsulitis

	Symptoms	Signs
Stage 1 (Preadhesive)	Achy pain at rest referred to deltoid insertion; sharp pain with movement Pain at night	Capsular sign on deep palpation Empty end feel = pain stops PROM before resistance felt by clinician Full motion under anesthesia
Stage 2 (Freezing)	Persistence of pain; increased night pain Pain extends to upper trapezius secondary to compensatory shrugging Progressive limitation of motion with ADLs	Motion restricted in capsular pattern; ROM reveals a capsular end feel. Forward flexion, abduction, internal and external rotation Pain at the end of the ROM Some improvement in motion under anesthesia
Stage 3 (Frozen)	Profound limitation of motion with ADLs Pain present at the end of range of motion only	Resistance to ROM felt before pain Significant loss of motion Tethering at ends of motion No improvement under anesthesia
Stage 4 (Thawing)	Minimal pain Slow, steady improvement in ROM with ADLs	Significant motion loss Gradual improvement in motion

Table 8-3 Possible Differential Diagnoses for Primary Adhesive Capsulitis

Possible Differential Diagnoses	Primary Factor to Supporting Differential vs. Primary Adhesive Capsulitis
Impingement Syndrome (Stage 1)[12]	Positive Neer, Hawkins tests Shoulder musculature may be tender upon palpation
Cervical spine and neurological pathologies	Character of pain is described as burning/stinging. Pain may follow a radicular pattern Deficit in strength, sensation, and/or reflexes may exist. Pain may change with motion of cervical spine
Calcific Tendonitis/Bursitis	Rotator cuff tendon(s) present with calcium deposits in radiography Pain is more sudden in onset. Pain with glenohumeral abduction, may be minimal with rotation in 0° abduction
Acromioclavicular arthritis	Tenderness present upon palpation of AC joint Positive crossover test
Bicep tendonitis	Tenderness present upon palpation of bicep tendon Local crepitus with humeral rotation
Severe glenohumeral osteoarthritis	Loss of joint space, osteophytes present on X-ray.
Rotator cuff tendonopathy	Pain present with internal rotation, abduction, and strength testing. MRI (+) for tendonosis.

between primary adhesive capsulitis and other disorders because the treatment is time sensitive. The common differential diagnoses are listed in Table 8-3.

Treatment

Nonoperative Management

- Physical therapy[13] including patient education, manual therapy,[13] therapeutic ROM exercises and periscapular strengthening, neuromuscular re-education and modalities for pain, relaxation, and tissue extensibility (moist heat, cryotherapy, TENS, low power laser)
- Oral nonsteroidal antiinflammatory medications (NSAIDs)
- Oral corticosteroid
- Intraarticular corticosteroid injection[14]
- Distension arthrography or hydrodilation
- Closed manipulation

Guidelines for Choosing Among Nonoperative Treatments

- Optimal treatment options should be selected according to:
  - The presenting stage of adhesive capsulitis
  - The degree of irritability
  - The pain level
  - The degree of restricted motion
  - The duration of symptoms and signs
  - The goals of the patient
- A combination of nonsurgical treatments may be ideal.

Surgical Indications

- When physical and pharmacological therapies have failed, surgical options should be considered and discussed with the patient.
- Failed therapy should be considered when a patient has reached a plateau or progress in increased ROM is extremely slow.
- Surgery may be indicated for a painful shoulder that has failed to respond to intraarticular corticosteroids.
- Surgery is indicated when the patient is failing to improve with a minimum of 6 months of conservative treatment.

Aspects of History, Demographics, or Exam Findings that Affect Choice of Treatment

- Surgical options are dependent on the stage of adhesive capsulitis and other concomitant pathology.
- Surgery is elective and based on patient pain, arm dominance, and goals.
- Failure to progress with physical therapy goals is a relative indication for surgical treatment.

Aspects of Clinical Decision Making When Surgery Is Indicated

- Options for surgical treatment include: (1) closed manipulation under anesthesia; (2) manipulation under anesthesia followed by arthroscopy; and (3) arthroscopy, capsular release, and manipulation.
- Surgeon preference, degree of osteopenia, and imaging studies guide decision making.
- Arthroscopy permits identification and treatment of associated pathology.
- Synovectomy is indicated when significant synovitis is present.
- Arthroscopic division of the capsule permits a more controlled and precise release than manipulation. The anterior and posterior capsule is released prior to manipulation. The axillary pouch can be released but care must be taken to avoid injury to the axillary nerve.
- Performing the manipulation prior to arthroscopy may result in intraarticular bleeding and an obscured view, as well as a risk for fracture.
- Patients with idiopathic adhesive capsulitis who have failed arthroscopic and closed manipulation procedures may benefit from an open release.
- Patients with secondary adhesive capsulitis may require lysis of adhesions in the subacromial space and release of the coracohumeral ligament.

Evidence

Carette S, Moffet H, Tardif J, et al: Intraarticular corticosteroids, supervised physiotherapy, or a combination of the two in

the treatment of adhesive capsulitis of the shoulder. *Arth Rheum* 48(3):829–838, 2003.

This controlled prospective study randomized 93 patients to compare the efficacy of intraarticular injection, supervised PT, the combo of PT and injection, and placebo. Utilizing the SPADI, the injection and PT group demonstrated faster results; however, injection alone yields better results than supervised PT alone. (Level II evidence)

Hazelman BD: The painful stiff shoulder. *Rheumatol Phys Med* 11:413–421, 1972.

This retrospective review of 130 patients noted that the efficacy of intraarticular hydrocortisone injections inversely correlates with the duration of symptoms. Further, discrimination between stage 1 and 2 disease can be determined based on the patient's response to the local anesthetic, and thus can be used for future treatment options. (Level III evidence)

Jewell DV, Riddle DL, Thacker LR: Interventions associated with an increased or decreased likelihood of pain reduction and improved function in patients with adhesive capsulitis: A retrospective cohort study. *Phys Ther* 89:419–429, 2009.

This retrospective cohort study examined the data from 2370 patients to determine whether physical therapy interventions predicted meaningful short-term improvement in four measures of physical health, pain, and function in patients with adhesive capsulitis who had completed outpatient physical therapy. Joint mobilization and mobility, and exercise increased the odds of increased the odds of meaningful improvement in bodily pain, and hybrid function, respectively. (Level III evidence)

Nevaiser AS, Hannafin JA: Adhesive capsulitis: A review of current treatment. *Am J Sports Med* 38(11):2346–2356, 2010.

This is a paper illustrating the histopathologic progression of disease in capsular biopsies from patients with Neviaser stages 1 through 3. (Level I evidence)

Neviaser RJ, Neviaser TJ: The frozen shoulder. Diagnosis and management. *Clin Orthop Relat Res* 223:59–64, 1987.

This is a paper describing the four stages of adhesive capsulitis—the preadhesive stage, the freezing stage, the frozen or maturation stage, and the thawing stage—by correlating the physical exam with the arthroscopic findings. (Level V evidence)

Oh JH, et al: Comparison of glenohumeral and subacromial steroid injection in primary frozen shoulder: A prospective, randomized short-term comparison study. *J Shoulder Elbow Surg* 20(7):1034–1040, 2011.

This prospective, randomized trial randomly divided 71 patients with primary adhesive capsulitis into glenohumeral or subacromial ultrasound guided injection. The GH steroid injection led to earlier pain relief. (Level II evidence)

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Multiple-Choice Questions

QUESTION 1. Which intrinsic factor can lead to primary adhesive capsulitis?

A. Calcific tendinitis
B. Contracture of RCI
C. Subacromial scarring
D. None of the above

QUESTION 2. Which stage of adhesive capsulitis is characterized by a Christmas tree (synovium is pedunculated and thickened) synovitis by arthroscopy?

A. Stage 1 Preadhesive
B. Stage 2 Freezing
C. Stage 3 Frozen
D. Stage 4 Thawing

QUESTION 3. Stage 3 adhesive capsulitis signs and symptoms include the following:

A. Pain at the end range of motion and no improvement under anesthesia
B. Profound stiffness and gradual improvement in motion
C. Severe night pain and gradual improvement in motion
D. Pain referred to deltoid insertion and full motion under anesthesia

QUESTION 4. What nonsurgical treatment for adhesive capsulitis can also be used as a diagnostic tool?

A. Oral NSAIDs
B. Oral corticosteroids
C. Intraarticular steroid injections
D. Distention arthrography

QUESTION 5. When is surgery indicated for patients diagnosed with primary adhesive capsulitis?

A. As soon as the patient's physical exam indicates Stage 2 signs and symptoms
B. When other physical and pharmacological therapies have failed
C. Anytime radiography demonstrates axillary recess thickening greater than 4 mm
D. After significant motion loss and stiffness has persisted longer than 4 months

Answer Key

QUESTION 1. Correct answer: **D** (see Pathophysiology)

QUESTION 2. Correct answer: **B** (see Pathophysiology)

QUESTION 3. Correct answer: **A** (see Clinical Presentation)

QUESTION 4. Correct answer: **C** (see Treatment)

QUESTION 5. Correct answer: **B** (see Treatment)

NONOPERATIVE REHABILITATION OF ADHESIVE CAPSULITIS

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GUIDING PRINCIPLES OF NONOPERATIVE REHABILITATION

- Understand the stages of adhesive capsulitis.
- The stage of presentation will guide rehabilitation to optimize results.
- The stage of presentation will determine the duration of each phase of rehabilitation.
- The patient's response to initial treatment (injection) will determine the duration of each phase.
- Achievement of phase-specific goals will determine advancement.
- Irritability of the shoulder will guide prescription for range of motion.
- Perform reassessment of the patient's response to treatment to avoid joint inflammation.
- Understand the patient's individual goals will determine discharge planning.
- Patient education will help increase compliance with HEP, activity modification, and decrease frustration.

Introduction

- The phases of rehabilitation for adhesive capsulitis have typically been written to coincide with the stages of adhesive capsulitis.
- These guidelines are written in phases for a patient presenting with stage 2 adhesive capsulitis, because this is when the majority of patients seek treatment.
- Stage 1 is characterized by pain, inflammation, and an active synovitis.
- Stage 3 is characterized by a stiff shoulder resulting from loss of capsular volume.
- Stage 2 is a continuum/transition from stage 1 to 3 and thus has characteristics of both stages.
- Five phases of rehabilitation are presented: 1, Symptom Control; 2, Mobility; 3, Optimization of ROM; 4, Strengthening; 5, Functional Activity/Return to Sport.
- Regardless of the stage at presentation, the patient will pass through all these phases. The duration of each phase will vary according to the stage of presentation, initial treatment and response, goals of the patient, as well as shoulder dominance.

Phase I (weeks 1 to 4): Symptom Control

Management of Pain and Swelling

- NSAIDs
- Intraarticular injection
- Patient education
- Activity modification
- Positioning (Figure 8-1)
- Cryotherapy
- TENS
- Hydrotherapy
- Manual therapy
- Moist heat
- Low power laser therapy

Techniques for Progressive Increase in Range of Motion

CLINICAL PEARL

Understand the irritability of the shoulder and monitor the shoulder's response to treatment. ROM should improve, not regress.

Manual Therapy Techniques

- Gentle shaking of the extremity. Gently grasp the patient's wrist and gently oscillate the upper extremity



FIGURE 8-1. Positioning of the UE in the plane of the scapula with the elbow higher than shoulder. Also support limitations in IR ROM.

in a comfortable, neutral position. This will allow the patient to relax and help to control pain.

- Joint mobilizations in the posterior/dorsal direction, inferior, and caudal, lateral distraction direction. The glenohumeral joint is mobilized using Grade I mobilizations to help modulate pain, progressing to Grade II mobilization. Distraction/traction can be performed in combination with the glides. The sternoclavicular, acromioclavicular, and scapulothoracic articulations are assessed for restrictions and addressed, as needed.
- ROM: Pain-free physiological movements such as scapular plane elevation with the arm in modified neutral, IR/ER in the plane of the scapula (PoS), and abduction will help modulate pain by stimulating mechanoreceptors. These movements are performed in a slow, consistent tempo by the therapist to promote relaxation. The hold time begins as a pause with gradual increase in duration as tolerance and irritability permits.

Soft Tissue Techniques

- Therapeutic massage for myofascial release of pectorals, triceps, latissimus, and subscapularis

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Pendulum exercises produce joint distraction and increase the arc of pain-free movement. Pendulum exercises should be pain free. This is achieved when the patient bends forward and uses body momentum to create arm movement. The arc of motion should be within an arc that is pain free and allows the upper extremity (UE) to relax. The patient chooses the direction of movement. These are performed three times for 10 to 30 seconds. This should be a "go-to" exercise during the day.
- Pain-free physiological movements using the opposite extremity with low load (intensity) and low duration performed three to five times per day. For example: supine forward flexion in modified neutral, supine IR, supine ER using a cane in the plane of the scapula. The patient is instructed to perform these ROM exercises to the edge of pain, not into pain. Irritability of the shoulder will help the PT instruct the patient regarding frequency, duration, and intensity. A good starting point is to hold for 5 to 10 seconds, and perform 10 repetitions. The shoulder's response to treatment will determine irritability and will guide parameters, in terms of duration of stretch and repetitions.
- Supine "T towel" positioning, with a towel roll positioned along the spine, and a second along the base of the head, is recommended to promote thoracic extension and allow the anterior positioned humeral head to sit back. This position is used to achieve thoracic mobility and to open up the anterior chest. The patient rests in this position for 10 minutes with her arms supported on pillows. The "T towel" can be performed two times per day.
- Continuous passive motion (CPM) in the PoS for IR/ER in modified neutral can be used. This modality allows the patient to relax as the shoulder is cycled through internal and external rotation. It can be used at comfortable, slow speeds—a pause can be used for a patient who can tolerate a longer time at end range. The duration of each session is 10 to 15 minutes.
- Hydrotherapy provides an environment for active-assistive exercise. To address any ROM deficits and/or maintain ROM: The water temperature is warm to create an environment that promotes relaxation. The patient is instructed to perform modified breast stroke movements (horizontal abduction and adduction), flexion in the plane of the scapula, and gentle internal and external rotation.

Other Therapeutic Exercises

- TLS to tolerance. Monitor and avoid exercises that involve loading the shoulder and upper extremity.
- Core stability emphasizing the lower abdominals can be performed using the legs to challenge the core. At this time, avoid exercises that load the shoulder with weight through the elbows.
- TAS: can perform scapular retraction, scapular elevation to tolerance, biceps curls, triceps extension with arm in neutral position. Avoid heavy weights that will cause compensatory anterior translation of the humeral head.

Activation of Primary Muscles Involved

- Strengthening of the scapular muscles can be initiated to tolerance such as retraction, elevation, protraction. Side lying position with the involved arm on top and supported by pillows can be used to decrease gravity for increased tolerance to exercise. Tactile cues can be helpful to ensure proper movement. Manual resistance can be given by the physical therapist. With increased strength, the patient can perform scapular retraction in sitting, scapular protraction in supine. Resistance can be added with elastic bands or hand weights. Perform

10 reps, 3 sets; however, the emphasis is on quality of movement.
- Hydrotherapy, because the buoyancy provides an environment for active-assistive exercise. The patient is instructed to perform modified breast stroke movements (horizontal abduction and adduction), flexion in the plane of the scapula, and gentle internal and external rotation. The water temperature is warm to create an environment that promotes relaxation.

Sensorimotor Exercises

- Hydrotherapy can be used for its hydrostatic properties, which create a "glove-like" effect stimulating the proprioceptors of the skin.

Open and Closed Kinetic Chain Exercises

- Pain-free, closed kinetic chain (CKC) exercises below shoulder height, such as physioball scapular stabilization exercises can be initiated with adequate ROM/soft tissue length. A physioball is placed on a stable surface (chair, resting on a toss back) so that the UEs are positioned below shoulder height and slightly wider than her body. With the elbows straight, the patient then compresses the ball and performs small movements as instructed by the therapist.

Techniques to Increase Muscle Strength, Power, and Endurance

- Strengthening of the scapular muscles can be initiated as described previously.

Neuromuscular Dynamic Stability Exercises

- Rhythmic stabilization exercise for IR/ER in the PoS in modified neutral to tolerance. With the patient lying in supine, the patient's upper extremity is positioned in the plane of the scapula and the elbow is supported on a towel roll with the elbow flexed to 90°. The therapist applies gentle pressure at the wrist in the direction of

TIMELINE 8-1: **Nonoperative Rehabilitation of Adhesive Capsulitis**

PHASE I (weeks 1 to 4)	PHASE II (weeks 5 to 8)

• PT modalities for pain and inflammation, relaxation: TENS, cryotherapy, moist heat, low-level laser therapy
• PT modalities to promote tissue extensibility and relaxation
• Oral NSAIDs, intraarticular injection
• Patient education: activity modification, disease progression, positioning
• Home exercise program: pendulums, ROM for supine scapular plane elevation, supine PoS ER, in modified neutral with cane, supine PoS IR, in modified neutral with opposite extremity
• Manual therapy: grade I and II joint mobilizations in posterior direction, inferior direction, distraction; pain-free ROM exercises; gentle shaking of the UE
• Soft tissue techniques: myofascial release latissimus, pectorals, subscapularis
• Codman's/pendulum exercises
• Initiate periscapular strengthening
• Rhythmic stabilization for IR/ER in the PoS
• Postural reeducation
• Continuous passive motion (CPM) for IR/ER (PoS) TBS/TAS/TLS activities as recommended and tolerated, for example:
  • TLS/ TBS: avoid exercises that avoid loading the shoulder and UE
  • Core stability emphasizing the lower abdominals can be performed using the legs to challenge the core.
  • TAS: Can perform scapular retraction, scapular elevation to tolerance, biceps curls, triceps extension with arm in neutral position
	• PT modalities to control pain, inflammation
	• PT modalities to promote tissue extensibility, relaxation
	• Oral NSAIDs, intraarticular injection
	• Patient education: activity modification, disease progression, positioning
	• Home exercise program: pendulums, ROM for supine shoulder elevation in PoS, supine ER in PoS, in modified neutral with cane, supine IR in PoS, in modified neutral with opposite extremity, standing ER doorway stretch with the arm in modified neutral.
	• Manual therapy (evaluation-based): Grade II joint mobs in posterior direction, inferior, distraction; mobilization of thoracic spine, scapula mobilization; pain-free ROM including IR/ER (PoS), and with gradually increasing abduction, elevation
	• Therapeutic massage for pectorals, latissimus, teres, subscapularis, triceps, rotator interval.
	• CPM for IR/ER (in the PoS) in modified neutral
	• Self-stretching: ROM exercises, as tolerated
	• Pendulums
	• Introduce pulleys when evidence of humeral head control and ≈130° elevation
	• Postural education
	• Upper body ergometry for active warmup
	• Neuromuscular reeducation: rhythmic stabilization in supine for IR/ER in the PoS and at shoulder height with elbow straight
	• Hydrotherapy
	• Strengthening of the periscapular muscles: scapular retraction, scapular protraction, shoulder extension to neutral
	• Pain-free RC isotonics to neutral in side-lying position
	• CKC scapular stabilization with physioball (bilateral UEs)
	• TBS/TAS/TLS activities as recommended and tolerated, for example:
	  • TBS using stationary bicycle, elliptical using arms to shoulder's tolerance
	  • Core strengthening can include lower abdominal strengthening, bridging.
	  • TAS: Avoid overhead exercise. Perform pain-free exercise within the available ROM such as biceps curls, triceps curls, scapular retraction, scapular protraction. Upper body ergometry can be incorporated as a warmup.
	  • TLS: Can perform squats, knee extension, knee flexion, side-lying hip abduction. Machines for hip abduction/adduction

internal and external rotation in alternating fashion to work on humeral head control. The patient is instructed to hold the arm stable, thus working on coordination. This can be performed for 10 seconds initially for three to four sets.

Milestones for Progression to the Next Phase

- Control of pain/inflammation
- Resolution of resting pain, and decreased irritability of the shoulder allows for progression of ROM exercises
- Patient compliance with home exercise program
- Minimize ROM loss
- Retard/halt the progression from synovitis to capsular fibroplasias, which is determined by end feel and pain. An empty end feel is more indicative of synovitis, whereas a capsular, firm end feel is more indicative of fibroplasia.
- Maximize function. During each phase the therapist wants to maximize the patient's functional strength within the available pain-free ROM. This allows the patient to then use the extremity during ADLs in the available ROM without compensatory movements. If the functional strength is not sufficient, and the patient continues to use the arm during ADLs, impingement symptoms will occur. This in turn will slow the return of ROM because the shoulder will be painful and inflamed. Use of the arm in pain-free arcs of motion will help the patient gain ROM.
- Avoid symptoms of impingement. The patient is not encouraged to use the arm outside available ROM/AROM.

Phase II (weeks 5 to 8): Mobility

Clinical Pearl

> The patient is encouraged to use the arm during the day in pain-free motions.

TIMELINE 8-1: Nonoperative Rehabilitation of Adhesive Capsulitis (Continued)

PHASE III (weeks 9 to 16)	PHASE IV (weeks 17 to 22)	PHASE V (weeks 23+)
• Patient education • Home exercise program: pendulums, supine forward elevation in the plane of the scapula (PoS), supine external rotation in the PoS and at 90° abduction with cane, internal rotation behind back with opposite hand, posterior capsule stretch as tolerated • Modalities: moist heat, cryotherapy • Upper body ergometry for an active warmup • Hydrotherapy: horizontal abduction/adduction, modified breast stroke, chest press with paddle • ROM: increase total end range time; initiate IR behind back with opposite hand or strap without compensatory movements, pulleys • Strengthening: periscapular muscles; rotator cuff PREs side-lying ER to TBIR/ER in the PoS • Manual therapy (evaluation-based): PNF contract-relax for IR in the PoS, ER in the PoS; joint mobilization; physiological movements • Therapeutic massage for length of subscapularis, teres, pectorals; mobilization for thoracic spine extension • CKC exercises progressing from double to single support • TBS/TAS/TLS activities as recommended & tolerated	• Patient education: activity modification; avoid "too much, too soon"; functional progression • Home exercise program, as instructed • Modalities, prn: moist heat, cryotherapy • Manual therapy: prn: contract-relax, joint mobilizations • Upper body ergometry for active warmup, endurance training • Advanced periscapular strengthening: prone exercises for middle trapezius, lower traps, latissimus • RC PREs, pain free • Upper body weight training • Soft tissue techniques for subscapularis, latissimus, pectorals, teres, posterior capsule • Hydrotherapy • Rhythmic stabilization • Ball stabilization • PNF diagonal patterns • ROM exercises: cane ER at 90° abduction; strap IR behind back • Flexibility exercises: door stretch for pectorals, sleeper stretch, chicken wing • TBS/TAS/TLS activities as recommended & tolerated	• Patient education • Modalities: cryotherapy • Home exercise program: as instructed • Upper body ergometry for warmup, endurance • Flexibility exercises for posterior cuff, posterior capsule, pectorals ROM exercises for maintenance • Manual therapy (evaluation-based): prn • Soft tissue techniques (evaluation-based): prn • Advanced periscapular strengthening continues • Advanced stabilization exercises • Rotator cuff strengthening: IR/ER at 90° abduction • Upper body weight training • PNF diagonal patterns • Isokinetic training • Plyometrics progression: ball toss • Sport-specific exercises • TBS/TAS/TLS activities as recommended and tolerated

Management of Pain and Swelling

- Oral NSAIDs
- Intraarticular injection
- Patient education
- Activity modification
- Positioning
- Modalities: cryotherapy, TENS
- Hydrotherapy
- Manual therapy
- Moist heat will promote relaxation and tissue extensibility and can assist with controlling pain.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Joint mobilizations in the A-P direction, caudal direction, distraction techniques. The shoulder is supported by the physical therapist in the resting position with the patient in supine-lying, then the glenohumeral joint is mobilized using Grade II mobilizations. Distraction/traction can be performed in combination with the glides. The sternoclavicular, acromioclavicular, and scapulothoracic articulations are assessed for restrictions and addressed, as needed.
- Gentle shaking of the UE for 10 to 15 seconds. The physical therapist gently grasps the patient's wrist and gently oscillates her upper extremity in a comfortable, neutral position. This will allow the patient to relax and help to control pain.
- Pain-free ROM using physiological movements are performed in the plane of the scapula for shoulder elevation, IR/ER, and abduction. The physical therapist "ranges" the patient's shoulder through shoulder abduction in the plane of the scapula, shoulder flexion in the plane of the scapula, internal rotation in the plane of the scapula, and external rotation in the plane of the scapula. During internal and external rotation, the proximal humerus is stabilized with one hand to avoid compensatory movements. The shoulder's response to treatment will guide how far the shoulder is stretched and how long the stretch is held. Decreased irritability of the shoulder will allow for a longer stretch.
- Mobilization of the scapula. Scapulohumeral dissociation is often limited, and is observed with scapular motion greater than humeral motion in arcs less than 90°. This is assessed during observation of posture and observation with passive and active shoulder elevation, and can be measured more objectively by measuring the distance between the spinous process and medial border of scapula and spine and inferior scapular angle, respectively. More formal assessment using the Lateral Scapular Slide Test can be instituted,
- Mobilization of the thoracic spine to promote thoracic extension can be performed by the physical therapist in the position that is most comfortable for the patient, and in which the PT is most comfortable in performing—sitting upright, sitting and leaning forward supported by a table, or prone.



FIGURE 8-2. Therapeutic massage. Subscapularis release.

Soft Tissue Techniques

- Therapeutic massage emphasizing the subscapularis, triceps, rotator interval, pectorals (minor and major), latissimus (Figure 8-2)

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Stretching exercises are performed daily, two to three times per day.
- Pendulum exercises produce joint distraction and increase the arc of pain-free movement. Pendulum exercises should be pain free. This is achieved when the patient bends forward and uses body momentum to create arm movement. The arc of motion should be within an arc that is pain free and allows the UE to relax. The patient chooses the direction of movement—the only criterion is that it is pain free. These are performed for 10 to 30 seconds, two or three sets, two to three times per day.
- Self-stretching using the opposite extremity for supine scapular plane elevation in modified neutral, supine internal rotation with the opposite extremity, and external rotation with a cane in the PoS. The arm can be positioned, as ROM allows, into greater abduction while performing ER with a cane.
- The dosage of ROM exercise can be increased and is dependent on the patient's response to treatment. ROM exercises can be performed more frequently and held for a longer duration.
- Pulley exercise can be performed with adequate ROM (≈130° flexion) and humeral head control to avoid shrug and impingement symptoms. The patient sits facing the pulley. The patient stretches the involved shoulder into flexion in the plane of the scapula. The involved elbow moves from a position of flexion to extension as it is stretched overhead to keep a short lever arm. The stretch is held for 10 seconds, and the exercise is continued as long as the patient is not experiencing impingement symptoms. As tolerated, the patient may hold the stretch longer. With increased duration of the stretch, the number of repetitions can decrease.

- Self-stretching in a doorway for ER in modified neutral affords the patient frequent stretching opportunities. The patient faces a door jam. With the elbow flexed to a right angle and held close to her side, the patient slowly turns to the direction opposite the shoulder (i.e., right shoulder, turn towards left) and holds the position to duration recommended by physical therapist—initially for 10 seconds, 10 reps.
- As IR in the PoS improves toward normal, AAROM for IR behind the back can be initiated using the opposite extremity for assistance (5- to 10-seconds hold for 5 to 10 reps)
- Hydrotherapy can be used to interrupt the pain-inflammation-spasm cycle and to provide an environment for active-assistive exercise. The water temperature is warm to create an environment that promotes relaxation. Supine abduction with buoyancy-assisted device at surface of water, ER ROM with paddle, and pass behind the back with buoyancy device for functional IR. If the patient is willing, the patient can go under water to increase arc of buoyancy.
- CPM for IR/ ER, PoS, in modified neutral

Other Therapeutic Exercises

- Strengthening exercises are performed two to three times per week.
- TBS
  - Stationary bicycle, elliptical. As the patient is comfortable using the UE for balance, the stationary bike and elliptical can be used. The bicycle will be introduced first followed by the elliptical without UE movement. Use of the UEs can be started progressively on an interval basis (30 seconds work, 1 minute rest). The individual will move the shoulder in a pain-free ROM, below shoulder height. Pain and progression of ROM will guide tolerance to these exercises.
  - Use of the arms below shoulder height with cardiovascular equipment (elliptical, bicycle) can be introduced for a short duration, as tolerated.
- Core strengthening
  - Lower abdominal strengthening using Sahrmann progression, bridging bilateral to marching in place, to single leg bridge. Avoid loading the elbow as in a plank position.
- TAS
  - Avoid overhead exercise.
  - Perform pain-free exercise within the available ROM such as biceps curls, triceps extensions, scapular retraction, and scapular protraction. While performing biceps curls and triceps extensions, it is important that the patient avoid forcing the humeral head anterior. This is achieved by making sure that the weight is not too heavy causing the patient to not go through the full ROM at the elbow. Upper body ergometry can be incorporated as a warmup.
- TLS
  - Squats, knee extension, knee flexion, side lying hip abduction
  - Machines for hip abduction/adduction

Activation of Primary Muscles Involved

- Emphasis is on periscapular muscles—rhomboids, serratus, latissimus, trapezius—to provide a proximal stable base for distal mobility and to reestablish force couples necessary for shoulder elevation: scapular retraction, protraction, extension to neutral. Scapular retraction can be performed in sitting—resistance with elastic bands can be added; scapular protraction in supine—resistance with hand weights can be added; lower trapezius isometrics in an upright position, which will also be postural cues, shoulder extension to neutral with elastic bands progressing from ≈45° flexion to 0° (side of body). These exercises will be performed three times per week. Three times 10 reps progressing to two times 15 reps before increasing resistance
- Progress from submaximal RC isometrics in modified neutral: 5-second hold, 5-second rest for 10 reps, two times per day to isotonics in S/L position to neutral. Five reps, three sets, two-three times per week.
- Active exercise is performed in the plane of the scapula.

Sensorimotor Exercises

- Hydrotherapy for its hydrostatic properties

Open and Closed Kinetic Chain Exercises

- CKC physioball stabilization exercises can be performed below shoulder height with double arm support. CKC exercise causes contraction of the force couples, allows the rotator cuff to work as a compressor, and creates an axial load (weightbearing). A physioball is positioned on a secured surface (chair, resting on a toss back) so that the UE is positioned below shoulder height. The size of the ball allows the patient to position her arms slightly wider than her body. With the elbows straight, the patient then compresses the ball and performs small movements in the coronal plane (side to side), the sagittal plane (up and down) with the shoulder girdle positioned, as instructed by the therapist, in retraction, protraction, or neutral. Three sets of 10 repetitions can be performed in each direction, as tolerated.
- OKC exercises such as pain-free forward flexion—full can position—in the plane of the scapula can be initiated with good scapulohumeral rhythm; dumbbell row with hand weights, shoulder extension in prone with hand weights, single arm cable column pulldown in plane of scapula.

Techniques to Increase Muscle Strength, Power, and Endurance

- These exercises should be pain-free and performed two to three times per week. Exercising into pain or with pain will further irritate the shoulder and cause loss of motion, and thus function. There is a balance of enough resistance to stimulate the muscle without aggravating the joint.
- Upper body ergometry can be incorporated: Airdyne (arms only) with elevated seat height for 5 minutes, as

tolerated; upper extremity bicycle also with high seat height.
- Use of arms below shoulder height with cardiovascular equipment (elliptical, bicycle) can be introduced for a short duration.
- Strengthening of the periscapular muscles for retraction in sitting or standing with elastic bands or manual resistance, protraction in supine with weight of arm, then progressing to hand weights, and extension in standing with elastic bands or prone with weight of arm against gravity progressing to hand weights to neutral is important to reestablish force couples for synchronous arm elevation.

Neuromuscular Dynamic Stability Exercises

- Proprioceptive neuromuscular facilitation (PNF) exercise such as rhythmic stabilization in supine is performed for IR/ER (PoS) in modified neutral and at shoulder height with the elbow as tolerated. This can be performed for 10 seconds initially for three to four sets.



FIGURE 8-3. Mobilization of the thoracic spine.

Functional Exercises

- Begin pain-free scapula plane elevation—full can position—to shoulder height when good scapulohumeral rhythm is evident.
- Hydrotherapy may be used initially to provide environment for active-assistive exercise.

Sport-Specific Exercises

- N/A with the exception of progressive ROM exercises.
- Incorporating exercises for core, TBS, TAS, and TLS is encouraged, keeping in mind the limitations and precautions associated with the involved shoulder.

Milestones for Progression to the Next Phase

- Control pain/inflammation
- Resolution of rest and night pain
- Compliance with home exercise program
- Avoid subacromial impingement
- Avoid rotator cuff inhibition, which is determined by increased pain with therapeutic exercise, pain at rest, and increased compensatory movements.
- Minimize loss of ROM
- Minimize capsular contracture. This can be determined by assessing joint play, end feel with humeral head glides, as well as by postural habitus and ROM deficits.
- Normalize scapulohumeral rhythm to shoulder height in the plane of the scapula, pain-free

Phase III (weeks 9 to 16): Optimization of ROM

Management of Pain and Swelling

- Patient education
- Oral NSAIDs
- Intrarticular injection
- Avoid pain with strengthening
- ROM exercises to the shoulder's tolerance
- Cryotherapy
- Moist heat
- Activity modification.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Joint mobilization techniques in the posterior direction, inferior direction, and distraction. Mobilization can be performed at end range positions.
- Pain-free ROM using physiological movements for scapula plane elevation, IR/ER, abduction, ER/IR at 90° abduction
- PNF such as hold-relax for IR ROM in the PoS; at 90° abduction; for ER ROM at the PoS; at 90° abduction
- Thoracic spine mobilization (Figure 8-3)

Soft Tissue Techniques

- Therapeutic massage for dissociation of the shoulder girdle: subscapularis, latissimus, teres, and pectorals

Stretching and Flexibility Techniques for the Musculotendinous Unit

- In this phase, as irritability of the shoulder decreases, ROM can be performed at end range and held for longer duration. Stretching exercises are performed two to three times per day.
- Pendulum exercise
- Pulley exercise can be performed with adequate ROM (≈130° flexion) and humeral head control to avoid shrug and impingement. The patient can use pulleys at home daily.

- Self-stretching using the opposite extremity or cane for supine scapular plane elevation: The patient lies on her back with the cane in her left hand steering/assisting the right arm into flexion—the right arm is positioned with the right palm facing the toward the body. Supine internal rotation with the opposite extremity or cane: The patient lies with the arm in the plane of the scapula or at 90° abduction. With the left hand or with a cane in the left hand, rotate the right arm in the direction of internal rotation; and supine external rotation with a cane in the PoS and at 90° abduction. With the left hand or with a cane in the left hand, rotate the right arm in the direction of external rotation.
- Low load, long duration stretching is recommended, with decreased irritability characteristic of the latter stage. The total end range time is increased to affect capsular extensibility and remodeling.
- *These stretches can be initiated for 10 second holds for 10 reps, two times per day.*
- Initiate posterior capsule stretching with avoidance of impingement symptoms.
- IR behind the back with a strap
- Inferior capsule stretch
- Chicken wing stretch: Lie on your back with hands behind head and arms positioned in horizontal abduction/ER.
- Pectoral stretch in doorway: Stand in the doorway.
- Sleeper stretch performed without impingement symptoms
- Cane forward flexion: The patient lies on her back with the cane in her left hand steering/assisting the right arm into flexion—the right arm is positioned with the right palm facing towards the body.
- Trunk rotation in supine hook-lying position or with legs supported by a physioball
- Hip stretching

Clinical Pearl

When introducing self-stretches, it is imperative that the patient feel the stretch in the targeted tissue. Avoid symptoms of impingement with horizontal adduction, sleeper stretch, etc.

Other Therapeutic Exercises

- Strengthening exercises are performed two to three times per week.
- TBS
  - Stationary bicycle
  - Elliptical
  - Use of the UE during cardiovascular exercise can be initiated to tolerance such as bike with arms, elliptical with arms.
  - The patient can perform a modified breast stroke.
- Core strengthening
  - Lower abdominal strengthening
  - Bridging
  - Introduce trunk rotation strengthening.
- TAS
  - Avoid overhead exercise.
  - Perform pain-free exercise within the available ROM such as biceps curls, triceps curls, scapular retraction, and scapular protraction.
  - Upper body ergometry, use of arms in c-v equipment progresses to tolerance.
- TLS
  - Squats, RDLs, knee extension, knee flexion, side-lying hip abduction
  - Machines for hip abduction/adduction, gluteals
  - Lunges, lunges with rotation

Activation of Primary Muscles Involved

- Perform two to three times per week.
  - With adequate ROM and no pain with muscle activation, rotator cuff exercises in the PoS are progressed from side-lying position to the upright position with elastic resistance in modified neutral.
  - With adequate ROM, advanced, progressive scapular strengthening can be performed. These exercises can include: single arm pull down with cable column from overhead, chest press, latissimus pulldown, and prone horizontal abduction for middle trapezius with adequate length of pectorals.

Sensorimotor Exercises

- Hydrotherapy for its hydrostatic properties: The water temperature is warm to create an environment that promotes relaxation. Supine abduction with buoyancy-assisted device at surface of water, ER ROM with paddle, and pass behind the back with buoyancy device for functional IR. If the patient is willing, the patient can go under water to increase arc of buoyancy. Walking forwards with arms abducted will help stretch the anterior chest. Gentle strengthening of proximal scapular musculature can be achieved with scapular retraction/protraction with dumbbells or paddle board; shoulder extension with gloves or paddles, scaption to surface of water with appropriate resistance as tolerated, as well as IR/ER with appropriate resistance of paddle. Walking backward in water will facilitate scapular retractors,
- Hydrotherapy exercises will replace one day of strengthening on land.

Open and Closed Kinetic Chain Exercises

- Quadruped can be initiated to tolerance for scapular stabilization.
- Physioball exercises below shoulder height can be progressed from double arm support to single support, as tolerated.

Techniques to Increase Muscle Strength, Power, and Endurance

- Upper body ergometry for 5 minutes
- Strengthening of the biceps and triceps with comfortable resistance.



FIGURE 8-4. Wall slides to assist with AROM.

- Reestablish force couples for arm elevation above shoulder height.
- Bench/chest press can be performed in water with a paddle, on land with dumbbells, and wall pushups.

Neuromuscular Dynamic Stability Exercises

- PNF such as PoS rhythmic stabilization for IR/ ER in modified neutral, and shoulder height elevation will be progressed to more challenging positions.
- Initiate PNF D2 flexion in supine for 10 reps, one set, three times per week.

Functional Exercises

- Scapular plane elevation (full can position) to shoulder height with good scapula-humeral rhythm
- Hydrotherapy
- Wall slides (Figure 8-4) are performed in the PoS.

Milestones for Progression to the Next Phase

- Resolution of night pain, pain with ADLs, therapeutic exercise
- AROM = PROM
- Maximize function. This is measured using an outcomes scale (DASH), and by observation of movement patterns such as raising the arm, reaching behind the back, reaching out to the side, as well as patient willingness to use the arm. This is also achieved when AROM = PROM.
- Normalize scapulohumeral rhythm above shoulder height—measured by observation as the patient raises the arm. In the middle of the arc of motion, scapular motion should be greater than humeral motion so that the glenoid is positioned to receive the humeral head.
- Reestablish force couples for arm elevation. Manual muscle testing allows the physical therapist to assess muscle strength; however, timing is assessed with observation.
- Avoid impingement.
- Compliance with home exercise program

Phase IV (weeks 17 to 22): Strengthening

Management of Pain and Swelling

- Cryotherapy
- Functional progression
- Avoid pain with exercise.
- Patient education: activity modification; avoid too much, too soon; avoid subacromial impingement
- Emphasize quality of movement.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Evaluation-based
- Pain-free ROM using physiological movements for scapula plane elevation, IR/ ER, abduction, ER/ IR at 90° abduction.
- Proprioceptive neuromuscular facilitation (PNF) such as hold-relax (Figure 8-5)

Soft Tissue Techniques

- Evaluation-based; maintenance of ROM

Stretching and Flexibility Techniques for the Musculotendinous Unit

- These stretches will be held for 30 seconds, three reps, two times per day:
  - Pectoral stretch in doorway
  - Sleeper stretch (avoid impingement)
  - Posterior capsule stretch (avoid impingement)
  - Cane forward flexion
  - Towel IR stretch behind back
  - Chicken wing



FIGURE 8-5. Hold-relax for internal rotation ROM at 90° abduction.

Other Therapeutic Exercises

- As described previously

Activation of Primary Muscles Involved

- These exercises are performed two to three times per week, emphasizing quality of movement:
  - Advanced periscapular strengthening such as prone exercises for lower trapezius, middle trapezius, and latissimus. These exercises are performed with scapular setting before upper extremity movement.
  - Pain-free RC PREs IR/ ER with elastic resistance. Place a towel roll under the arm and rotate only to neutral position.

Sensorimotor Exercises

- PNF diagonal pattern D2 flexion progressions from supine to standing

Open and Closed Kinetic Chain Exercises

- Wall pushup progression to pushups beginning with an upright position and gradually progressing to floor, single arm ball stabilization

Techniques to Increase Muscle Strength, Power, and Endurance

- Upper body ergometry
- Cardiovascular equipment with UEs
- Upper body weight training: row, lat pulldown, chest press

Neuromuscular Dynamic Stability Exercises

- PNF diagonal patterns D2 flexion progressing from supine to standing progression
- Bodyblade can be introduced in modified neutral position with IR/ER oscillations for 30 seconds.

Plyometrics

- Latter part of phase: Ball toss such as chest pass, overhead toss, and side to side toss can be introduced.

Functional Exercises

- PNF diagonal patterns D2 flexion initiated in supine for 10 reps
- Scapular plane elevation—full can position—with good scapula-humeral rhythm, pain-free (emphasize quality of movement). Emphasize posture and stabilization through core. Do not perform more than 10 reps in a set. May perform three sets.

Sport-Specific Exercises

- These are introduced based on the demands of the sport that the athlete is returning to.

Milestones for Progression to Advanced Sport-Specific Training and Conditioning

- Resolution of pain with ADLs, therapeutic exercise
- AROM/ flexibility to meet demands of sport
- Strength to meet the demands of sport; 85% of uninvolved shoulder with isokinetic dynamometer or manual muscle tester
- Pain-free progression of exercises
- Normalized S-H Rhythm throughout the ROM via observation. In the early part of the ROM (0° to 60°), humeral motion is greater than scapular motion. Between 60° and 120°, scapula motion is greater than humeral motion, and in the final phases of elevation (120° to180°), humeral motion is greater than scapular motion.

Phase V (weeks 23+): Return to Sport

Management of Pain and Swelling

- Cryotherapy
- Patient education: Avoid too much, too soon; emphasize quality of movement, functional progression. As described above, as patient demonstrates decreased irritability, improved ROM, and strength, exercise progressions will build on previous reached milestones.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Evaluation-based

Soft Tissue Techniques

- Evaluation-based; maintenance of ROM

Stretching and Flexibility Techniques for the Musculotendinous Unit

- These stretches are held for 30 seconds, and performed three times, twice daily:
  - Pectoral stretch in doorway: Stand in the doorway.
  - Sleeper stretch
  - Posterior capsule stretch
  - Cane forward flexion: The patient lies on her back with the cane in her left hand steering/assisting the right arm into flexion—the right arm is positioned with the right palm facing towards the body.
  - Towel IR stretch behind back. Stand
  - Chicken wing

Other Therapeutic Exercises

- As described previously

Activation of Primary Muscles Involved

- Advanced periscapular strengthening such as prone exercises for lower trapezius, middle trapezius, latissimus
- RC PREs: IR/ ER at 90° abduction as tolerated

Sensorimotor Exercises

- These are initially performed for 10 repetitions and then progresses to three sets:
  - PNF diagonal pattern progressions from supine to standing; from no resistance to manual resistance and resistance with elastic bands.

Open and Closed Kinetic Chain Exercises

- Wall pushup progression to pushups
- Single arm ball stabilization
- Quadruped activities continue

Techniques to Increase Muscle Strength, Power, and Endurance

- Upper body ergometry: can be incorporated using a rowing ergometer, upper body bicycle, or Airdyne beginning with 5 minutes and progressing to patient tolerance.
- Cardiovascular equipment with UEs: such as elliptical, rowing ergometer, Nordic track
- RC and periscapular strengthening: prone exercises such as prone horizontal abduction, prone lower traps
- Isokinetic training for IR/ER
- Upper body weight training: row, lat pulldown, chest press

Neuromuscular Dynamic Stability Exercises

- Beginning with 10 reps.
- PNF diagonal patterns progressing from supine to standing progression (Figure 8-6)
- Bodyblade with longer lever arm, in diagonal patterns
- Stabilization exercises
- RC strengthening at 90/90 position with rhythmic stabilization at end range for five reps
- Quadruped on unstable surfaces for 15 to 30 seconds, three reps



FIGURE 8-6. Proprioceptive neuromuscular facilitation performed manually in supine.

Plyometrics

- Ball tosses are performed for 10 reps each, two sets.
- Initiate ball toss—two-hand chest pass
- Activity-specific plyos
- Ball tosses: chest pass, overhead pass progressing from two-handed to single-handed, side passes

Functional Exercises

- PNF diagonal patterns progressing from supine to standing progression
- Deceleration exercises with cable column, ball toss

Sport-Specific Exercises

- These are introduced based on the demands of the sport and position that the athlete is returning to and will be introduced on an individual basis.
  - If the athlete is returning to throwing, an interval throwing program should be used to gradually introduce stresses.
- The program will be adjusted according to sport and position, and will begin with a day of rest in between throwing sessions. Soreness is expected, sharp pain should not be worked through.
  - Throwing
  - Catching/receiving
  - Tackling
  - Swimming
  - Swinging
  - Batting
  - Rowing
  - Lifting

Criteria for Abandoning Nonoperative Treatment and Proceeding to Surgery or More Intensive Intervention

- When physical and pharmacological therapies have failed, surgical options should be considered and discussed with the patient.
- Failed therapy should be considered when the patient has reached a plateau or progress in increasing ROM is extremely slow for the patient function.
- Painful shoulder that has failed to respond to intraarticular corticosteroids
- Surgery is indicated when the patient is failing to improve with minimum of 6 months of conservative treatment.

Tips and Guidelines for Transitioning to Performance Enhancement

- Transition to performance will begin in the latter phases (phases IV and V) with regard to training the upper extremity.

- When the patient has achieved the phase III milestones, transition to performance can be made.
- Core exercises and lower body transition to performance can be ongoing from the early phases. This will help keep the athlete engaged.
- As always, communication between the physical therapist and performance specialist must be ongoing.

Performance Enhancement and Beyond Rehabilitation: Training/ Trainer and Optimization of Athletic Performance

- Maintaining a solid foundation of strength is important for safe progression of functional exercises. This is monitored through observation of quality of movement and strength testing.
- Care is taken to monitor ROM and flexibility throughout to ensure proper shoulder mechanics.
- Lower extremity, and trunk strength and mobility will take stress off the shoulder.
- Adequate core strength will transfer power from the lower extremities to the upper extremities.
- Adequate rest is incorporated into the upper extremity training program to prevent flaring the joint.
- Close attention is paid to the volume of exercise. The performance specialist must recognize signs and symptoms of inflammation such as pain, loss of motion, and a decrease in strength, and readily communicate with the physical therapist. The athlete will not be pushed through pain and inflammation to avoid setbacks.
- Be careful not to perform more than two exercises per muscle isolation.

Specific Criteria for Return to Sports Participation: Tests and Measurements

- ROM/flexibility to meet the demands of the sport
- Full, pain-free ROM
- IR/ ER strength 3:2 ratio in involved extremity. This can be measured with an isokinetic dynamometer or with a manual muscle tester.
- Strength 85% of uninvolved extremity. This can be measured with an isokinetic dynamometer or with a manual muscle tester.

Evidence

Carette S, Moffet H, Tardif J, et al: Intraarticular corticosteroids, supervised physiotherapy, or a combination of the two in the treatment of adhesive capsulitis of the shoulder. *Arth Rheum* 48(3):829–838, 2003.

This controlled prospective study randomized 93 patients to compare the efficacy of intraarticular injection, supervised PT, the combo of PT and injection, and placebo. Using the SPADI, the injection and PT group demonstrated faster results; however, injection alone yields better results than supervised PT alone. (Level II evidence)

Diercks RL, Stevens M: Gentle thawing of the frozen shoulder: a prospective study of supervised neglect versus intensive physical therapy in seventy-seven patients with frozen shoulder syndrome followed up for two years. *J Shoulder Elbow Surg* 13(5):499–502, 2004.

This prospective study of 77 patients randomized into supervised neglect (education, instructed not to exercise in excess of pain threshold, pendulums, AROM within pain threshold) and intensive physical therapy (executed by a physical therapist: AROM up to and beyond pain threshold, passive stretching and manipulation, and home stretching based on maximal stretching and reaching). A Constant score of ≥80 was reached by 89% at 24 months (64% at 12 months) in the supervised neglect group, and by 63% at 24 months in the intensive physical therapy group. (Level II evidence)

Griggs SM, Ahn A, Green A: Idiopathic adhesive capsulitis. A prospective functional outcome study of non-operative treatment. *J Bone Joint Surg* 10(82–A):1398–1407, 2000.

This prospective study evaluated the outcomes of patients with stage II idiopathic adhesive capsulitis who were treated with a four-direction shoulder-stretching program. Outcomes included assessment of pain, range of motion, and function. Ninety percent of the patients reported a satisfactory outcome with a significant decrease in pain at rest, with activity and increase in active and passive ROM. (Level IV evidence)

Hazelman BD: The painful stiff shoulder. *Rheumatol Phys Med* 11:413–421, 1972.

This retrospective review of 130 patients noted that the efficacy of intraarticular hydrocortisone injections inversely correlates with the duration of symptoms. Further, discrimination between stage 1 and 2 disease can be determined based on the patient's response to the local anesthetic and thus can be used for future treatment options. (Level III evidence)

Johnson AJ, Godges JJ, Zimmerman GJ, et al: The effect of anterior versus posterior glide joint mobilization on external rotation range of motion in patients with shoulder adhesive capsulitis. *J Orthop Sports Phys Ther* 37(3):88–99, 2007.

This randomized control trial (RCT) demonstrated a significant difference in ER ROM when posteriorly directed mobilization was added to the treatment as compared to anteriorly directed mobilization. (Level II evidence)

Light KE, Nuzik S, Personius W, et al: Low-load prolonged stretch vs. high-load brief stretch in treating knee contractures. *Phys Ther* 64(3):330–333, 1984.

Sequential medical trials were used to compare the results of high-load brief stretch to low-load prolonged stretch knee extension PROM. A 10° difference was noted in favor of LLPS. (Level II evidence)

McClure PW, Blackburn LG, Dusold C: The use of splints in the treatment of joint stiffness: Biologic rationale and an algorithm for making clinical decisions. *Phys Ther* 74(12):1101–1107, 1994.

This paper discusses the total end range time (TERT), the amount of time the joint is held at or near end-range position.

The total algorithm is based on pain and ROM. (Level VI evidence)

Neviaser RJ, Neviaser TJ: The frozen shoulder: diagnosis and Management. *Clin Orthop Rel Res* 223:59–64, 1987.

This evidence paper describes 4 stages of adhesive capsulitis—the preadhesive stage, the freezing stage, the frozen or maturation stage, and the thawing stage—by correlating physical exam with the arthroscopic findings. (Level V evidence)

Oh JH, et al: Comparison of glenohumeral and subacromial steroid injection in primary frozen shoulder: A prospective, randomized short-term comparison study. *J Shoulder Elbow Surg* 20(7):1034–1040, 2001.

This prospective, randomized trial randomly divided 71 patients with primary adhesive capsulitis into glenohumeral or subacromial ultrasound guided injection. The GH steroid injection led to earlier pain relief. (Level II evidence)

Multiple-Choice Questions

QUESTION 1. The optimal way to gain ROM

A. Push the shoulder into painful ROM.
B. Ignore the patient's response to treatment.
C. Determine the irritability of the shoulder and apply TERT principles.
D. A and C

QUESTION 2. Stage 2 adhesive capsulitis is characterized by

A. Pain in the early stage
B. Stiffness in the late stage
C. Transition from stage 1 to 3
D. All of the above

QUESTION 3. To increase ER ROM, the most effective direction for joint mobilization is

A. Inferior
B. Posterior to anterior
C. Anterior to posterior
D. Distractive

QUESTION 4. Abandonment of nonoperative treatment should be considered when

A. Physical and pharmacological therapies have failed
B. Failure to improve with a minimum of 6 weeks of conservative treatment
C. Failure to improve with a minimum of 6 months of conservative treatment
D. A and C

Answer Key

QUESTION 1. Correct answer: **C** (see Phase I)

QUESTION 2. Correct answer: **D** (see Introduction)

QUESTION 3. Correct answer: **C** (see Phase III)

QUESTION 4. Correct answer: **D** (see end of Phase IV)

POSTOPERATIVE REHABILITATION AFTER CAPSULAR RELEASE FOR GLENOHUMERAL ADHESIVE CAPSULITIS

Theresa A. Chiaia, PT, DPT, Jo A. Hannafin, MD, PhD, and A. Simone Maybin, BS, NSCA-CPT

Indications for Surgical Treatment

- When physical and pharmacological therapies have failed, surgical options should be considered and discussed with the patient.
- Failed therapy should be considered when patient has reached a plateau or progress in increased ROM is extremely slow for the patient's function.
- Painful shoulder that has failed to respond to intraarticular corticosteroids
- Surgery is indicated when the patient is failing to improve with a minimum of 6 months of conservative treatment.

Brief Summary of Surgical Treatment

Major Surgical Steps

- Examination under anesthesia to document glenohumeral and total ROM
- Shoulder arthroscopy in beach chair position (author preference)
- Diagnostic arthroscopy before manipulation
- Thorough diagnostic arthroscopy with synovectomy as needed
- Capsular release is performed using thermal device from 1 to 5 o'clock (right shoulder, medial to labrum)

- Adequate visualization of subscapularis muscle belly
- Beginning release superiorly permits better visualization for distal release
- Switch arthroscope to anterior portal and continue release from 11 to 7 o'clock
  - Pearl: Keep pump pressure at 25 mmHg to decrease shoulder swelling.
- Remove instruments and perform manipulation.
- Author's preference: external rotation, forward flexion, abduction and internal rotation

Factors That May Affect Rehabilitation

- Regional anesthesia is used to permit passive ROM.
- Pain management is critical to permit physical therapy on postoperative day 1.

Other Surgical Techniques and Options

- Some surgeons prefer to manipulate the shoulder before arthroscopy.
- If synovectomy is needed, time may be limited secondary to swelling.

Before Surgery: Overview of Goals, Milestones, and Guidelines[1]

GUIDING PRINCIPLES OF POSTOPERATIVE REHABILITATION

- Understand the procedure performed.
- Understand the duration of symptoms and preoperative ROM.
- Understand the anatomic structures.
- Achievement of phase-specific goals will determine advancement.
- Control pain and inflammation.
- Understand the goals of the patient.
- Attain ROM achieved post manipulation in the OR.
- Discourage the formation of adhesions.

Phase I (days 0-14): Immediate Postoperative Period

Clinical Pearls

- Pain management is the key to this phase of rehabilitation.
- Adequate pain control will allow the patient to attain post-manipulation ROM achieved in the OR.
- ROM exercises are performed with the goal of achieving postmanipulation ROM.
- The patient is seen five times per week for 2 weeks to meet this objective.

[1]*Prehabilitation, if appropriate, is described in the Nonoperative Rehabilitation section of this chapter.*

Goals

- Control postoperative pain and inflammation.
- Comply with activity modification, HEP, positioning.
- Attain ROM achieved postmanipulation in the OR.
- Discourage the formation of adhesions.
- Minimize rotator cuff inhibition.

Protection

- Sling is used until block wears off.

Management of Pain and Swelling

- For pain:
  - Block may be kept in overnight for pain control so intraoperative ROM can be achieved repeatedly. Also, it allows the patient to see their extremity move through the ROM.
  - TENS
  - Oral NSAIDs
  - Oral pain medication
  - Cryotherapy
- To decrease swelling:
  - Cryotherapy
  - Oral NSAIDs

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Gentle shaking of the extremity: Gently grasp the patient's wrist and gently oscillate her upper extremity in a comfortable, neutral position for 10 to 15 seconds. This will allow the patient to relax and help to control pain.
- Joint mobilizations: The glenohumeral joint is mobilized using Grade I mobilizations to help modulate pain in the posterior/dorsal direction, inferior, and caudal, lateral distraction direction. The sternoclavicular, acromioclavicular, and scapulothoracic articulations are assessed for restrictions and addressed, as needed.
- ROM: Physiological movements such as scapular plane elevation with the arm in modified neutral, IR/ ER in the plane of the scapula (PoS), and abduction will help modulate pain by stimulating mechanoreceptors. These movements are performed in a slow, consistent tempo by the therapist to promote relaxation. The duration is up to 10 seconds for 10 repetitions with gradual increase in duration and frequency as tolerance and irritability of the shoulder permit. The goal is to work toward ROM achieved following capsular release.

Soft Tissue Techniques

- Therapeutic massage for myofascial release of pectorals, triceps, latissimus, and subscapularis (Figure 8-7). Firm, consistent pressure is applied to soft tissue so that it surrenders and relaxes.



FIGURE 8-7. Demonstrating therapeutic massage: Myofascial release for pectorals.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Pendulum exercises produce joint distraction and increase the arc of pain-free movement. Pendulum exercises should be pain-free. This is achieved when the patient bends forward and uses body momentum to create arm movement. The arc of motion should be within an arc that is pain-free and allows the UE to relax. The patient chooses the direction of movement. These are performed three times for 10 to 30 seconds. This should be a "go-to" exercise during the day.
- Physiological movements using the opposite extremity with low load (intensity) and low duration exercises performed three to five times per day. For example: supine forward flexion, supine IR, supine ER in the plane of the scapula with a cane. There is a balance of moving the shoulder to increase ROM and flaring the shoulder and losing ROM. The goal is ROM achieved during capsular release.
- Supine "T towel" positioning, with a towel roll positioned along the spine and a second along the base of the head, is recommended to promote thoracic extension and allow the anterior positioned humeral head to sit back. It is recommended that the patient lie in this position for 10 minutes, twice a day.
- Continuous passive motion (CPM) in the PoS for IR/ER in modified neutral can be used. This modality allows the patient to relax as the shoulder is cycled through internal and external rotation. It can be used at comfortable, slow speeds—a pause can be used for a patient who can tolerate a longer time at end range. The duration of each session is 10 to 15 minutes.
- Hydrotherapy provides an environment for active-assistive exercise and can be initiated with occlusive dressing to protect the incisions, as per surgeon's recommendations and clearance. The water temperature is warm to create an environment that promotes relaxation. The patient is instructed to perform modified breast stroke movements (horizontal abduction and adduction), flexion in the plane of the scapula, and gentle internal and external rotation.

Other Therapeutic Exercises

- Light cardiovascular exercise such as stationary bicycle. Avoid perspiration in the surgical wounds.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Exercises for the distal extremity may be performed, such as gripping, wrist extension/flexion, forearm pronation/ supination, and elbow flexion/extension. These are performed with no resistance initially.
- Postural retraining. The patient is instructed in scapular retraction with the arms supported on her lap, as well as sternal lifts. The patient is encouraged to do posture checks throughout the day.
- Scapular mobility in side-lying with UE supported in the PoS. The patient actively moves the scapula in the direction of elevation, depression, retraction, and protraction—10 times each direction for two sets. Manual tactile cues can be given.

TIMELINE 8-2: **Postoperative Rehabilitation after Capsular Release for Glenohumeral Adhesive Capsulitis**

PHASE I (weeks 1 to 2)	PHASE II (weeks 3 to 6)
• Sling immobilization until block wears off • PT modalities for pain, inflammation • Codman's/ pendulum exercises • Manual therapy: mobilizations, ROM • Therapeutic massage • Self-stretching • Initiate scapula strengthening • Submaximal deltoid isometrics • Postural retraining • Hydrotherapy • CPM for IR/ER • Exercises for distal extremity • Home exercise program • TBS/TAS/TLS activities as recommended & tolerated	• PT modalities for pain, inflammation, relaxation • Manual therapy • Therapeutic massage • Home exercise program • Hydrotherapy • CPM for IR/ER • Upper body ergometry for active warm-up • Scapular exercises • RC isometrics to RC PREs • Neuromuscular reeducation: rhythmic stabilization exercise • TBS/TAS/TLS activities as recommended & tolerated

Techniques to Increase Muscle Strength, Power, and Endurance

- Light cardiovascular exercise

Neuromuscular Dynamic Stability Exercises

- With the patient lying in supine, the patient's upper extremity is positioned in the plane of the scapula and the elbow is supported on a towel roll with the elbow flexed to 90°. The therapist applies gentle pressure at the wrist in the direction of internal and external rotation in alternating fashion to work on humeral head control. The patient is instructed to hold the arm stable, thus working on coordination. This can be performed for 10 seconds initially for three to four sets.

Milestones for Progression to the Next Phase

- Control pain/ inflammation
- Resolution of rest pain
- Compliance with activity modification
- Achievement of postmanipulation ROM (i.e., full ROM).

Phase II (postoperative weeks 2 to 6)

Clinical Pearls

- Postmanipulation ROM should be maintained during this phase. Monitor the patient for loss of ROM and signs of increased shoulder irritability.
- Compliance with activity modification will control pain/inflammation and avoid impingement during use of the extremity, and thus assist with ROM goals.
- Scapular strengthening is progressed so that an adequate strength base is developed for functional use of the extremity and more advanced exercises.
- RC strengthening can be initiated if pain free.

Goals

- Control pain/inflammation
- Achieve/maintain post-manipulation ROM
  - Minimize rotator cuff inhibition, which is determined by increased pain with therapeutic exercise, pain at rest, and increased compensatory movements.
- Compliance with activity modification, and with home exercise program
- AROM in the PoS to shoulder height with good S-H rhythm

Management of Pain and Swelling

- Treatment for pain/analgesia
  - TENS
  - Oral NSAIDs
  - Oral pain medication
  - Cryotherapy

Clinical Pearl

The use of cryotherapy is continued to control post-operative pain, and inflammation, as patient activity level continues to increase.

- To decrease swelling
  - Cryotherapy
  - Oral NSAIDs

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Joint mobilizations are evaluation-based, Grade I to II (in the latter phase (evaluation-based), in the posterior direction, inferior, and caudal direction, and lateral

TIMELINE 8-2: **Postoperative Rehabilitation after Capsular Release for Glenohumeral Adhesive Capsulitis** (Continued)

PHASE III (weeks 6 to 10)

- Patient education: activity modification, avoid "too much, too soon," functional strengthening progression
- Home exercise program, as instructed
- Modalities, prn: moist heat, cryotherapy
- Manual therapy: prn: contract-relax, joint mobilizations
- Upper body ergometry for active warm-up, endurance training
- Advanced periscapular strengthening: prone exercises for middle trapezius, lower traps, latissimus
- RC PREs, pain-free
- Upper body weight training
- Soft tissue techniques for subscapularis, latissimus, pectorals, teres, posterior capsule
- Hydrotherapy
- Rhythmic stabilization
- Ball stabilization
- PNF diagonal patterns
- ROM exercises: cane ER at 90° abduction; strap IR behind back
- Flexibility exercises: door stretch for pectorals, sleeper stretch, chicken wing
- TBS/TAS/TLS activities as recommended & tolerated

PHASE V (weeks 10 to 14+)

- Patient education
- Modalities: cryotherapy
- Home exercise program: as instructed
- Upper body ergometry for warmup, endurance
- Flexibility exercises for posterior cuff, posterior capsule, pectorals
- ROM exercises for maintenance
- Manual therapy (evaluation-based): prn
- Soft tissue techniques (evaluation-based): prn
- Advanced periscapular strengthening continues
- Advanced stabilization exercises
- Rotator cuff strengthening: IR/ER at 90° abduction
- Upper body weight training
- PNF Diagonal patterns
- Isokinetic training
- Plyometrics progression: ball toss
- Sport-specific exercises
- TBS/TAS/TLS activities as recommended & tolerated

distraction. Distraction may be applied in combination. This is a healing capsule.
- ROM: Pain-free physiological movements such as PoS forward flexion, IR/ER at 0°, 45°, and 90° abduction. The goal is to achieve intraoperative ROM. May need to perform high intensity (into discomfort), low duration for 10 repetitions. Tempo should be consistent to promote trust and relaxation.
- PNF: Hold-relax techniques can be performed for increasing IR and ER in the PoS. The patient holds an isometric contraction against resistance (determined by the therapist) from the therapist for a few seconds then gently releases followed by the therapist moving the arm into greater ROM for a few seconds. This can performed for three to five reps.

Soft Tissue Techniques

- Therapeutic massage for myofascial release of pectorals (supine), triceps (prone), latissimus (side-lying), and subscapularis (supine or side-lying)
- Mobilization of the scapula

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Pendulum exercises can be performed as described to produce joint distraction and increase the arc of pain-free movement. The duration of this exercise can be increased.
- Pulley exercise can be performed with adequate ROM (≈130° flexion) and humeral head control to avoid shrug and impingement (Figure 8-8). The patient sits facing the pulley. The patient stretches the involved shoulder into flexion in the plane of the scapula. The involved elbow moves from a position of flexion to extension as it is stretched overhead to keep a short lever arm. The stretch is held for 10 seconds, and the exercise is continued as long as the patient is not experiencing impingement symptoms. As tolerated, the patient may hold the stretch longer. With increased duration of the stretch, the number of repetitions can decrease.
- Physiological movements using the opposite extremity with increasing intensity and increasing duration exercises performed three to five times per day. For example, supine forward flexion, supine IR, supine ER in the plane of the scapula with a cane. Supine ER at 90° abduction is added, as well as supine IR at 90° abduction with a cane. Initially these new additions are held for 10 seconds, 10 repetitions, and performed twice/day.
- Abduction/ER position with hands behind head in supine for 10 seconds. The patient can adduct arms so elbows are pointed toward the ceiling for rest position.
- Supine "T towel" positioning, with a towel roll positioned along the spine, and a second along the base of the head, is recommended to promote thoracic extension, and to allow the anterior positioned humeral head to sit back. The patient can relax in this position for 10°, twice a day.
- CPM in the PoS for IR/ER in modified neutral can be used.
- Hydrotherapy provides an environment for active-assistive exercise (Figure 8-9).

Other Therapeutic Exercises

- TBS exercises are performed in a progressive fashion so as not to flare the shoulder. Monitor for this.
  - Stationary bicycle, elliptical
  - Use of the arms below shoulder height with cardiovascular equipment (elliptical, bicycle) can be introduced for a short duration, as tolerated.
- Core strengthening
  - Lower abdominal strengthening (Sahrmann progression), bridging. Avoid loading through the shoulder such as planks at this time.

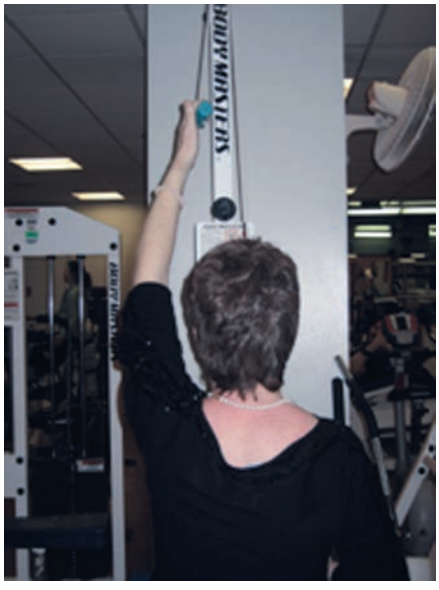

FIGURE 8-8. Pulleys are initiated when the athlete demonstrates ≈130° flexion and humeral head control to avoid a shrug and symptoms of impingement.



FIGURE 8-9. Hydrotherapy provides an environment for active-assistive exercise. Horizontal abduction is shown.

- TAS
  - Avoid overhead exercise.
  - Perform pain-free exercise within the available ROM such as biceps curls, triceps extensions, scapular retraction with elastic band resistance, and scapular protraction in supine with hand weights. Light resistance so full elbow flexion and extension occurs and compensatory anterior movement of the humeral head is avoided. These are performed thrice weekly for three sets of 10 repetitions.
  - Upper body ergometry can be incorporated as a warmup for 3 to 5 minutes. Adjust seat height to meet available AROM.
- TLS
  - Squats (no weight), knee extension, knee flexion, side lying hip abduction
  - Monster/crab walks, the clock

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Submaximal rotator cuff isometrics are initiated if pain free in the early part of this phase (5 seconds on, 5 seconds off for 10 reps, twice daily). Pain-free RC strengthening is progressed from submaximal isometrics to isotonics (ER in side-lying in modified neutral) only if pain free and toward the middle or latter phase for three sets of 5 to 10 reps, two to three times per week.
- Periscapular muscles such as scapular retraction with elastic bands, scapular protraction performed in supine performed three times per week: three sets of 10 repetitions.
- Active exercise is performed in the plane of the scapula.

Sensorimotor Exercises

- Hydrotherapy can be used for its hydrostatic properties. The water temperature is warm to create an environment that promotes relaxation. Supine abduction with buoyancy-assisted device at surface of water, ER ROM with paddle, and pass behind the back with buoyancy device for functional IR. If the patient is willing, the patient can go under water to increase arc of buoyancy. Walking forward with arms abducted will help stretch the anterior chest. Gentle strengthening of proximal scapular musculature can be achieved with scapular retraction/ protraction with dumbbells or paddle board; shoulder extension with gloves or paddles, scaption to surface of water with appropriate resistance as tolerated, as well as IR/ER with appropriate resistance of paddle. Walking backward in water will facilitate scapular retractors.
- Hydrotherapy exercises will replace one day of strengthening on land.

Open and Closed Kinetic Chain Exercises

- CKC physioball stabilization exercises are performed below shoulder height with double arm support. CKC exercise causes contraction of the force couples, allows the rotator cuff to work as a compressor, and creates an axial load (weightbearing). Arms are held wider than shoulder width and are moved in a clockwise and counterclockwise direction for two sets of 10, three times per week.

Techniques to Increase Muscle Strength, Power, and Endurance

- Scapular strengthening is initiated in this phase to include rhomboids, serratus anterior, latissimus in the PoS (two to three sets of 10 to 15 repetitions, respectively, three times per week).
- Pain-free RC strengthening is progressed from submaximal isometrics to isotonics (ER in side-lying in modified neutral) only if pain free and toward the middle and latter phase for three sets of 5 to 10 reps, three times per week.
- Upper body ergometry may be initiated at this time for an active warmup for 5 minutes. Adjust seat height to work within available ROM without compensatory hiking of shoulder girdle.

Neuromuscular Dynamic Stability Exercises

- Rhythmic stabilization exercises performed in supine in the plane of the scapula and with the arm at shoulder height (supine) in the plane of the scapula for 10 seconds, three to four reps.

Functional Exercises

- Begin scapula plane elevation—full can position—to shoulder height when good, pain-free scapulohumeral rhythm is evident (no shrug). These are initiated with no weight and maximum volume is three sets of 10 reps, three times per week.
- Wall slides with physioball are begun in the PoS to achieve strength above shoulder height.
- Hydrotherapy may be used initially to provide environment for active-assistive exercise.

Sport-Specific Exercises

- N/A with the exception of progressive ROM exercises
- Incorporating exercises for core, TBS, TAS, TLS is encouraged, keeping in mind the limitations/precautions associated with the involved shoulder.
- Can initiate trunk rotation and hip ROM

Milestones for Progression to the Next Phase

- Resolution of resting pain, night pain
- PROM of the glenohumeral joint and scapulothoracic joint WNLs
- Normalize scapulohumeral rhythm with elevation to shoulder height in the PoS and observe for compensations (shrug, scapular winging, delayed movement).

Phase III (postoperative weeks 6 to 10)

Clinical Pearls

- Activity levels should be increased gradually in order to optimize muscular fitness and avoid aggravating the joint.
- Patients should be educated and monitored to avoid signs and symptoms of impingement.
- Scapular strengthening is progressed so that an adequate strength base is developed for more advanced exercises.
- Care is taken to follow a functional exercise progression.
- Cryotherapy is continued as activity levels increase.

Goals

- Control pain/inflammation
- ROM WNLs
- Normalize scapular plane elevation above shoulder height which is observed for compensations and timing. In the early part of the ROM (0° to 60°), humeral motion is greater than scapular motion. Between 60° and 120°, scapula motion is greater than humeral motion, and in the final phases of elevation (120° to 180°, humeral motion is greater than scapular motion.
- Avoid impingement.
- Avoid pain with strengthening, ADLs.
- Compliance with home exercise program

Management of Pain and Swelling

- Treatment for pain/analgesia
  - Cryotherapy
  - Patient education: activity modification, avoid too much, too soon pitfall
  - Functional progression
  - Avoid pain with active exercise, strengthening
  - Avoid impingement
- To decrease swelling
  - Cryotherapy

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Evaluation-based. Treat areas that have deficits.
- Pain-free ROM using physiological movements for scapula plane elevation, IR/ER, abduction, ER/IR at 90° abduction
- PNF: Hold-relax techniques are used for IR and ER in the PoS, 90° abduction as indicated.
- Joint mobilizations (evaluation-based) at end range will be used, as needed.



FIGURE 8-10. Chicken wing. Horizontal abduction, external rotation.

Soft Tissue Techniques

- Evaluation-based: maintenance of ROM

Stretching and Flexibility Techniques for the Musculotendinous Unit

- These stretches are performed to patient's tolerance. Initially 10 seconds duration for ten repetitions two times per day progressing to 30 seconds duration for three repetitions, two times per day
  - Pectoral stretch in doorway at varying arm heights
  - Inferior capsule stretch
  - Sleeper stretch (avoid impingement which means stretch should be felt posteriorly, not anterior superior)
  - Posterior capsule stretch (avoid impingement as described)
  - Cane forward flexion
  - Towel IR stretch behind back
  - Horizontal abduction/ER with hands behind head = Chicken wing (Figure 8-10)

Other Therapeutic Exercises

- TBS:
  - Stationary bicycle
  - Running
  - Elliptical, using arms to shoulder's tolerance
  - Use of the UE during cardiovascular exercise can be incorporated to tolerance such as rowing ergometer, elliptical with arms, etc.
  - The patient can perform a modified breast stroke.
- Core strengthening
  - Quadruped position using alternating arm lifts, then alternating leg lifts, then rocking back to forward for transitional movements at the core. This will provide added benefit of scapular stabilization.
  - Lower abdominal strengthening using Sahrmann progression with pressure cuff from 10 reps to 1 minute
  - Bridging (bilateral to marching to single leg progression)



FIGURE 8-11. Advanced strengthening of the periscapular muscles.

  - Trunk rotation with cable column resistance, Theraband resistance, or medicine ball resistance
- TAS
  - Avoid overhead exercise such as military press.
  - Perform pain-free exercise within the available ROM such as biceps curls, triceps curls, scapular retraction, scapular protraction, extension (dumbbell row), lat pulldown, or chest press.
  - Upper body ergometry, use of arms in c-v equipment (row, elliptical, bicycle) progresses pain free
- TLS
  - Squats, RDLs, knee extension, knee flexion, sidelying hip abduction
  - Dead lifts, monster walks, clocks for hip stability
  - Lunges, lunges with rotation

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- These exercises are performed two to three times per week, emphasizing quality of movement:
  - Advanced periscapular strengthening such as prone exercises for lower trapezius, middle trapezius, latissimus (Figure 8-11). These exercises are performed with scapular setting before upper extremity movement.
  - Pain-free rotator cuff PREs progressing from sidelying to standing with elastic resistance. This is performed in modified neutral with towel roll under arm—ER is performed to neutral.

Sensorimotor Exercises

- Hydrotherapy
- PNF diagonal patterns D2 flexion are introduced in supine and progressed to standing.

Open and Closed Kinetic Chain Exercises

- CKC physioball stabilization exercises progressing from bilateral to single arm at shoulder height performed for time or repetitions (1 minute or 10 repetitions, three sets)
- Wall pushup progression from upright position to progressively lower position and ultimately to floor
- Quadruped position as described

Techniques to Increase Muscle Strength, Power, and Endurance

- Upper body ergometry (5 to 10 minutes)
- Cardiovascular equipment with UEs (gradually progress—leg component will be for longer duration than arm component, which will be used in intervals)
- Upper body weight training: chest press, row, lat pull down
- Introduce Bodyblade in modified neutral with oscillations for IR/ER for 30 seconds, three sets.

Neuromuscular Dynamic Stability Exercises

- PNF diagonal patterns D2 flexion in supine to manual resistance to standing to tubing resistance (progressing from 1 to 2 sets of 10 to 15 reps)
- Bodyblade can be introduced in modified neutral position with oscillations for IR/ER, 30 seconds, three sets.

Plyometrics

- Ball toss such as chest pass, side to side pass, and overhead pass can be introduced in latter phase.

Functional Exercises

- PNF diagonal patterns initiated in supine D2 flexion in supine to manual resistance to standing to tubing resistance (progressing from one to two sets of 10 to 15 reps, three times per week)
- Scapular plane elevation performed with no resistance to light resistance for maximum of three sets of 10 reps with good S-H rhythm observed, three times per week. Emphasize posture and stabilization through core.

Sport-Specific Exercises

- These are introduced based on the demands of the sport that the athlete is returning to. Incorporate hip mobility and trunk rotation.

Milestones for Progression to the Next Phase

- Absence of pain with ADLs, therapeutic exercise
- AROM/flexibility to meet demands of sport
- Strength to meet the demands of sport; 85% of uninvolved shoulder measured with isokinetic dynamometer or manual muscle testing dynamometer. Pain-free progression of exercises
- Normalized S-H Rhythm throughout the ROM, which is observed for timing and compensations measured by observation as the patient raises the arm. In the middle of the arc of motion, scapular motion should be greater than humeral motion so that the glenoid is positioned to receive the humeral head.

Phase IV (postoperative weeks 10 to 14+)

Clinical Pearls

- Communication with the surgeon is imperative to begin return to play activities.
- An adequate strength base is required for progression to plyometrics.
- The patient should be monitored for symptoms of pain and inflammation.

Goals

- ROM/flexibility to meet the demands of the sport
- Full, pain-free ROM
- IR/ER strength 3:2 ratio in involved extremity measured with dynamometer, either isokinetic or manual muscle tester

Management of Pain and Swelling

- Treatment for pain/analgesia
  - Cryotherapy continued as exercise increases
  - Monitor volume of exercise: No more than two to three exercises should be performed for specific muscle.
  - Functional progression as outlined in chapter: ROM progression with initiation of strengthening of scapular muscles. Introduction of RC strengthening begins with isometric training and is progressed. With solid foundation of ROM and strength, more challenging exercises (incorporate diagonal patterns, planes of motion) are introduced and endurance is added.
- Decrease swelling
  - Cryotherapy

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Evaluation-based

Soft Tissue Techniques

- Evaluation-based

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Evaluation-based: as needed, and as tolerated progressing from 10 seconds duration for 10 repetitions to 30 second duration for three repetitions
- Pectoral stretch in doorway with varying degrees of abduction
- Inferior capsule stretch
- Sleeper stretch (avoid impingement)
- Posterior capsule stretch (avoid impingement)
- Cane forward flexion
- Towel IR stretch behind back
- Horizontal abduction/ER with hands behind head (chicken wing)

Other Therapeutic Exercises

- As described previously

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Advanced periscapular strengthening such as prone exercises for lower trapezius, middle trapezius, and latissimus. The goal is three sets of 10 repetitions, twice a week. It is imperative that the patient stabilizes the scapula before performing movement of the extremity.
- RC PREs: IR/ER at 90° abduction as tolerated with elastic tubing in standing or prone. Three sets of 10 repetitions are performed, three times per week.

Sensorimotor Exercises

- PNF diagonal pattern progressions from supine to standing, from no resistance to manual resistance and resistance with elastic bands.
- Quadruped exercises are performed for alternating shoulder elevation in the PoS, to alternating LE lifts.
- Rhythmic stabilization is added to resistance exercises at end range.

Open and Closed Kinetic Chain Exercises

- Wall pushup progression to pushups as described
- Single arm ball stabilization
- Quadruped position

Techniques to Increase Muscle Strength, Power, and Endurance

- Upper body ergometry
- Cardiovascular equipment with UEs
- RC and periscapular strengthening
- Isokinetic training
- Upper weight training
- Wall/ball dribbles

Neuromuscular Dynamic Stability Exercises

- PNF diagonal patterns progressing from supine to standing progression
- Bodyblade progressing to away from body but with arm in the PoS; mimicking path of follow through in throwing
- Quadruped training
- RC strengthening at 90/90 position with rhythmic stabilization at end range for five reps
- Quadruped on unstable surfaces for 15 to 30 seconds, three reps

Plyometrics

- Ball tosses are performed for 10 reps each, two sets.
  - Initiate ball toss—2 hand chest pass
  - Activity-specific plyos

- Ball tosses: chest pass, overhead pass progressing from two handed to single-handed, side throws with trunk rotation; two sets of 10 for each

Functional Exercises

- PNF diagonal patterns progressing from supine to standing progression
- Deceleration exercises with cable column, ball toss

Sport-Specific Exercises

- These are introduced based on the demands of the sport that the athlete is returning to. If the athlete is returning to throwing, an interval throwing program should be used to gradually introduce stresses. The program will be adjusted according to sport and position, and will begin with a day of rest in between throwing sessions. Soreness is expected; sharp pain should not be worked through.
  - Throwing
  - Catching/ receiving
  - Tackling
  - Swimming
  - Swinging
  - Batting
  - Rowing
  - Lifting

Evidence

Anderson NH, Sojbjerg JO, Johanssen HV, et al: Frozen shoulder: Arthroscopy and manipulation under general anesthesia and early passive motion. *J Shoulder Elbow Surg* 7(3):218–222, 1998.

This paper discusses the advantages to performing an arthroscopic examination before capsular release or manipulation: Diagnosis and staging can be confirmed, a therapeutic synovectomy can be performed, and potential secondary causes of symptoms can be recognized. (Level III evidence)

Driscoll SW, Kumar A, Salter RB: The effect of continuous passive motion on the clearance of a hemarthrosis from a synovial joint. An experimental investigation in the rabbit. *Clin Orthop Rel Res* 176:305–311, 1983.

(Level X evidence)

Lin JJ, Wu YT, Wang SF, et al: Trapezius muscle imbalance in individuals suffering from frozen shoulder syndrome. *Clin Rheumatol* 24:569–575, 2005.

This study compared upper and lower trapezius muscle activity in 15 asymptomatic subjects to 15 patients with frozen shoulder. It demonstrates that patients with adhesive capsulitis have greater EMG activity in their upper trapezius as compared to their lower trapezius. (Level II evidence.)

Olgilvie-Harris DJ, Biggs BJ, Fitsialos DP: The resistant frozen shoulder: manipulation versus arthroscopic release. *Clin Orthop Rel Res* 319:238–248, 1995.

This prospective cohort study divided 50 patients with persistent pain, stiffness, functional loss for at least 1 year into arthroscopy before and after manipulation, and arthroscopic division of the contracted tissue. Patients treated with arthroscopic division had significantly better pain relief and restoration of function. (Level III evidence.)

Rizk TE, Christopher RP, Pinal RS, et al: Adhesive capsulitis (frozen shoulder): A new approach to its management. *Arch Phys Med Rehabil* 64:29–33, 1983.

This study divided 50 outpatients with adhesive capsulitis into Group A (heat modalities, therapeutic exercise, and gentle manipulation) and Group B (prolonged pulley traction accompanied by TENS). Group B demonstrated greater improvements in ROM. (Level II evidence)

Salter RB: The biologic concept of continuous passive motion of synovial joints: The first 18 years of basic research and its clinical application. *Clin Orthop Rel Res* 242:12–25, 1989.

This paper presents an overview of 18 years experience with basic animal research relevant to the biological concept of CPM of synovial joints in vivo, and 10 years of clinical application to joints in humans. (Level I evidence)

Multiple-Choice Questions

QUESTION 1. Which of the following statements is true?

A. MUA is the favored method to achieve ROM intraoperatively.
B. Capsular release is performed before manipulation.
C. Manipulation is performed before capsular release.
D. B and C

QUESTION 2. Which of the following is NOT true?

A. A block may be kept in for 24 hours.
B. Sling immobilization is used for 6 weeks.
C. ROM exercises are initiated immediately.
D. The sling is discharged when the block wears off.

QUESTION 3. The 6 week postoperative goals include all of the following except

A. Return to sport
B. Resolution of pain at rest
C. PROM WNLs
D. PoS elevation to shoulder height: without a shrug, without pain

QUESTION 4. The advantages of performing arthroscopy before capsular release include:

A. Diagnosis and staging can be confirmed.
B. Therapeutic synovectomy can be performed.
C. Potential secondary causes of symptoms can be recognized.
D. All of the above

QUESTION 5. Abandonment of nonoperative treatment should be considered when

A. Physical and pharmacological therapies have failed.
B. Failure to improve with a minimum of 6 weeks of conservative treatment.
C. Failure to improve with a minimum of 6 months of conservative treatment.
D. A and C

Answer Key

QUESTION 1. Correct answer: **B** (see Surgical Technique)

QUESTION 2. Correct answer: **B** (see Phase I)

QUESTION 3. Correct answer: **A** (see Phase II)

QUESTION 4. Correct answer: **D** (see Evidence)

QUESTION 5. Correct answer: **D** (see Failed Conservative Treatment)

POSTOPERATIVE REHABILITATION AFTER ARTHROPLASTY (REPLACEMENT), HEMIARTHROPLASTY, AND TOTAL SHOULDER OR JOINT RECONSTRUCTION

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Indications for Surgical Treatment

- Glenohumeral degenerative osteoarthritis
- Secondary degenerative osteoarthritis
- Capsulorraphy arthropathy
- Rheumatoid arthritis
- Shoulder fracture
- Avascular necrosis

Brief Summary of Surgical Treatment

Major Surgical Steps

- A standard deltopectoral approach is used.
- The pectoralis tendon is released no more than 1 cm if additional exposure is required.
- The subscapularis (SSC) tendon is released 1 cm lateral to the myotendinous junction from the rotator interval to the ligated anterior circumflex vessels. Adequate tendon stump is left on the lesser tuberosity for later repair.
- The entire SSC tendon is then mobilized by releasing the superior aspect to the base of the coracoid and included release of the coracohumeral ligament. Any loose bodies within the subcoracoid space are carefully removed.
- The inferior SSC border is released by incising the capsule inferiorly to the glenoid rim. The anterior capsule is then released from the anterior glenoid leaving a square patch of capsule firmly attached to the posterior side of the SSC.
- Adequate release was determined by the ability to "bounce" the tendon using two traction sutures in the lateral edge of the tendon. The myotendinous unit should be mobilized easily to the lateral tendon stump with the arm in a minimum of 60° of external rotation with the arm adducted. In cases of total shoulder arthroplasty (TSA), additional releases are performed for placement of the glenoid component, if needed.
- The long head of the biceps is routinely tenotomized or tenodesed. If a tenodesis was performed, it was done at the lower border of the bicipital groove by sewing it to the pectoralis major tendon with a locking No. 2 high-strength polyester braided suture (Fiberwire, Arthrex, Naples, FL). The portion proximal to this is then excised.
- Shoulder arthroplasty is then performed using component specific technique. Anatomic replacement is performed regardless of implant chosen. For stemmed hemiarthroplasty (SHA) or TSA, the humeral head is removed without the use of a guide along the anatomical neck. This allows for preservation of the patient's specific humeral rotation (version) and neck inclination.
- An anatomical humeral implant is then used with the head diameter determined from the size of the humeral osteotomy neck surface. All stemmed prostheses are of a noncemented design. If a glenoid component is used (TSA), it is a nonconforming, cemented all polyethylene pegged design. Resurfacing humeral head replacement arthroplasty is performed in many cases using a noncemented hydroxyapatite-coated cobalt chromium implant placed in anatomical fashion preserving humeral head inclination, offset, and version.
- An extensive capsular release on the humeral neck is performed for all cases, with additional capsular release performed on the glenoid side for TSA cases. The

capsule is not excised in any case and no capsular plications were performed.
- SSC repair is then performed using four No. 5 nonabsorbable sutures in a Mason-Allen suture configuration on the medial side and the lateral side. In cases of SHA or TSA, the lateral limbs of the sutures are passed through drill holes in the lesser tuberosity and are then pulled through the cancellous bone of the humeral neck until they reach the anterior humeral cortex. Laterally, these sutures are passed at the medial edge of the bicipital groove. The placement of these sutures allows the medial SSC tendon to approximate the lateral stump in a side-side fashion, thus resulting in a tendon-tendon repair without lengthening or medialization. A running, locking No. 2 polyester braided suture is then used (Fiberwire, Arthex, Naples, FL) from the rotator interval to the inferior aspect of the SSC.
- For humeral head replacement cases, a tendon-tendon repair is performed in a similar fashion but without using transosseous drill holes in the lesser tuberosity. In cases in which there had been an SSC tear noted before tenotomy or when tissue quality is a concern, PEEK 5.5 mm suture anchors with braided No. 2 polyester suture (PEEK FT anchors, No. 2 Fiberwire, Arthrex, Naples, FL) are used along the lesser tuberosity. If anchors are used, a total of three anchors (six sutures) are used. Sutures are passed by placing the anchor at the level of the tenotomy and passing one limb of each suture through opposing sides of the tendon with a Mason-Allen suture configuration.
- The tendon is not medialized to the anatomical neck, lengthened by coronal "Z" lengthening, or released from the lesser tuberosity.
- After SSC repair all patients are required to have a minimum of 60° of external rotation (ER) with arm at the side and 90° ER in 90° of abduction without tension on the repair.
- Wounds are then closed using absorbable suture in a standard fashion. A drain is not used routinely.

Before Surgery: Overview of Goals, Milestones, and Guidelines[2]

GUIDING PRINCIPLES OF POSTOPERATIVE REHABILITATION

- Initial protection of the subscapularis repair while allowing early range of motion to optimize range of motion recovery postoperatively
- Early activation of the scapular stabilizers and rotator cuff to improve glenohumeral stabilization and scapulohumeral rhythm.
- Progressive resistive exercise to improve shoulder function via enhanced muscular strength and endurance

[2]*Prehabilitation, if appropriate, is described in the Nonoperative Rehabilitation section of this chapter.*

Phase I (days 0–14): Immediate Postoperative Period

Clinical Pearls

- It is imperative at this time of the rehabilitation following arthroplasty that patients be educated on the key limitations and contraindications pertaining to early ROM and functional activity.
- Because of the subscapularis repair, no external rotation beyond 30° should be performed, as well as no internal rotation resistance.
- Additionally, there should be no elbow resistive exercise or lifting because of the concomitant biceps tenodesis that is performed during the procedure.

Goals

- Protect subscapularis repair while facilitating passive movement of the glenohumeral joint to minimize range of motion loss.
- Encourage movement of the distal upper extremity to minimize disuse atrophy and range of motion loss/stiffness.
- Initiate scapular stabilization exercise to enhance proximal stability of the upper extremity.

Protection

- The patient uses a sling with abduction pillow during this phase during waking hours and also at night to maximally protect the shoulder and structures addressed during the surgical procedure.

Management of Pain and Swelling

- Treatment for pain/analgesia
  - Modalities consisting of cryotherapy and electrical stimulation are used during this phase for pain control. In our experience, interferential electrical stimulation is used.
- Decrease swelling
  - Swelling around the incision and ecchymosis in the upper arm and pectoral region are commonly encountered; however, unlike the knee or ankle, excessive swelling is not typically a major or primary complication of this procedure. Use of the modalities coupled with passive range of motion and gentle edema massage can be used when increased swelling is encountered.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Mobilization of the glenohumeral and scapulothoracic joints is performed from the first postoperative visit moving forward. Range of motion limitations are for

the protection of the subscapularis, as mentioned, with no more than 30° to 45° of passive external rotation range of motion and likely more importantly no external rotation stretching or loading the extremity into external rotation.
- Care should be taken when interpositional arthroplasty is performed, with respect to accessory mobilization or glides.
- Protection of the graft jacket or soft tissue graft on the glenoid is recommended via limited humeral head shear activities and hence, less anterior/posterior accessory glide mobilization and less caudal glide mobilization use in these patients in the first 4 to 6 weeks of rehabilitation. A greater reliance on physiological movement and range of motion is warranted.

Soft Tissue Techniques

- Gentle soft tissue massage and scar tissue management for the anterior based scar can be applied at this phase as tissue healing progresses.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Passive range of motion activities as previously listed are the primary means of flexibility exercise applied postoperatively.
- The primary muscle tendon unit emphasized is the posterior shoulder (infraspinatus and teres minor) through the use of internal rotation range of motion and cross arm adduction stretching.
- Many patients present with internal rotation range of motion loss, and the use of stretching and passive motion during this phase is recommended to address often chronic shortening of the posterior shoulder from years of motion loss and disuse before arthroplasty.

Other Therapeutic Exercises

- Grip exercise and wrist flexion extension range of motion and active range of motion are encouraged in the first phase postoperatively.

Milestones for Progression to the Next Phase

- Initial tolerance to passive range of motion of the shoulder and scapulothoracic joint
- Tolerance of manual scapular stabilization exercise
- Decreased pain levels allowing for therapeutic exercise and manual therapy.

Phase II (postoperative weeks 2 to 6)

Clinical Pearls

- Continue use of subscapularis precautions to minimize rehabilitation stress to the healing subscapularis tendon.
- Use a low-load, long-duration range of motion concept to improve glenohumeral joint range of motion in this early phase of rehabilitation.

Goals

- Improve passive and active assisted range of motion of the glenohumeral joint.
- Initiate rotator cuff and scapular strengthening exercise.

TIMELINE 8-3: **Postoperative Rehabilitation after Arthroplasty (Replacement), Hemiarthroplasty, and Total Shoulder or Joint Reconstruction**

PHASE I (weeks 1 to 4)

- General guidelines
  - Sling use directed by surgeon in postoperative instructions
  - Immediate postoperative passive and active assistive range of motion consisting of stomach rubs, sawing movements, and elbow range of motion instructed following hospital discharge
  - Initial postoperative range of motion limitations may be set by surgeon based on underlying shoulder mobility status and range of motion obtained in the OR post implantation
- Modalities to decrease pain and inflammation
- Passive range of motion initiated with no limitation in flexion, abduction, or internal rotation. NO EXTERNAL ROTATION stretching or anterior capsular mobilization in this rehabilitation phase to protect the subscapularis repair. Gentle PROM into external rotation allowed without overpressure up to 30° to 45° with 45° abduction. NO EXTERNAL ROTATION ROM in 90° abduction during this phase.
- Elbow, wrist, and forearm range of motion/stretching
- Manually applied scapular resistive exercise for protraction/retraction strengthening and scapular mobilization
- No biceps manual resistance for initial 6 to 8 weeks because of bicep tenodesis performed with procedure
- Ball approximation (closed chain Codman's) using Swiss Ball or table top
- Initiation of active assistive range of motion using pulley for sagittal plane flexion and scapular plane elevation as well as supine active assistive exercise using a cane or stick

PHASE II (weeks 2 to 6)

- Continuation of Phase I program
- Initiation of submaximal multiple angle isometrics and manual resistive exercise for shoulder external rotation, ab/adduction, flexion/extension. No internal rotation resistive exercise for initial 6 weeks to protect the subscapularis repair
- Upper body ergometer (UBE)
- External rotation isotonic exercise using pulley or weight/tubing with elbow supported and glenohumeral joint in scapular plane and 10° to 20° of abduction (towel roll or pillow under axilla)
- Manual resisted external rotation exercise in scapular plane position by therapist in varying degrees of elevation (30° 60°) from full internal rotation position to neutral external rotation position

- Develop and advance a home exercise program to augment in-clinic activity for ROM and strengthening.
- Activate the entire upper extremity kinetic chain to minimize disuse atrophy of the regions both proximal and distal to the glenohumeral joint.

Protection

- Sling use continues in precarious situations outside the home, with gradual weaning of protection during seated and less stressful situations toward the 4- to 6-week stage of the recovery process.

Management of Pain and Swelling

- Treatment for pain/analgesia
  - Modality use continues with cryotherapy, electrical stimulation, heat, and joint mobilization being applied.
- Decrease swelling
  - Modality care and soft tissue work are used to address swelling if present.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- For the first 6 weeks, specific subscapularis precautions must be followed to protect this important structure postoperatively. This entails limitation of passive or active external rotation range of motion, and no active resistive exercise for internal rotation.
- Although gentle attempts at passive external rotation can occur to as far as 30° to 45° of external rotation beyond neutral, techniques which place increased or undue tension on the anterior capsule and subscapularis are avoided for the first 6 weeks following surgery.
- Additional precautions may be needed depending on the repair of additional rotator cuff tendons at the time of surgery, as well as whether bicep tenolysis, tenodesis, or tenotomy has been performed.
- To address selective capsular tightness, posterior glides of the humeral head relative to the glenoid, with varying degrees of internal rotation of the glenohumeral joint, are used to mobilize the posterior capsule and address limitations in internal glenohumeral joint rotation.
- Anterior glides of the humeral head are often used later in the rehabilitation process once initial subscapularis healing has occurred, to address limitations in external rotation if indicated. Optimization of capsular length between the anterior and posterior capsule is theoretically purported to minimize humeral head shear within the glenoid with glenohumeral joint movement.
- In addition to the use of glenohumeral joint mobilization, application of passive stretching using the low-load, long-duration stretching concept is also recommended.

Soft Tissue Techniques

- Soft tissue techniques to address the periscapular structures and upper arm are used for pain control and to improve circulation, but are not a main emphasis during this phase of the rehabilitation.
- Although these techniques can be comforting to the patient, their short-term response limits endorsement as a primary technique in shoulder rehabilitation.

TIMELINE 8-3: **Postoperative Rehabilitation after Arthroplasty (Replacement), Hemiarthroplasty, and Total Shoulder or Joint Reconstruction** (Continued)

PHASE III (weeks 6 to 12)

- Initiation of passive external rotation range of motion and stretching beyond 30° to 45° in 45° to 60° of abduction.
- Initiation of internal rotation submaximal resistive exercise progression
- Traditional rotator cuff isotonic exercise program
  - Side-lying external rotation
  - Prone extension
  - Prone horizontal abduction (limited from neutral to scapular plane position initially with progression to coronal plane as ROM and scapular control improves)
- Biceps/triceps curls in standing with glenohumeral joint in neutral resting position
- Oscillation exercise with flex bar or Bodyblade
- Rhythmic stabilization in open kinetic chain environments
- Scapular stabilization exercise progression including seated rows, external rotation with retraction, low rows and serratus presses/punches
- Initiation of elevation progression consisting of rhythmic stabilization with shoulder on small Swiss ball in 80° to 90° in the scapular plane

PHASE V (weeks 12 to 16)

- Continuation of rehabilitation
- Isometric Internal/external rotation strength testing assessment in neutral scapular plane position, functional rating scales SST, SANE, and ASES.
- Addition of ball dribbling and upper body plyometrics with small Swiss ball
- Advanced rotator cuff and scapular exercise progressions



FIGURE 8-12. External rotation manual resistance exercise performed by the physical therapist in 45° of elevation in the scapular plane.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- As in preceding manual therapy techniques section.

Other Therapeutic Exercises

- Range of motion of the distal upper extremity occurs, specifically the elbow, wrist, and forearm to minimize loss of motion secondary to sling use. Additionally, the use of ball squeezing exercise and wrist flexion and extension curls can be applied to minimize disuse atrophy of the distal upper extremity during this phase.
- Care must be taken to respect proximal tissue healing while selecting isolated wrist and forearm exercises as well as grip strengthening during this initial postoperative phase.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Initial activation of the posterior rotator cuff begins in the first 10 days following surgery.
- Manual resistance for glenohumeral external rotation at 30° to 45° of abduction (Figure. 8-12) and the use of side-lying external rotation exercise are used.



FIGURE 8-13. Side-lying scapular exercise with manual resistance provided by the therapist.

- Additionally, manual scapular stabilization exercise in side-lying (Figure 8-13) is used from the first postoperative visit onward to ensure activation of the important scapular stabilizers.

Sensorimotor Exercises

- Rhythmic stabilization techniques are used in the balance point (90° of flexion) position.
- Scapular protraction is used during this technique to enhance activation of the serratus anterior via the "plus" position[1,2] with initially very gentle perturbations applied by the therapist to activate the stabilizing musculature and also provide proprioceptive input.

Techniques to Increase Muscle Strength, Power, and Endurance

- Early strengthening following glenohumeral arthroplasty focuses on the scapular stabilizers and safe, submaximal rotator cuff activation. As mentioned earlier, manual scapular stabilization is used in side-lying with manual contact from the therapist to the scapula. This technique allows for early contraction of the lower trapezius and serratus anterior force couple components without stressing the glenohumeral joint. Multiple sets to induce muscular fatigue of these important muscles are indicated.[3]
- In addition to the scapular stabilization exercise, early application of external rotation exercise is initiated. As mentioned throughout this chapter, internal rotation strengthening cannot commence before 6 weeks postop to protect the subscapularis muscle tendon unit.
- Progression of rotator cuff strengthening follows patterns outlined in the literature with documented high levels of activation of the posterior rotator cuff to enhance recruitment, and to improve local muscular endurance in formats of multiple sets of 15 to 20 repetitions.[4-7]
- Additionally in this early stage, external rotation isometrics with elastic resistance (Theraband, Performance Health Corp., Akron, OH) are performed as pictured in Figure 8-14. The neutral position is used with a towel roll placed under the axilla. This neutral starting position is maintained during the exercise wherein the patient steps laterally away from the attachment point of the tubing. After a several-second pause at the point of increased tension, the patient is directed to step again back toward the attachment point of the tubing. Actual motion at the glenohumeral joint does not occur, yet variable loading during this isometric exercise is transmitted to the glenohumeral and scapulothoracic muscles. This exercise is well tolerated, safe, and can be used as a home program exercise to begin to facilitate development of the posterior rotator cuff and scapular stabilizers.
- Gradual progressions in rotator cuff and scapular strengthening occur with increased intensity and variety following 4 to 6 weeks postop. The important role of the rotator cuff muscle-tendon units in controlling and centering the humeral head, especially during midrange movement patterns, cannot be underestimated.

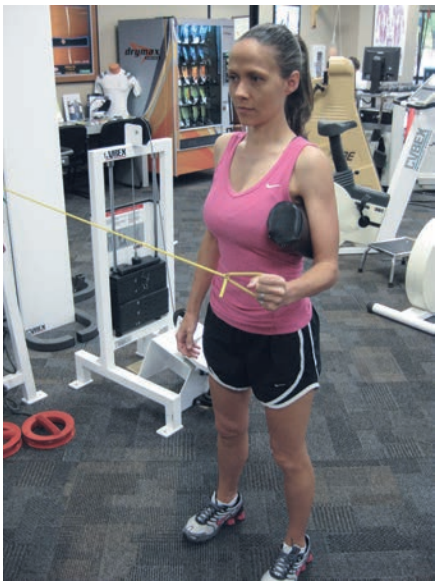

FIGURE 8-14. External rotation isometric with elastic resistance.

- The use of submaximal strengthening methods to selectively recruit the rotator cuff musculature, using exercise patterns placing the shoulder in neutral, non-impinging positions, forms the basis for in-clinic and home-based rehabilitative exercise.
- Exercises such as side-lying external rotation, prone extension, and prone horizontal abduction are used and recommended and are based on research using EMG that documented high levels of posterior rotator cuff activation.[4-7]
- As a general rule, exercises for the shoulder that keep the shoulder below 90° of elevation and the arm slightly anterior to, and in the scapular plane, are recommended.[8]
- Progressive advances in exercise for the muscles that stabilize the scapula are also indicated. Exercises that strengthen the serratus anterior and lower trapezius are particularly recommended to improve scapular upward rotation during elevation.[9] Resistance patterns with light weights, medicine balls, or Thera-Band can be used to perform shoulder punches, with emphasis on the position of maximal scapular protraction (termed the "plus" position) to recruit the serratus anterior.[1,2]
- Scapular retraction exercises, such as rowing with multiple positions of arm abduction, are also indicated.
- Lower resistance levels allow rotator cuff activation, with less compensation and shoulder girdle elevation that often accompanies independent exercise programs with higher resistance levels and movement patterns characterized by full, end range, overhead elevation. Care must be taken to ensure that resistive exercise does not elevate pain levels, which leads to muscular inhibition and compensation.
- The restoration of optimal muscle balance is imperative during the rehabilitation of all shoulder injury and pathologies; however, it is particularly important following shoulder arthroplasty.
- The effect of unbalanced muscular forces during shoulder muscular contraction and volitional movement is important to point out and is a concept that underlies the clinical application of the initial exercise prescription during postoperative rehabilitation in this early phase. Unbalanced internal rotation strength or dominant anterior muscular strength development can lead to anterior translation of the humeral head relative to the glenoid.[10]
- Likewise, excessive posterior development could accentuate posterior subluxation from an eroded posterior glenoid and overly tight anterior structures (obligate translation) and produce posterior instability.
- Optimal muscle balance between the external and internal rotators has been reported and recommended in the range between 66% and 75% ER/IR.[11] This can be assessed with a hand-held dynamometer or isometric function of an isokinetic dynamometer system in the later stages of rehabilitation to ensure proper restoration of this optimal muscle balance.[11]
- Patients frequently present with overly dominant anterior muscular strength, which can jeopardize glenohumeral mechanics and lead to complications and functional impairment.
- Rockwood et al. have demonstrated the concept of the "rocking horse" phenomenon, which can lead to implant loosening, one of the most frequently encountered complications following total shoulder arthroplasty.[12]
- Unbalanced muscular contractions creating humeral head shear can lead to implant loosening and failure of the glenoid implant. Restoration of proper muscular balance via monitoring and addressing the ER/IR strength ratio, as well as application of the range of motion, physiological stretching, and use of accessory mobilization techniques during postoperative rehabilitation ensure proper capsular excursion and minimize the effect from obligate translation.

Milestones for Progression to the Next Phase

- Enhanced glenohumeral joint passive range of motion to allow for progression of resistive exercise and functional range of motion
- Tolerance of initial submaximal exercise progression for rotator cuff and scapular strengthening
- Improved shoulder function in supine gravity eliminated position for shoulder elevation. The patient's ability to move from the 90° flexed position on the supine position termed the "balance point" position is evaluated based on scapular substitution and pain in addition to the overall quality of the motion. As the patient progresses, they are able to move further into flexion beyond 90° as well as into extension from the 90° flexed position. This is used as a precursor to standing against gravity exercise progressions and assures that the patient can engage the appropriate musculature without undue compensation from the upper trapezius and overall use of inappropriate motor patterns in this progression.

Phase III (postoperative weeks 6 to 12)

Clinical Pearls

- At 6 to 8 weeks postop, patients can begin internal rotation resistive exercise and receive external rotation passive overpressure stretching to complement the initial rehabilitation program initiated following surgery.
- Care is taken also at this stage to use techniques and positions appropriate for the patient's strength levels to begin successful attempts at initiating functional elevation.
- Early reliance on long lever arm techniques against resistances that exceed the patient's tolerance produce excessive scapular compensation and result in nonoptimal biomechanical movement patterns.

Goals

- Advance rotator cuff and scapular resistive exercise progressions.
- Progress against gravity elevation progressions using techniques and positions that minimize scapular compensation.
- Begin subscapularis and biceps strengthening at 6 to 8 weeks postop.
- Advance ROM to terminal ranges in all planes as the subscapularis precautions are lifted.

Protection

- Sling is removed for all patients and all activities at 6 weeks postop.

Management of Pain and Swelling

- Treatment for pain/analgesia
  - Modality application continues to facilitate healing and blood flow, decrease pain, and optimize recovery following increased resistive exercise interventions.
- Decrease swelling
  - Swelling at this phase is typically not encountered. If there are continued issues with swelling, soft tissue work and modality care coupled with edema control measures such as compression would be employed. This is not typically encountered, however.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Glenohumeral joint mobilization continues during this phase to assist and facilitate passive range of motion and stretching in all planes.
- Restrictions in capsular mobility continue to be addressed to minimize the negative effects of obligate translation whereby excessive anterior translation can be produced from posterior capsular tightness as well as excessive posterior humeral head translation is produced from anterior capsular tightness.[13]
- This anterior capsular tightness can occur secondary to the initial protection of the subscapularis and anterior capsular protection afforded in the initial postoperative weeks.
- Great care and emphasis on the restoration of optimal passive and active range of motion to the postoperative extremity through directional accessory mobilization techniques continues during this phase of rehabilitation. Mobilization of the glenohumeral joint is performed with emphasis on the initial postoperative phases of rehabilitation on posterior glides to improve internal rotation as well as caudal glides. The posterior glides are initially applied in 30° to 45° of elevation in the scapular plane with progression toward 80° to 90° of elevation as the patient's range of motion improves. These posterior glides can be performed with the shoulder in varying amounts of internal rotation to increase tension in the posterior capsule and increase the intensity of the mobilization. Additionally, caudal glides are performed to improve humeral elevation. These are also initially performed in 40° to 50° of elevation with progression of the mobilization application to 80° to 90° of elevation as the patient's range of motion improves.
- Figure 8-15 shows a posterior glide performed with the glenohumeral joint in the scapular plane position.

Soft Tissue Techniques

- Soft tissue mobilization and massage are not emphasized during this phase of rehabilitation; however, in the presence of periscapular trigger points and muscular soreness, these can be applied to assist patients in recovery and pain relief.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Stretching of the glenohumeral joint as described commences to terminal range of motion in all planes.



FIGURE 8-15. Posterior glide of the humeral head with the shoulder placed in the scapular plane.



FIGURE 8-16. Upper-body ergometer.



FIGURE 8-17. "Ball on the wall" exercise with perturbations provided by the therapist and shoulder placed in the scapular plane.

- This stretching can occur in both adduction and abduction for external rotation beyond 30° to 45° to prepare the patient for a return to functional activity.
- Frequently these patients have had consideration range of motion loss before surgery and the reestablishment of greater arcs of glenohumeral joint range of motion in all planes is a desired outcome during this critical phase of postoperative rehabilitation.[14]

Other Therapeutic Exercises

- Exercise continues for the proximal and distal aspects of the upper extremity kinetic chain with fewer limitations during this phase because of the disappearance of the subscapularis precautions.
- Use of the upper body ergometer progresses during this phase to provide endurance-oriented scapular stabilization and entire extremity activation (Figure 8-16).

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Activation continues as detailed above and below for the rotator cuff and scapular musculature.
- At this time activation of the subscapularis via internal rotation strengthening, as well as specific exercises for the biceps either in isolation or in combination (such as rowing), are employed.
- Internal rotation strengthening is performed using the scapular plane position and approximately 30° of elevation. This is achieved by placing a towel roll under the axilla to ensure that insolated internal rotation movement is performed and more optimally position the patient's extremity in the scapular plane in slight elevation. Starting position is initially from neutral rotation to full internal rotation toward the patient's stomach. Activation of the biceps can now commence after initially protecting against any bicep activity owing to the tenodesis.
- Elbow flexion curls with very light weight and controlled movement are used along with seated rows that do involve biceps contraction and upper body ergometry, which results in repetitive activation for endurance training.

Sensorimotor Exercises

- Perturbation exercises continue to be used, progressing from the 90° flexed (balance point) position to positions with greater amounts of humeral elevation and also external rotation to mimic functional positions required during sport and daily activities.
- Removal of visual cues and increasingly challenging intensities are used with the rhythmic stabilization interventions during this phase of rehabilitation.

Open and Closed Kinetic Chain Exercises

- The integration of close chain exercises are used during this phase of rehabilitation is recommended with the use of the "Ball on the wall" exercise (Figure 8-17).
- Progression to quadruped positions for perturbation as well as use of the BOSU ball or rocker platform to simulate weight bearing is applied to prepare patients for weight-bearing functional positions during this phase.
- It is important to emphasize that the weight-bearing (closed kinetic chain) exercise positions use distal upper extremity positions that create proximal glenohumeral joint positioning at or near the scapular plane (30° anterior to the coronal plane). Progression to closed kinetic chain exercises is followed. Initial closed chain exercise involves merely weight shifting in a standing position with the extremities on a table, progressing to rocker board or BAPS board type proprioceptive activation. As healing progresses and patient tolerance to exercise improves, the use of a quadruped position is recommended because of the functional position required from many patients during work and ADLs. Rhythmic stabilization in the quadruped position can be applied by the physical therapist to challenge the patient and create coactivation in the closed kinetic chain environment.
- Use of narrow, weight-bearing hand positions can align the glenohumeral joint closer to the sagittal plane, thereby creating a posterior shear position or situation within the glenohumeral joint.
- Careful alignment of the extremity during all exercise applications is warranted, but particularly when integrating closed kinetic chain exercises.



FIGURE 8-18. Upper extremity ranger exercise for active assisted elevation.

Techniques to Increase Muscle Strength, Power, and Endurance

- Progression to elevated positions of rotator cuff and scapular stabilization are indicated to assist patients with the return of against-gravity elevation following these extensive surgical procedures.
- Figure 8-17 shows an exercise position using the scapular plane and 80° to 90° of elevation and an exercise ball (Hygenic Corporation, Akron, OH). The patient is asked to maintain the position on the ball while the therapist provides challenges or perturbations to the extremity in all directions to elicit muscular activation in this functional position.
- As with all shoulder elevation exercises, great care is given to avoid the presence of excessive scapular elevation "hiking" the shoulder during exercise.[15] This compensatory pattern leads to the development of inappropriate motor patterns and produces long-term scapular pathology with arm elevation.
- Additional exercises used during this phase are assisted elevation exercises using the Upper Extremity Ranger device (Figure 8-18) and Thera-Flex device (Figure 8-19) to assist with arm elevation initially when the patient is unable to perform this motion against gravity without excessive scapular compensation.
- Figure 8-20 shows the typical shrug sign employed by patients when attempting arm elevation when limited rotator cuff strength is available.
- To allow patients to begin exercising at or near the functional position of 90° of scapular plane elevation, a sling device can be used (Figure 8-20) to provide elevation assistance while rotational exercise or perturbation/oscillation tasks are integrated to provide muscular activation.
- Figure 8-21 shows how a sling comprised of and elastic band (Thera-Band, Performance Health, Akron, OH) can be used to support the extremity with appropriate levels of assistance requiring muscular activation by the patient to maintain the elevated position without scapular compensation. As patients progress in their rehabilitation, the amount of resistance afforded by the elastic resistance is lessened both by the density or

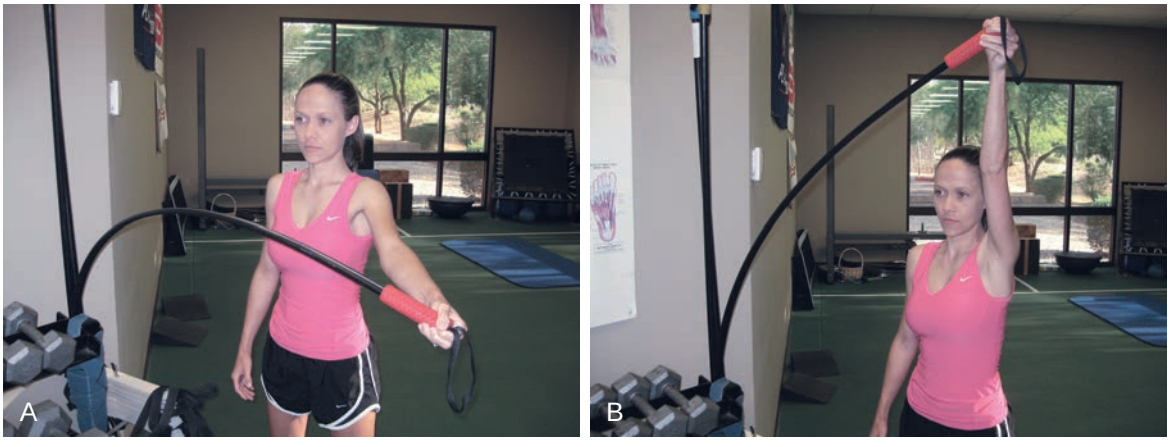

FIGURE 8-19. Thera-Flex assisted elevation in the scapular plane.



FIGURE 8-20. Abnormal compensation with arm elevation exercise. This characteristic compensation is to be avoided by modifying exercise techniques and loading strategies.

property inherent in the band as well as by the location of the band (proximal or distal aspect of the extremity) application to the extremity. A distal application of the assistive sling provides much greater overall assistance to the patient compared to a more proximal position of the band application.

Plyometrics

- During the later stages of this phase of rehabilitation, two-hand plyometric exercise is applied using a small physio ball or basketball. These two-hand plyometric exercises involve movement patterns that simulate functional exercise like a chest pass plyometric, golf swing plyometric, as well as forehand and backhand plyometric.
- The timing of application of these exercises is based on the successful progression of rotator cuff and scapular resistive exercise as well as available range of motion in the patient's postoperative extremity.
- Multiple sets of 15 to 30 repetitions using very light loads to minimize joint loading and provide an initial functional arc of lightly resisted motion are recommended.



FIGURE 8-21. Supported oscillation exercise in the scapular plane with 90° of elevation.

- See Beyond Basic Rehabilitation: Return to Golf, Swimming, and Tennis after Shoulder Arthroplasty for photos of these exercises.

Functional Exercises

- The use of exercise progressions in the stage of rehabilitation discussed includes the integration of shoulder elevation progressions and plyometrics.
- The use of wall pushups and quadruped exercise positioning is based on the functional goals and occupational demands of the individual patients. Traditional pushups and dips are not recommended for obvious reasons because of the inappropriate joint loading that these exercises would produce.
- Other traditional exercises like seated rowing, bent-over rows, and triceps and biceps exercises for the upper extremity can be integrated cautiously during this phase of rehabilitation to provide additional strength training stimuli to the upper extremity kinetic chain.
- Loading on these exercises has to be rehabilitation appropriate to avoid nonoptimal loading for joint and soft tissue protection.

Sport-Specific Exercises

- See previous Plyometrics exercise section.

Milestones for Progression to the Next Phase

- Tolerance of isotonic rotator cuff and scapular resistive exercise. Patient is able to perform isotonic resistive exercise for the rotator cuff and scapular muscles without pain and uses appropriate movement strategies without compensation to repetitive loading.
- Ability to attain against gravity elevation with minimal scapular compensation
- Ability to perform functional movement patterns of ADLs and sport simulation
- Objective testing of shoulder active and passive range of motion; isometric shoulder internal and external rotation strength, using a hand-held dynamometer, manual muscle testing, or the isometric mode of an isokinetic dynamometer (i.e., Biodex); and functional rating scales such as the Simple Shoulder Test (SST) and modified American Shoulder and Elbow Surgeons (ASES) are also completed at 12 weeks to provide clinicians with valuable objective information to base future exercise prescription, and manual mobilization and ROM interventions.

Phase IV (postoperative weeks 12–16)

Clinical Pearls

- Continued use of resistive exercise progressions to improve elevation control without scapular compensation is warranted as well as the use of the 90°

elevated position for rotational exercise in the younger, more active patient whose goal is to also return to sport activity or elevated work environments with repetitive movement.
- Mobilization and passive stretching to attain as full an arc as possible continues using the low-load long-duration stretching concepts coupled with in-clinic muscle tendon unit stretching and accessory mobilization techniques.

Goals

- Advance rotator cuff and scapular exercise and provide objective measurement and quantification of ER/IR muscle balance.
- Continue to address ROM limitations via aggressive mobilization and passive stretching techniques.
- Prepare the patient for gradual weaning of formal PT and incorporation of end stage ROM and strength activity for a return to full activity.

Management of Pain and Swelling

- Modality applications weaned but still used for recovery and to address joint pain or muscle soreness as needed
- Treatment to address swelling is not typically needed.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Continued use of end range of motion passive stretching coupled with accessory mobilization to regain as full an arc of motion as possible in all planes. Continued use of passive range of motion and glenohumeral joint mobilization is applied in all planes and directions based on range of motion response from the patient. This includes posterior, anterior, and caudal glides as well as joint distraction techniques if there is continued joint hypomobility encountered.
- There are no ROM limitations and using the goal of achieving both active and passive range of motion values equal to the contralateral side remains.

Soft Tissue Techniques

- This is not an emphasis during this phase of the rehabilitation program.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Continues as listed above with prolonged holds at end ROM to enhance joint ROM

Other Therapeutic Exercises

- Specific exercises for the core and distal upper extremity continue to be applied in in-clinic rehabilitation as well as in the home program as patients return to gym-based workout programs for all regions of their body. Examples of core exercises include the use of resisted trunk rotation with a light medicine ball to encourage trunk rotation in preparation for return to work, ADL, and sport activity.
- Education is given, however, to continue to minimize joint loading to the shoulder, and modification of traditional exercise programs is warranted to ensure that the shoulder joint is not loaded or positioned in a harmful way to exercise adjacent body structures or segments.[16]

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Rotator cuff and scapular exercise continue in this phase to be the primary emphasis for activation, and the application of specific exercises showing high levels of rotator cuff and scapular muscle EMG activity continues.[4-7]
- Rotational exercises coupled with proper scapular stabilization without compensation form are important exercises for inclusion during this phase. The use of prone rotator cuff and scapular stabilization exercises are also used in addition to the traditional humeral rotation exercise.

Sensorimotor Exercises

- Perturbation exercise and rhythmic stabilization progressions are used to challenge the sensorimotor system during this phase and have been outlined in the prior stages of rehab in this chapter.

Open and Closed Kinetic Chain Exercises

- Rehabilitation exercise continues to favor open kinetic chain rehabilitation for muscle group isolation and activation; however, some closed kinetic chain exercises in quadruped positions are used particularly in persons returning to either work environments in which crawling or upper extremity weightbearing is needed as well as for individuals who are involved in gardening or home based activities requiring upper body weight loading. Quadruped-based exercises with therapist perturbations as mentioned earlier continue as well as progression to tripod and pointer applications. It is important to point out that increased loading in the closed chain are not used and closed chain exercises are progressed very slowly in this population.
- Pushups are NOT recommended or used; however, placement of the extremity on a BOSU platform, or foam stability or rocker platforms is indicated to enhance proximal muscle activation and encourage proprioceptive input.

Techniques to Increase Muscle Strength, Power, and Endurance

- Exercise progressions in this final phase of formal rehabilitation progress to greater levels of resistive exercise intensity. Progression for the younger, more active patients to isokinetic internal and external rotation

training using a position with the shoulder placed in 30° of elevation in the scapular plane[11] allows for high-level activation of the rotator cuff at higher joint angular velocities.
- Additionally, isokinetic testing can be performed to allow for objective strength quantification to allow clinicians to know both bilateral comparisons and ER/IR muscle balance.
- In addition to isokinetic training, greater levels of manual resistance and external loading with elastic tubing and cuff weights or dumbbells are recommended. Loading schemes that allow for multiple sets of 15 repetitions to be performed without compensatory movements or exaggerated muscle compensation from the upper trapezius are used.

Plyometrics

- Two-hand plyometric exercise progressions continue with end stage application of one-hand plyometric exercises in only a small subset of patients who have regained appropriate range of motion levels for a return to throwing or swinging activity.
- These exercises are outlined and discussed in greater detail in the following section on Beyond Basic Rehabilitation: Return to Golf, Swimming, and Tennis after Shoulder Arthroplasty.
- The initial use of a basketball or soccer ball for two-hand plyometrics can be advanced gradually to light medicine balls to increase upper extremity loading for the performance of these plyometric functional exercises.

Functional Exercises

- Continued integration of overhead elevation activities, and limited weight-bearing postures in the rehabilitation program outlined during this phase provide functionally-based strength training stimuli for the patient in this important phase of rehabilitation.
- Modified return to traditional exercises such as the lat pulldown, rowing, chest press, and biceps and triceps curls are followed for individuals who are involved in these activities recreationally, as well as for those returning to manual labor type jobs.[16]

Sport-Specific Exercises

- See Beyond Basic Rehabilitation: Return to Golf, Swimming, and Tennis after Shoulder Arthroplasty for exercise progression and interval program specifics.
- Exercises listed earlier in this rehabilitation program detail the use of an elevated 90° scapular plane position used for strengthening, oscillation, and perturbation based exercise progression aimed at returning appropriate patients to overhead sport-specific activities.

Milestones for Progression to the Next Phase

- Stabilizing active and passive range of motion values despite continued interventions for mobilization and passive stretching. Deficits of 10° to 20° compared with the contralateral extremity can be expected; however, active range of motion should closely approximate passive range of motion before discharge.
- ER/IR ratio of 66% is a target. Deficits in strength compared with the contralateral uninjured extremity are common; however, a goal of returning equal IR and ER strength remains in the long-term functional outcome for the active patient following arthroplasty.
- Demonstrated independence with a home exercise program for range of motion maintenance and strengthening of the rotator cuff and scapular musculature
- Provision of initial guidance in an interval based functional or sport return program tolerated by the patient. This allows continued and gradual return to sport and functional activities in the ensuing months following discharge in an independent or consulting status for the patient.

Criteria for Return to Sport

- Unique challenges exist during the rehabilitation of the patient following shoulder arthroplasty. It is often not possible to achieve full, desired range of motion of the joint because of the chronic capsular changes and alterations of range of motion that existed pre-operatively; however, the use of an aggressive program of rehabilitation following surgery does strive to achieve a minimum of 70° of external rotation in the 90° abducted position.
- Active flexion and abduction (elevation) typically exceed 145° in these patients and are acceptable for the sports being discussed in this chapter.
- One additional consideration for the sport of golf is the achievement of optimal amounts of cross arm adduction to allow for either proper take back (e.g., left shoulder arthroplasty in a right handed golfer) or during following through (e.g., right shoulder arthroplasty in a right handed golfer).
- Careful monitoring of sport-specific movement patterns is needed by the physical therapist and physician during this phase of the rehabilitation because often some modifications (often shortening) of the stroke pattern is needed to facilitate the return to that sport.
- Although not always optimal from a performance enhancement standpoint, careful monitoring and use of video feedback to obtain the most efficacious movement pattern allowed by that patient's range of motion and strength levels is indicated.
- The use of computer programs such as Dartfish are indicated and used by these authors to monitor movement strategies and provide meaningful feedback to the patient during this critically important phase of the rehabilitation process.
- Objective criteria such as minimal pain-free range of motion characteristics, negative instability and impingement clinical tests, strength test within 15% to 20% of the contralateral limb in addition to acceptable unilateral strength ratios (optimal 66% to 75% ER/IR ratios, accepted minimal standards 55% to 65%) are used to guide the process objectively from a clinical standpoint.

Exercises and Other Techniques for Prevention of Recurrent Injury

- Maintenance programs given to the patients upon completion of their supervised rehabilitation include rotator cuff and scapular exercises to be performed using a low resistance high repletion format (multiple set training).
- These include exercise with elastic resistance for external and internal rotation both at the 30/30/30 position at the side and with 90° of elevation.
- Additionally, scapular stabilization exercises for the serratus anterior and lower trapezius are recommended.
- It is also recommended that range of motion exercises be continued to prevent range of motion loss including the cross arm and sleeper stretches for internal rotation as well as external rotation with a stick or implement and use of a pulley or external device such as a stick or cane for forward flexion.

Evidence

Bailie DS, Llinas PJ, Ellenbecker TS: Cementless humeral resurfacing arthroplasty in active patients less than fifty-five year of age. *J Bone Joint Surg* 90:110–117, 2008. doi: 10.2106/JBJS.F.01552.

Thirty six patients with a mean age of 42.3 years were tested at 38.1 months status post cementless humeral resurfacing hemiarthroplasty. All patients followed the rehabilitation protocol contained in this chapter. Significant improvements in single assessment numeric evaluation (SANE) scores, and ASES rating scales were reported just over 3 years postop. Visual pain rating scales changed from mean values of 7.5 preop to 1.3 at 2 years follow-up, ASES from 29.8 preoperative to 90.4 at 2 years follow-up. No signs of radiographic loosening were witnessed, and there was one complication of a subscapularis rupture form a traumatic incident and three cases of arthrofibrosis. These young, active patients reported high levels of satisfaction with their surgical outcome and returned to many forms of recreational and functional activities. (Level IV evidence)

Bartelt R, Sperling JW, Schleck CD, et al: Shoulder arthroplasty in patients aged fifty-five years or younger with osteoarthritis. *J Shoulder Elbow Surg* 20:123–130, 2011.

This study profiled 46 total shoulder arthroplasties and 20 hemiarthroplasties performed in 63 patients age 55 or younger. A minimum 2-year follow-up was used, and patients on average were followed up 7 years postop. The implant survival rate was 92% at 10 years for total shoulder arthroplasty in this young, active population and 72% for hemiarthroplasty. Patient satisfaction and feeling that they were better than before the operation was 87% for TSA and 65% for hemiarthroplasty. Patients receiving TSA had a 46° improvement in forward elevation from 105° preop to 151° at latest follow-up and 24° improvement in external rotation from 23° to 48°. This study also demonstrates significant range of motion and functional improvements in young active patients receiving either total or hemiarthroplasty. (Level IV evidence)

McCarty EC, Marx RG, Maerz D, et al: Sport participation after shoulder replacement surgery. *Am J Sports Med* 36:1577–1581, 2008.

This retrospective study described the return to sport outcomes of patients following shoulder arthroplasty. The frequency of returning to sports such as golf, tennis, fishing, and even kayaking shows the present ability of many patients to return to upper extremity sport activities following shoulder arthroplasty. (Level IV evidence)

Raiss P, Pape G, Becker S, et al: Cementless humeral surface replacement arthroplasty in patients less than 55 years of age. *Orthopade* 39(2):201–208, 2010.

This study followed 23 patients with 26 total implants using a cementless humeral resurfacing implant 1 to 6 years (mean 2.5 years) following surgery. Constant scores improved from a value of 33 to 61 points at last follow-up. Significant improvements were also noted in shoulder flexion, abduction, and external rotation range of motion in addition to the functional rating scale. This study shows excellent outcomes following humeral resurfacing in young active patients. (Level IV evidence)

Saltzman MD, Chamberlain AM, Mercer DM, et al: Shoulder hemiarthroplasty with concentric glenoid reaming in patients 55 years old or less. *J Shoulder Elbow Surgery* 20:609–615, 2011.

This study followed 65 young, active patients who underwent shoulder hemiarthroplasty with concentric glenoid reaming. A 2-year minimum follow-up was used to measure functional outcome and patient satisfaction following the procedure. Simple shoulder tests (SST) improved from 4.1 to 9.5/12 points at an average follow-up of 43 months. At final follow-up all patients with radiographic follow-up (N = 22) had centered humeral heads. Nine of the 65 patients did require revision surgery. Ninety-four percent of the patients felt their shoulder was functioning better following surgery. This study again shows the results of shoulder hemiarthroplasty in a younger patient base and its immediate outcomes following surgery at initial follow-up. (Level IV evidence)

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Multiple-Choice Questions

QUESTION 1. The rehabilitation limitations commonly termed "subscapularis precautions" consist of which of the following restrictions?

A. No external rotation ROM and no internal rotation resistance application
B. No internal rotation ROM and no external rotation resistance application
C. No abduction and internal rotation ROM
D. No flexion and external rotation ROM

QUESTION 2. Which of the following structures is most affected during the deltopectoral surgical approach used during arthroplasty?

A. Triceps
B. Infraspinatus
C. Subscapularis
D. Deltoid

QUESTION 3. What characteristic compensation strategy is employed by patients with inadequate rotator cuff strength during humeral elevation?

A. Posterior subluxation of the humeral head
B. Superior scapular elevation or shrug sign
C. Elbow extension jutting
D. Ipsilateral cervical spine lateral flexion

Answer Key

QUESTION 1. Correct answer: **A** (see Phase I)

QUESTION 2. Correct answer: **C** (see Brief Summary of Surgical Technique)

QUESTION 3. Correct answer: **B** (see Phase II)

BEYOND BASIC REHABILITATION: RETURN TO GOLF, SWIMMING, AND TENNIS AFTER SHOULDER ARTHROPLASTY

Todd S. Ellenbecker, DPT, MS, SCS, OCS, CSCS, and David S. Bailie, MD

Introduction

ASPECTS OF GOLF, SWIMMING, AND TENNIS THAT REQUIRE SPECIAL ATTENTION IN REHABILITATION

- Swimming, golf, and tennis all require extensive ranges of motion as well as high levels of muscular stabilization in the rotator cuff and scapular musculature.
- Additionally, all three sports are very repetitive in nature and involve repeated muscular activations to train and perform, requiring high levels of muscular endurance.
- In golf, the movement of cross-arm adduction is required for the take-back portion of the golf swing and also on the contralateral extremity during the follow-through. This requires an acceptable range of pain-free motion for successful performance and return to sport.
- Likewise, in tennis and swimming, large arcs of rotational motion are needed to properly perform the biomechanical patterns of the serve and other strokes. This requires full rehabilitation following a progressive rehabilitation program to ensure optimal range of motion return as well as high levels of both muscular stabilization and endurance are in place before starting an interval program.

The athletic shoulder with glenohumeral arthritis is very common especially in patients following stabilization procedures. This has led to the terms *dislocation arthropathy* or *capsulorraphy arthropathy*. Athletic individuals requiring shoulder arthroplasty are becoming very popular patients in orthopaedic and sports medicine

clinics and require progressive rehabiltation protocols for their management in addition to a return to activity of return to sport program when applicable.

Literature Review

- Healy et al.[1] published a list of recommendations from the American Shoulder and Elbow Surgeons on recreational and sport activities to return to after shoulder arthroplasty. In their guidelines, they include upper extremity sports like golf and doubles tennis as well as swimming, bowling, canoeing, and shooting.
- General sports, like running, cross country skiing, and aerobics, were also included among the recommended activities following shoulder arthroplasty.
- McCarty et al.[2] performed a postsurgical survey of sport activities patients were successfully able to return to following shoulder arthroplasty. Their study found that the return rates for fishing (92%), swimming (86%), downhill skiing (81%), golf (76%), and tennis and squash/racquetball (75%) indicate a large majority of patients return to preoperative sport activity levels following shoulder arthroplasty.
- These studies provide evidence and guidance for the functional return programs that are incorporated into rehabilitation following shoulder arthroplasty.

Advanced Rehabilitation Program

- The advanced rehabilitation activities do vary based on the sport activity patients are involved in but do have certain commonalities beyond the interval sport return programs utilized following successful rehabilitation.[3]
- Several key components of the advanced rehabilitation progression for return to sport include exercises performed with 90° of elevation. Figure 8-22 shows the use of oscillation in 90° in the scapular plane, with Figure 8-23 depicting rhythmic stabilization performed by the therapist in 90° of elevation in the scapular plane with 70° of external rotation.
- In many patients following arthroplasty, external rotation range of motion may be limited to approximately 70° to 80° owing to the anterior approach, subscapularis repair, and chronic capsular changes occurring over years of osteoarthritis in the involved shoulder.[4]
- Therefore patients are progressed in this exercise with increasing amounts of external rotation in the abducted shoulder to utilize the newfound external rotation range of motion to prepare them for swimming and other overhead activities that require an abducted, externally rotated position.
- Closed chain exercises are not typically preferred because of the compressive forces incurred with this classification of exercise.
- Open chain exercises with increasing amounts of abduction/elevation are utilized to enable patients to transition to higher levels of function and their interval sport return program.[4]
- Plyometric exercises are recommended in the advanced stages following arthroplasty with the general progression from two-hand plyometric exercise drills such as the tennis groundstroke (Figure 8-24) or golf plyometric (Figure 8-25) with eventual progression to side-lying ball drops which elicit high levels of fatigue due their endurance format of multiple sets of 20 to 30 seconds of rapid repetitions of briefly letting go of the ball and then quickly regrabbing the ball (Figure 8-26).
- These exercise progressions along with continued rotator cuff and scapular isotonic exercises form the basis for many of the higher level rehabilitation activities during the end stages of rehabilitation following arthroplasty in the active patient.
- Continued focus on mobilization and passive stretching to improve and optimize glenohumeral joint range of motion are of critical importance throughout the rehabilitation process and continue to be indicated in this final phase of rehabilitation as well.[5]



FIGURE 8-22. External rotation oscillation exercise to improve endurance with the shoulder placed in the 90° abducted position in the scapular plane.

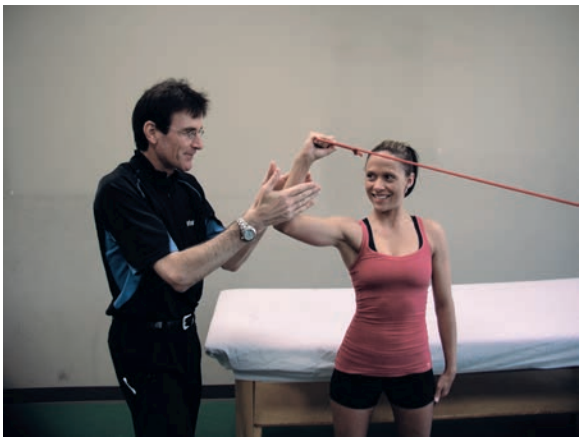

FIGURE 8-23. External rotation position with approximately 70° ER in 90° of abduction in the scapular plane. Therapist provides rhythmic stabilization in this position.



FIGURE 8-24. Plyometric exercise position simulating forehand and backhand ground strokes to provide a progression for a return to tennis.

Phase I: Advanced Strength and Conditioning Programs[3]

Periodization

- Undulating

Program Design/Performance Training Program

- Flexibility/joint mobility for joint stability
- Training with optimum posture
- Multi-planar training activities
- Training for optimum muscle balance
- Plyometric training
- Sport-specific training
- Training for optimum muscle functional strength

Training Principles Used in the Design of the Program

- Principle of progression
- Principle of overload
- Principle of variation
- Principle of individualization
- Principles of specificity—specific adaptation to imposed demands (SAID)

Application of Acute Training Variables

- For most of the exercises listed in the rehabilitation program following shoulder arthroplasty (see previous section of this chapter) with specific application for return to sport, two to three sets of 15 repetitions are followed to not only encourage the development of local muscular endurance but also to promote muscular fatigue with the use of lighter loads minimizing joint loading and stress to the tendinous repair to the subscapularis and bicep tenodesis.
- Rest intervals of 20 to 30 seconds are used again to promote muscular endurance, and are sport specific, for example in tennis wherein rest periods of 20 seconds are allowed between points.
- Rather than use what has traditionally been applied as repetition maximum loading schemes, these authors use clinical observation of loading (i.e., patient's ability to perform up to 15 repetitions per set without compensation), patient feedback (absence of joint or tendinous insertional pain) as well as ratings of perceived exertion such as the OMNI scale between 4 and 6 (0 being very easy resistance and 10 being very hard).[6]
- Training frequency consists of 3 training days per week with recovery days between.
- Duration of training consists of rehabilitation sessions lasting approximately 90 minutes in length over a 3- to

[3]See Postoperative Rehabilitation After Arthroplasty (Replacement), Hemiarthroplasty, and Total Shoulder or Joint Reconstruction for the rehabilitation timeline.

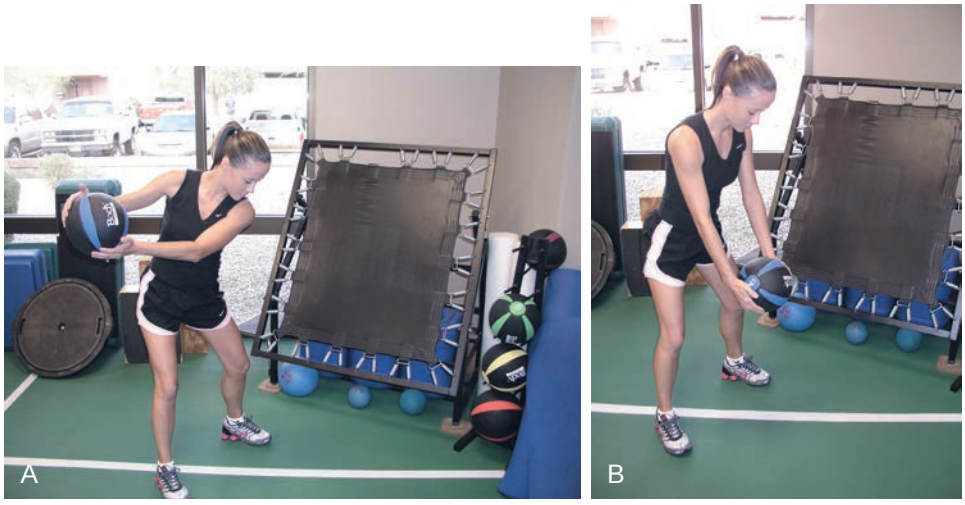

FIGURE 8-25. A,B, Plyometric exercise position simulating the golf swing to provide a progression for a return to golf.



FIGURE 8-26. Side-lying plyometric exercise to provide advanced rotator cuff strengthening following shoulder arthroplasty.

4-month period with 4 to 6 weeks dedicated to the return to activity programming and phase discussed in this chapter.

Application of Chronic Training Variables

- In addition to the exercises discussed earlier in this chapter, specific advanced training exercises are applied in this phase of training to improve rotator cuff strength and endurance and scapular stabilization.
- These include Jobe rotator cuff exercises such as side-lying external rotation, 90° abducted external rotation in the prone position, and prone extension and prone horizontal abduction exercise.
- These exercises are used to provide base rotator cuff and scapular muscle activation and are coupled with external rotation oscillation and "statue of liberty" exercises with elastic resistance (Figures 8-22 and 8-27).
- Isokinetic training for internal and external rotation (Figure 8-28) are also used to provide accommodative resistance in the modified base or "Davies" position. This position is also used for testing to compare bilateral strength variables of torque, work, and external/internal rotation unilateral strength ratios. Ratios ranging between 66% and 75% are desired to provide substantial posterior rotator cuff strength and stabilization.[7]
- Plyometric exercises described earlier in this chapter provide the sport-specific transitional exercise to simulate upper extremity and trunk segmental rotational movement patterns that are essentially precursors for patient initiation in a sport-specific interval return program.

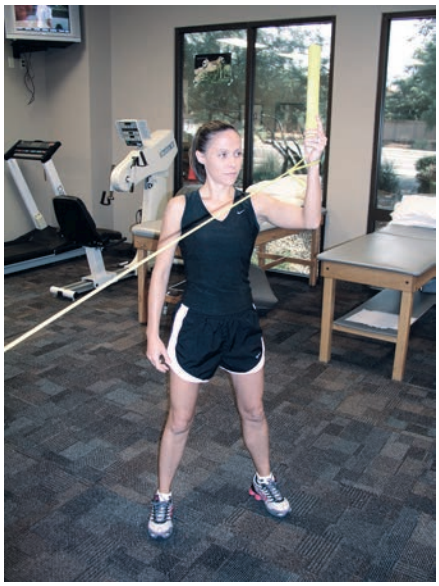

FIGURE 8-27. External rotation oscillation with arm in greater amounts of abduction to improve strength and endurance of the posterior rotator cuff and prepare the patient for a return to functional activity in this position.



FIGURE 8-28. Isokinetic internal and external rotation modified base (Davies Position) used for training and testing rotator cuff strength following shoulder arthroplasty on the Biodex Isokinetic Dynamometer.

Phase II: Sport-Specific Training (Interval Functional Return Programs)

Periodization

- Undulating

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- Flexibility/joint mobility for joint stability
- Core training
- Multi-planar training activities

- Training for optimum muscle balance
- Training for optimum muscle functional strength
- Training for optimum muscle functional power
- Neuromuscular dynamic stability exercises
- Sport-specific training

Training Principles Used in the Design of the Program

- Principle of progression
- Principle of overload
- Principle of variation
- Principle of individualization
- Principles of specificity—specific adaptation to imposed demands (SAID)

Application of Acute Training Variables

- For the programs listed below, progression of the patient via each of the stages of increased functional overload is followed with alternate days of performance of the exercise to allow for rest and recovery of the upper extremity between sessions.
- The interval program (Box 8-1) is most often built into the rehabilitation session (tennis and throwing) as the patient undergoes a warmup on an upper body ergometer, and receives stretching and mobilization of the joint before performance of the interval program.
- Before performing significant amounts of resistive exercise for the rotator cuff and scapular musculature, the patient performs the interval tennis program or throwing program completing their exercises in the clinic after the interval sport program.
- Golf and swimming interval sport programs often cannot be performed in the clinic because of size and space limitations (lack of a pool in many clinics) and therefore must be guided by the therapist but cannot always occur under direct supervision of the therapist.
- Some golf related activity can be performed in the clinic with the use of netting, and/or wiffle balls.
- Tennis-related initial activity can be performed with the use of low compression tennis balls (e.g., Star ball, Penn Racquet Sports) or foam balls and tennis balls used during tennis instruction and development for children termed *red balls*, *orange balls*, and *green balls* that have remarkable characteristics for ball bounce without the heavier feel of a standard tennis ball impact, and also are easier to utilize inside clinic spaces for safety concerns.[8]
- For a detailed discussion of interval sport return programs, the reader is referred to Ellenbecker et al.[3,8]

Sports Performance Testing

General Information

- General history
- Subjective questionnaires
- Medical history
- Sports injury history
- Surgical history
- Chronic conditions/medication

Specific Tests

- Static and dynamic posture and scapular assessments begin very early in the rehabilitation program and continue throughout rehabilitation.
- Assessments and measurement of glenohumeral joint range of motion also begins on the first postoperative visit and is closely monitored throughout the rehab process.
- Isometric and isokinetic internal and external rotation testing is performed starting at approximately 12 weeks

BOX 8-1 Interval Tennis Program Guidelines

- Begin at a stage indicated by your physical therapist or physician.
- Do not progress or continue the program if joint pain is present.
- Always stretch your shoulder, elbow, and wrist before and after the interval program, and perform a whole-body dynamic warmup before performing the interval tennis program.
- Play on alternate days, giving your body a recovery day between sessions.
- Do not use a wall board or back board because it leads to exaggerated muscle contraction without rest between strokes. Ball feeds or a ball machine are preferred.
- Ice your injured arm after each session of the interval tennis program.
- It is highly recommended to have your stroke mechanics formally evaluated by a USPTA tennis teaching professional.
- Do not attempt to impart heavy topspin or underspin to your ground strokes until later stages in the interval program.
- Contact your therapist or doctor if you have questions or problems with the interval program.
- Do not continue to play if you encounter localized joint pain.

Interval Tennis Program

Perform each stage _____ times before progressing to the next stage. Do not progress to the next stage if you have pain or excessive fatigue on your previous outing—remain at the previous stage until you can perform that part of the program without fatigue or pain.

STAGE 1

a. Have a partner feed 20 forehand groundstrokes to you from the net using a foam ball. (Partner must use a slow, looping feed that results in a waist-high ball bounce for player contact.)

Continued on following page

BOX 8-1 Interval Tennis Program Guidelines *(Continued)*

b. Have a partner feed 20 backhand groundstrokes as in 1a above with a foam ball.
c. Rest 5 minutes.
d. Repeat 20 forehand and backhand feeds as above.

STAGE 2

Repeat Stage 1 with a low compression ball (e.g., Pro-Penn Star Ball, Penn Racquet Sports, Phoenix, AZ).

STAGE 3

Repeat Stage 1 with a real (regulation) tennis ball.

STAGE 4

a. Begin as in Stage 3 above, with a partner feeding 10 forehands and 10 backhands from the net as a warmup.
b. Rally with a partner from baseline, hitting controlled groundstrokes until you have hit 50 to 60 strokes. (Alternate between forehands and backhands and allow 20 to 30 seconds rest after every two or three rallies.)
c. Rest 5 minutes.
d. Repeat the rally instructions in 4b above.

STAGE 5

a. Rally groundstrokes (forehands and backhands) from the baseline for 15 minutes.
b. Rest 5 minutes.
c. Hit 10 to 15 forehand and 10 to 15 backhand volleys, emphasizing a contact point in front of your body.
d. Rally groundstrokes for 15 additional minutes from the baseline.
e. Hit 10 to 15 forehand and backhand volleys as listed above.

PRE-SERVE INTERVAL: (PERFORM BEFORE STAGE 6)

(Note: This can be performed off court and is meant solely to determine readiness for progression into stage 6 of the interval tennis program.)
a. After stretching, with racquet in hand, perform serving motion for 10 to 15 repetitions without a ball or any ball contact.
b. Using a foam ball, hit 10 to 15 serves without concern for performance result (only focusing on form, contact point, and the presence or absence of symptoms).
c. If successful and pain-free, progress to stage 6.

STAGE 6

a. Hit 20 to 30 minutes of groundstrokes, mixing in volleys using an 80% groundstroke/20% volley format.
b. Perform 5 to 10 simulated serves without a ball.
c. Perform 5 to 10 serves using a foam ball.
d. Perform 10 to 15 serves using a standard tennis ball at approximately 75% effort. (Note: It is important to hit flat or slice serves, not kick serves, in the initial phase of the interval tennis program)
e. Finish with 10 to 15 minutes of groundstrokes.

STAGE 7

a. Hit 30 minutes of groundstrokes, mixing in volleys using an 80% groundstroke/20% volley format.
b. Perform 5 to 10 serves using a foam ball.
c. Perform 10 to 15 serves using a standard tennis ball at approximately 75% effort.
d. Rest 5 minutes.
e. Perform 10 to 15 additional serves as in 7c above.
f. Finish with 15 to 20 minutes of groundstrokes.

STAGE 8

a. Repeat Stage 7 listed above, increasing the number of serves to 20 to 25 instead of 10 to 15.
b. Before resting between serving sessions, have a partner feed easy short lobs to attempt 4 to 5 controlled overheads.

STAGE 9

Before attempting match play, complete steps 1 to 8 without pain or excess fatigue in the upper extremity. Continue to progress the amount of time rallying with groundstrokes and volleys in addition to increasing the number of serves per workout until 60 to 80 overall serves can be performed interspersed throughout a workout. Initiate kick serves once the initial stages of the program have been completed. Remember that an average of up to 120 serves can be performed in a singles tennis match, therefore be prepared to gradually increase the number of serves in the interval program before full competitive play is engaged.

postop to determine IR and ER strength as well as muscular balance.
- Tolerance of the 90° abducted position during functional plyometric and elastic resistance exercises is also used as a precursor to beginning any functional activity interval sport return program (i.e., golf, tennis, swimming, throwing).

Objective Tests

- Static/dynamic postural assessments
- Dynamic muscle performance testing
- Movement performance testing
- Sport-specific testing

Specific Criteria for Progression to the Next Stage to Determine Readiness for Swimming, Golf and Tennis

- Unique challenges exist during the rehabilitation of the patient following shoulder arthroplasty. It is often not possible to achieve full, desired range of motion of the joint because of the chronic capsular changes and alterations of range of motion that existed preoperatively; however, the use of an aggressive program of rehabilitation following surgery does strive to achieve a minimum of 70° of external rotation in the 90° abducted position.
- Active flexion and abduction (elevation) typically exceed 145° in these patients and are acceptable for the sports being discussed in this chapter.
- One additional consideration for the sport of golf is the achievement of optimal amounts of cross-arm adduction to allow for either proper take back (e.g., left shoulder arthroplasty in a right handed golfer) or during following through (e.g., right shoulder arthroplasty in a right handed golfer).
- Careful monitoring of sport-specific movement patterns is needed by the physical therapist and physician during this phase of the rehabilitation because often some modifications (often shortening) of the stroke pattern are needed to facilitate the return to that sport.
- Although not always optimal from a performance enhancement standpoint, careful monitoring and use of video feedback to obtain the most efficacious movement pattern allowed by that patient's range of motion and strength levels are indicated.
- The use of computer programs such as Dartfish are indicated and used by these authors to monitor movement strategies and provide meaningful feedback to the patient during this critically important phase of the rehabilitation process.
- Objective criteria such as minimal pain-free range of motion characteristics, negative instability and impingement clinical tests, strength test within 15% to 20% of the contralateral limb in addition to acceptable unilateral strength ratios (optimal 66% to 75% ER/IR ratios, accepted minimal standards 55% to 65%) are used to guide the process objectively from a clinical standpoint.

Specific Criteria for Release to Unsupervised Complete Participation in Swimming, Golf, and Tennis

- Successful completion of a supervised rehabilitation program
- Isokinetically documented strength within 10 % of the contralateral side with acceptable (66–75%) ER/IR unilateral strength ratios
- Pain-free range of motion required for sport activity (i.e., negative cross-arm adduction range of motion for a golfer, etc.)
- Successful completion of a supervised interval sport return program

Recommended Ongoing Exercises

- Maintenance programs given to the patients upon completion of their supervised rehabilitation include rotator cuff and scapular exercises to be performed using a low-resistance high repletion format (multiple set training).
- These include exercise with elastic resistance for external and internal rotation both at the 30/30/30 position at the side and with 90° of elevation.
- Additionally, scapular stabilization exercises for the serratus anterior and lower trapezius are recommended.
- It is also recommended that range of motion exercises be continued to prevent range of motion loss including the cross-arm and sleeper stretches for internal rotation as well as external rotation with a stick or implement and use of a pulley or external device such as a stick or cane for forward flexion.

Evidence

Bailie DS, Llinas PJ, Ellenbecker TS: Cementless humeral resurfacing arthroplasty in active patients less than fifty-five years of age. *J Bone Joint Surg Am* 90:110–117, 2008. doi: 10.2106/JBJS.F.01552.

This retrospective study presented the outcome of shoulder arthroplasty in patients 55 years of age or less. Improvements in range of motion and functional outcomes were documented in this study with humeral resurfacing using the Biomet Copeland Humeral Resurfacing Prosthesis. (Level IV evidence)

Healy WL, Iorio R, Lemos MJ: Athletic activity after joint replacement. *Am J Sports Med* 29(3):377–388, 2001.

This publication involved interviewing 35 members of the American Shoulder and Elbow Surgeons Society regarding their recommendations for returning to sport after shoulder arthroplasty. The responses were analyzed statistically to determine a consensus recommendation. Recommended activities such as swimming, doubles tennis, bowling, low-impact aerobics, and bicycling were all recommended activities among the panel with golf, shooting, ice skating, and downhill skiing recommended if patients were experienced in that sport participation. Contact sports such as football and hockey were not recommended. (Level V evidence)

Jensen KL, Rockwood CA: Shoulder arthroplasty in recreational golfers. *J Shoulder Elbow Surg* 7:362–367, 1998.

This study consisted of a retrospective review of 24 patients who were recreational golfers who underwent shoulder arthroplasty. Three patients in this group had bilateral arthroplasty. The findings of this retrospective review were that 96% of the patients were able to return to playing golf after surgery. Six in this group of patients were hemiarthroplasties and 20 were total shoulder arthroplasties. The authors found that the average time to return to golf from time of surgery was 4.5 months, and of 18 patients who reported a preoperative handicap golf rating, an improvement of five shots postoperatively was noted. (Level IV evidence)

McCarty EC, Marx RG, Maerz D, et al: Sport participation after shoulder replacement surgery. *Am J Sports Med* 36:1577–1581, 2008.

This retrospective study described the return to sport outcomes of patients following shoulder arthroplasty. The frequency of returning to sports such as golf, tennis, fishing, and even kayaking and fishing shows the present ability of many patients to return to upper extremity sport activities following shoulder arthroplasty. (Level IV evidence)

Saltzman MD, Chamberlain AM, Mercer DM, et al: Shoulder hemiarthroplasty with concentric glenoid reaming in patients 55 years old or less. *J Shoulder Elbow Surgery* 20:609–615, 2011.

This article does not specifically review return to sport but does profile improvements in shoulder function in young active individuals who had shoulder arthroplasty and are less than 55 years of age. Improved functional outcomes scores are reported in this study, with a 44 month follow-up after surgery. (Level IV evidence)

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8. Ellenbecker TS, Reinold MM, Nelson CO: Clinical concepts for treatment of the elbow in the adolescent overhead athlete. *Clin Sports Med* 29(4):705–724, 2010.

Multiple-Choice Questions

QUESTION 1. According to research by McCarty et al., what percentage of patients following shoulder arthroplasty return to sports like golf, fishing, swimming, and softball?

A. Less than 20%
B. Approximately 50%
C. 75 to 90%
D. 100% return to these sports

QUESTION 2. Which of the following are objective criteria that can be used to determine whether a patient is ready to return to sport following arthroplasty?

A. Pain-free range of motion
B. Negative instability and impingement tests
C. Strength to within 15% to 20% of the contralateral limb with objective strength testing
D. All of the above would be indicators.

QUESTION 3. What characteristic would NOT be considered important for patients following shoulder arthroplasty?

A. Low load, high repetition training formats
B. Closed kinetic chain exercises
C. Rest periods of approximately 30 seconds between sets
D. Alternate day training (day of recovery between training sessions)

QUESTION 4. Regarding an interval tennis program, which statement does not accurately characterize the recommendations for successful return to sport?

A. Begin with forehand and backhand groundstrokes before serving.
B. Hit on alternate days to allow recovery between training sessions.
C. Use video and other feedback to ensure proper mechanics are used.
D. Begin with overhead serving before any other types of tennis activity.

QUESTION 5. Which of the following tests are important when evaluating a patient before returning to an interval sport program?

A. Static and dynamic posture with specific emphasis on scapular position
B. Glenohumeral joint active and passive range of motion
C. Repetition maximum testing for shoulder flexion in overhead position
D. A and B are correct

Answer Key

QUESTION 1. Correct answer: **C** (see Literature)

QUESTION 2. Correct answer: **D** (see Specific Criteria for Progression to the Next Stage to Determine Readiness for Swimming, Golf, and Tennis)

QUESTION 3. Correct answer: **B** (see Application of Chronic Training Variables)

QUESTION 4. Correct answrr: **D** (see Application of Acute Training Variables)

QUESTION 5. Correct answer: **D** (see Application of Acute Training Variables)

Chapter 9



Epicondylitis

INTRODUCTION

Michael Levinson, PT, CSCS, and David Altchek, MD

Epidemiology

Age/Sex

- Age: Those 35 to 50 years of age are at the highest risk
- Females and males

Sport

- Tennis
- Golf
- Occupations or hobbies with repetitive activities
- 1% to 3% of the general population affected
  - Adult players: 35% to 50%
  - Elite players: 11% to 12%

Pathophysiology

Intrinsic Factors

- Proximal strength deficits at the scapula and glenohumeral joint
- Glenohumeral flexibility deficits such as loss of posterior shoulder flexibility
- Poor weightshifting during backhand, late backswing, and hitting with the front shoulder up
- Increased wrist extension at ball impact
- Poor general condition
- Poor upper-limb posture
- Inadequate rest and recovery
- Inadequate warmup

Extrinsic Factors

- Improper racquet grip size
- Racquet string tension too high
- Strings not resilient or soft enough
- Improper handle size of racquet or other sporting equipment that requires grip

Traumatic Factors

- Gradual increased load-related pain with increased activity
- Repetitive microtrauma
- Vascular compromise
- High eccentric and concentric stresses on the common extensor tendon (especially during the tennis backhand)

Classic Pathological Findings

- Angiofibroblastic hyperplasia, tendinosis
- Excessive vascular granulation
- Disorganized or degenerative collagen
- Degeneration, tendonopathy, tendinosis, and microtears of the extensor carpi radialis brevis (ECRB) and EDU tendon

Clinical Presentation

History

- Gradual onset of pain at the origin of the common extensor tendon (Figure 9-1)

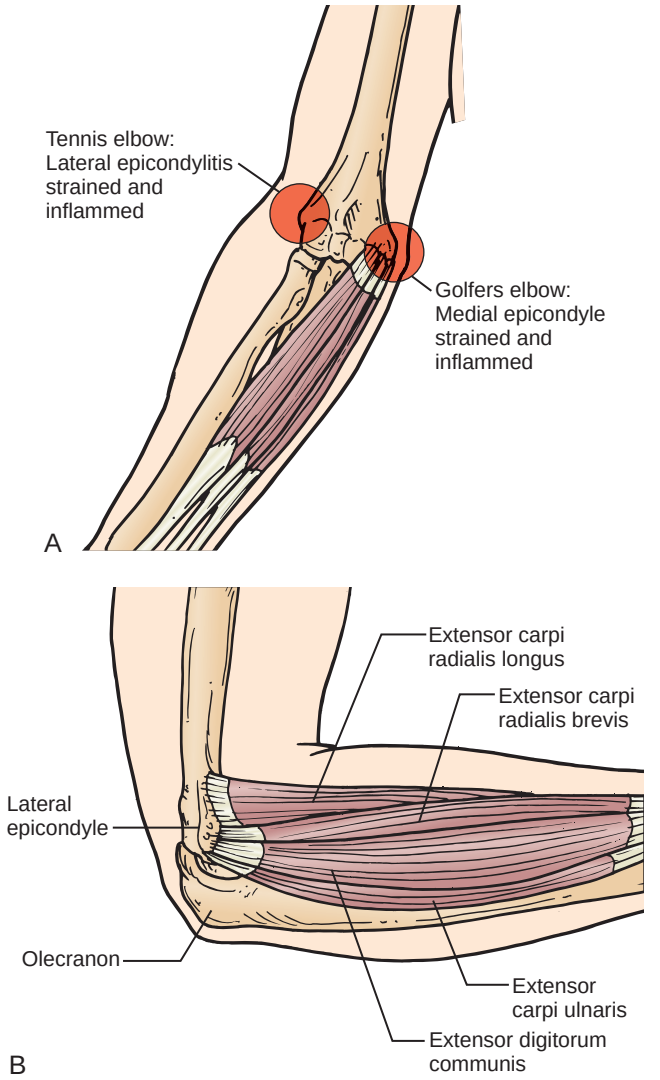

FIGURE 9-1. Lateral and medial epicondylitis. **A**, In lateral epicondylitis, or "tennis elbow," inflammation and pain occur in the outer side of the elbow, where muscles and tendons attach to the bone. The structures involved are the muscles or tendons of the forearm that bring the wrist back or extend the wrist, which is why this condition occurs not only in tennis players but also in anyone who performs repeated resisted motions of the wrist. In medial epicondylitis, or "golfer's elbow," inflammation and pain occur in the inner side of the elbow, where muscles and tendons attach to the bone. The structures involved are the muscles and tendons of the forearm that bring the wrist down and flex the wrist. This occurs not only in golfers but in anyone who performs repeated resisted motions of the wrist. **B,** Origin of the common extensor tendon.

- Often related to the backhand, especially in the novice and the recreational tennis player
- Other complaints may be related to repetitive labor activities, excessive computer work, or carrying bags with the elbow in extension.
- Symptoms often progress from pain after athletic or work-related activities to simple activities of daily living, such as shaking hands or holding an object with the elbow in extension.
- The elbow becomes painful at rest and disturbs sleep.

Physical Examination

Abnormal Findings

- Loss of wrist flexion range of motion
- Tenderness to palpation of the extensor origin at the lateral epicondyle (see Figure 9-1*B*)
- Localized edema, erythema
- Grip weakness
- Pain with passive wrist flexion
- Pain with resistive wrist and third-finger extension

Imaging

- Radiographs: tendinous calcific changes
- Magnetic resonance imaging (MRI): tears of the extensor tendon, abnormal tendinous tissue

Differential Diagnosis

- C6 to C7 nerve root compression: symptoms more radicular in nature
- Posterior interosseous nerve syndrome: may be differentiated by pain with wrist extension and radial deviation, weakness of finger extensors, and pain with thumb extension at the lateral epicondyle
- Lateral antebrachial cutaneous nerve irritation (the terminal sensory branch of the musculocutaneous nerve)

Treatment

Nonoperative Management

- Activity modification to avoid the aggravating behaviors
- Corticosteroid injections
- Nonsteroidal antiinflammatory drugs
- Counterforce bracing, wrist cockup splint
- Shock-wave therapy
- Physical therapy: strength, flexibility, conditioning, manipulation, and mobilization
  - Physical therapy modalities: cryotherapy, transcutaneous electrical nerve stimulation, iontophoresis, ultrasound, and low-level laser
- Improvement of sport mechanics
- Plasma-rich platelet injections

Guidelines for Choosing Nonoperative Treatments

- Diagnosis of tendinitis versus tendonopathy
- Severity and history of symptoms
- Clinical findings, such as strength, flexibility, postural, and conditioning deficits

Surgical Indications

- Failure of injections
- Associated intraarticular pathology
- Failure of conservative treatment for a minimum of 6 months

Aspects of History, Demographics, or Examination Findings that Affect Choice of Treatment

- Persistent pain that interferes with activities of daily living and disturbs sleep
- Pain that prevents return to sport such as tennis
- Persistent pain localized to the origins of the ECRB and extensor digitorum communis (EDC)
- Tear of the extensor demonstrated on MRI evaluation

Aspects of Clinical Decision-Making When Surgery Is Indicated

- Surgeon's experience and the efficiency of the procedure
- Other intraarticular pathology may dictate an arthroscopic procedure.
- Lateral epicondyle drilling can increase pain and potentially damage the EDC.
- Release techniques have potential for complications, such as damage to the lateral ligament complex, instability, and loss of grip strength.

Evidence

Barr S, Cerisola FL, Blanchard V: Effectiveness of corticosteroid injections compared with physiotherapeutic interventions for lateral epicondylitis: a systematic review. *Physiotherapy* 95:251–265, 2009.

This systematic review of randomized control trials compares corticosteroid injections with physiotherapeutic interventions. The authors indicate that injections are effective at short-term follow-up examinations and physiotherapeutic interventions are effective at intermediate and long-term follow-up examinations. (Level IIIA evidence).

Garg R, Adamson GJ, Dawson PA, et al: A prospective randomized study comparing a forearm strap brace versus a wrist splint for the treatment of lateral epicondylitis. *J Shoulder Elbow Surg* 19:508–512, 2010.

In this prospective, randomized study, 42 patients with lateral epicondylitis were given either a counterforce forearm strap or a wrist extension splint. Utilizing the Mayo Elbow Performance and ASES Assessment form, the researchers found that the wrist extension splint led to a greater degree of pain relief. (Level II evidence).

Nirschl RP, Rodin DM, Ochiai DH, et al: Iontophoretic administration of dexamethasone sodium phosphate for acute epicondylitis. *Am J Sports Med* 31:189–195, 2003.

In this randomized, double-blind, placebo-controlled trial, 199 patients with epicondylitis either were treated with iontophoresis with dexamethasone or received placebo treatment. More patients treated with dexamethasone scored moderate or better on the investigators' global improvement scale at 2 days, but the difference was not significant at 1 month. (Level IV evidence).

Oken O, Kahraman Y, Ayhan F, et al: The short-term efficacy of laser, brace and ultrasound treatment in lateral epicondylitis: a prospective, randomized, controlled trial. *J Hand Surg* 21:63–68, 2008.

In this prospective, randomized, controlled trial, three groups of patients with lateral epicondylitis were treated with braces and exercise, ultrasound and exercise, or low-level laser and exercise. Laser therapy was more effective than ultrasound or bracing in restoring grip strength. (Level IIIb evidence).

Peerbooms JC, Sluimer J, Bruijn DJ, et al: Positive effect of an autologous platelet concentrate in lateral epicondylitis in a double-blind randomized controlled trial: platelet-rich plasma versus corticosteroid injection with a 1-year follow-up. *Am J Sports Med* 38:255–262, 2010.

In this double-blind, randomized control trial, the researchers compared treatment of 100 patients with lateral epicondylitis, 51 treated with platelet-rich plasma (PRP), and 49 with corticosteroid injection. The results, based on the score on the visual analogue scale Disabilities of the Arm, Shoulder, and Hand Module, demonstrated that PRP reduces pain and increases function, exceeding the results of corticosteroid injection. (Level I evidence).

Multiple-Choice Questions

QUESTION 1. Which of the following is not an intrinsic factor that may predispose the patient to lateral epicondylitis while playing tennis?

A. Proximal strength or flexibility deficits
B. Increased wrist extension at ball impact
C. Increased wrist flexion at ball impact
D. Inadequate rest and recovery

QUESTION 2. Which of the following is not an extrinsic factor that contributes to lateral epicondylitis?

A. Improper racquet grip size
B. Racquet string tension that is too high
C. Improper footwear
D. Racquet string that is not resilient or soft enough

QUESTION 3. Which of the following conditions can easily be confused with, and needs to be differentiated from, lateral epicondylitis?

A. Posterolateral instability
B. Posterior interosseous nerve syndrome
C. Ulnar collateral ligament tear
D. C4 to C5 radiculopathy

QUESTION 4. Which of the following would not be a finding in a clinical examination for lateral epicondylitis?

A. Decreased grip strength
B. Loss of passive wrist extension
C. Pain with passive wrist and third-finger extension
D. Tenderness to palpation at the lateral epicondyle

QUESTION 5. Which of the following activities of daily living can exacerbate symptoms of lateral epicondylitis?

A. Handshaking
B. Excessive computer use
C. Carrying bags with the elbow in extension
D. All of the above

Answer Key

QUESTION 1. Correct answer: **C** (see Pathophysiology)

QUESTION 2. Correct answer: **C** (see Extrinsic Factors)

QUESTION 3. Correct answer: **B** (see Differential Diagnosis)

QUESTION 4. Correct answer: **D** (see Clinical Examination)

QUESTION 5. Correct answer: **D** (see Clinical Presentation)

NONOPERATIVE REHABILITATION OF LATERAL EPICONDYLITIS (TENNIS ELBOW)

Michael Levinson, PT, CSCS, and David Altchek, MD

GUIDING PRINCIPLES OF NONOPERATIVE REHABILITATION

- Understand the pathology: tendinitis versus tendonopathy
- Reduction of pain and inflammation and promotion of healing are the primary goals
- Control excessive loads to the injured area
- Pathologic tissue needs to be repaired and revitalized
- Reproduce the functional demands throughout the entire kinetic chain
- The patient's general fitness is critical to recovery and avoiding reinjury

Phase I (Guidelines are evaluation-based)

Protection

- Counterforce bracing or a wrist-cockup splint may be used for activities of daily living (Figure 9-2).
- Wrist splints should not be used during sleep, as they may cause shortening of the extensor tendons.
- Activity modification should be a significant factor in the treatment plan. The amount of incidental activities performed at home or at work (e.g., computer work, hand-shaking, carrying bags) should be taken into account.

Management of Pain and Swelling

- Modalities include cryotherapy, iontophoresis, ultrasound, TENS, and low-level laser.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Joint mobilization may be used for pain control or if any capsular restrictions are present. Manipulations (Mill's manipulation) may also be utilized. Mill's manipulation is a small-amplitude, high-velocity thrust performed at the end of elbow extension while the wrist and hand are held flexed.

Soft-Tissue Techniques

- It is the authors' opinion that deep-tissue massage often exacerbates symptoms and has little therapeutic value.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Stretching of the wrist and finger extensors should be initiated in a pain-free range of motion (ROM) (Figure 9-3).

Other Therapeutic Exercises

- Multijoint, upper-extremity exercises should be initiated to restore total arm strength (TAS) and proximal stability. These should include scapula, deltoid, and rotator cuff strengthening.
- Often, the tennis player has a proximal muscle deficit.
- Biceps and triceps strengthening should be initiated in a pain-free ROM, avoiding full elbow extension.



FIGURE 9-2. Counterforce brace.

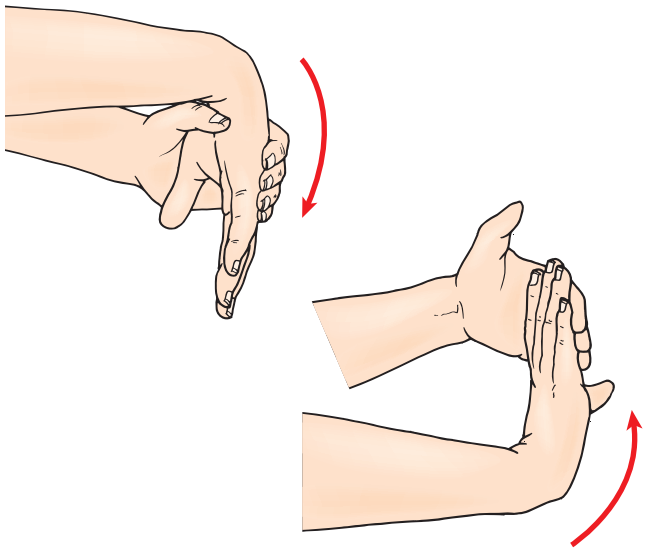

FIGURE 9-3. Stretching of the wrist and finger extensors.

- For the tennis player, core and lower-extremity strengthening may be initiated without holding weights in the hands.
- Upper-extremity posture should be addressed.

Open and Closed Kinetic Chain Exercises

- Closed kinetic chain exercises generally are performed with the wrist in extension and the elbow moving into full extension. This is contraindicated in Phase I.

Milestones for Progression to the Next Phase

- Reduction of symptoms (pain, edema, inflammation)
- Restoration of proximal stability (scapula function, rotator cuff strength)
- Normal wrist flexion ROM

Phase II (Guidelines are evaluation-based)

Protection

- Counterforce bracing or wrist-cockup splint as needed.

Management of Pain and Swelling

- Cryotherapy, iontophoresis, ultrasound, TENS, low-level laser as needed

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Joint mobilization and manipulation if any capsular restrictions are needed

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Continue pain-free stretching of the wrist and finger extensors. Begin to address any shoulder flexibility deficits. For example, many tennis players have a loss of posterior shoulder flexibility.

Other Therapeutic Exercises

- Continue to progress general upper-extremity, multijoint exercises to normalize shoulder and scapula strength. For the tennis player, emphasize the scapula and posterior rotator cuff.
- Continue biceps- and triceps-strengthening to include concentric and eccentric activity.
- Initiate forearm-strengthening to include wrist flexion.
- Core and lower-extremity strengthening may be progressed, but the patient should still avoid holding heavy weights in the hands.

Activation of Primary Muscles Involved

- Initiate wrist extension and forearm pronation and supination. Exercises should be initiated with the elbow supported and in flexion to reduce the amount of bone-to-tendon contact at the origin of the common extensor tendon (Figure 9-4).

Techniques to Increase Muscle Strength, Power, and Endurance

- If proximal strength is adequate, the upper-body ergometer can be used to begin to restore power and endurance.

Neuromuscular Dynamic Stability Exercises

- Rhythmic stabilization should be initiated proximal to the elbow.

Functional Exercises

- Proprioceptive neuromuscular facilitation (PNF) patterns should be initiated.

Milestones for Progression to the Next Phase

- Normal upper-extremity flexibility
- Normal proximal upper-extremity strength
- Minimal pain with wrist extension exercises

Phase III (Guidelines are evaluation-based)

Management of Pain and Swelling

- Continue with prior modalities as needed as forearm-strengthening is progressed, symptoms may increase.



FIGURE 9-4. Forearm pronation (**A**) and supination (**B**) with the elbow in flexion.

Techniques for Progressive Increase in Range of Motion

Stretching and Flexibility Techniques for the Musculotendinous Unit

- A full upper-extremity flexibility program should be continued. Overstretching of the wrist and finger extensors should be avoided.

Other Therapeutic Exercises

- Continue to progress a full upper-extremity strengthening program, including overhead activities.
- Progress core and lower-extremity strengthening and flexibility program.
- Sport-specific general conditioning exercises

Activation of Primary Muscles Involved

- Eccentric wrist extension should be emphasized if tolerated. This should be initiated with the elbow in flexion and progressed to extension (Figure 9-5). All muscle groups of the forearm should be addressed to restore normal functional movement patterns.

Neuromuscular Dynamic Stability Exercises

- Rhythmic stabilization may be progressed to a longer-lever arm (distal to the elbow).



FIGURE 9-5. Resistive eccentric wrist extension.

- Exercises may be progressed to more challenging positions for the shoulder and elbow (Figure 9-6).
- The patient may then progress to the Bodyblade from a neutral position to positions throughout the tennis stroke.

Plyometrics

- A plyometric program should be initiated if the patient is asymptomatic and has a normal strength base and normal upper-extremity flexibility.

TIMELINE 9-1: **Nonoperative Rehabilitation of Lateral Epicondylitis (Tennis Elbow)**

PHASE I	PHASE II
• Physical therapy (PT) modalities • Pain-free wrist extensor stretching • Counterforce bracing/wrist-cockup splint • TBS/TAS/TLS activities as recommended and tolerated • Multijoint shoulder, scapula, and elbow strengthening • Mobilization and manipulation as needed	• PT modalities • Shoulder flexibility exercises • TBS/TAS/TLS activities as recommended and tolerated • Scapular exercises, shoulder exercises, and elbow exercises (including eccentrics) • Wrist flexion–extension, forearm pronation–supination (elbow in flexion) • Core and lower-extremity exercises • Rhythmic stabilization with proximal resistance • PNF patterns • Upper-body ergometer

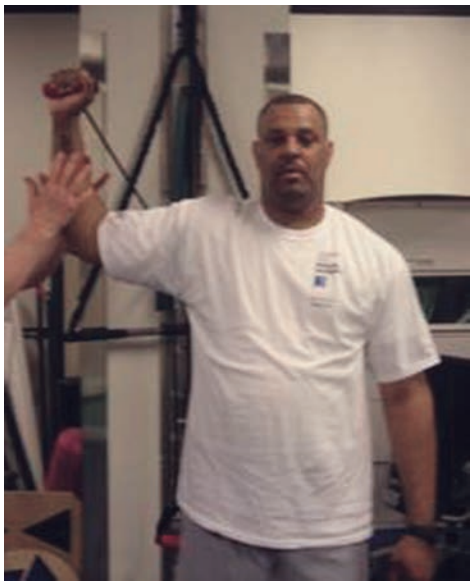

FIGURE 9-6. Rhythmic stabilization in the overhead position with distal resistance.

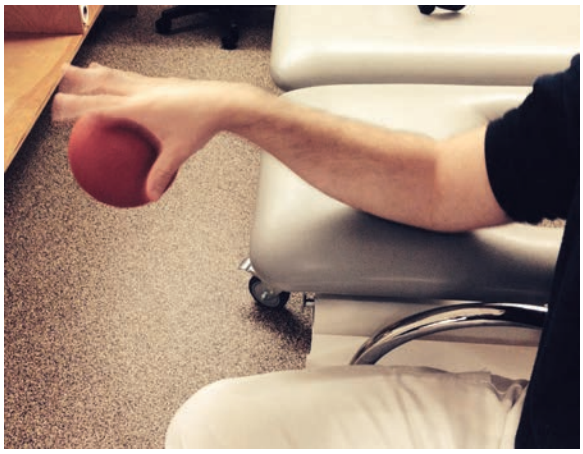

FIGURE 9-7. Wrist flips and snaps.

- A functional progression for a tennis player would follow: two-handed chest pass, side-to-side wood chops, overhead soccer pass, one-handed external rotation, one-handed backhand, one-handed 90° internal and 90° external position.
- Deceleration exercises by catching the plyo ball and slowing it down should be included.
- Wrist flexion flips and wrist flexion snaps may be incorporated (Figure 9-7).

Sport-Specific Exercises

- Resistive forehand and backhand exercises using elastic resistance or a cable system should be initiated.

Milestones for Progression to Advanced Sport-Specific Training and Conditioning

- Completion of a plyometric program without symptoms
- Full forearm strengthening without residual symptoms
- Upper-extremity strength and endurance that is equal or greater than the contralateral side

Phase IV (Guidelines are evaluation-based)

Management of Pain and Swelling

- Cryotherapy should be utilized throughout the return.

Techniques for Progressive Increase in Range of Motion

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Continue full upper-extremity flexibility program.
- Avoid overstretching the extensor tendons.
- Stretching should always be pain-free.

Other Therapeutic Exercises

- Continue a full upper-extremity strengthening program to include the scapula, shoulder, elbow, forearm, and wrist.

TIMELINE 9-1: **Nonoperative Rehabilitation of Lateral Epicondylitis (Tennis Elbow)** (Continued)

PHASE III	PHASE IV
• PT modalities as needed • TBS/TAS/TLS activities as recommended and tolerated • Scapular exercises: PREs • TAS: Biceps/triceps PREs • Glenohumeral exercises: PREs • Rotator cuff exercises, including 90° internal and 90° external position PREs • Full forearm PREs • Eccentric wrist extension: PREs • PNF exercises • Rhythmic stabilization exercises with long lever arm; progress to Bodyblade • Core and lower-extremity exercises • Sport-specific plyometrics • Sport-specific PREs (forehand and backhand)	• PT modalities as needed • Full upper-extremity flexibility program • Wrist flexion–extension isokinetics • TBS/TAS/TLS activities as recommended and tolerated • Scapular exercises: PREs • TAS: biceps/triceps PREs • Glenohumeral exercises: PREs • Rotator cuff exercises: PREs • Forearm exercises • Core and lower extremity: PREs • PNF exercises • Open kinetic chain rhythmic stabilization exercises • Core and lower-extremity flexibility exercises • Interval tennis program

- Continue core stability with emphasis on trunk rotation and posture.
- Continue full lower-extremity strengthening program with emphasis on closed-chain activities, hip rotation, and unilateral activities. These may include leg press, squats, forward stepups, lunges, side lunges, back lunges, split squats, and lunges with trunk rotation.

Techniques to Increase Muscle Strength, Power, and Endurance

- Isokinetics for wrist flexion–extension and pronation–supination once a strength base has been established. This can be used to reproduce sport-specific speeds and train for endurance.

Plyometrics

- As an interval tennis program is initiated, plyometrics should be phased out.

Sport-Specific Exercises

- An interval tennis program should be initiated if criteria are met.
- The program should entail a progression of volume and intensity. The program should be progressed individually.
- Each phase should be completed without significant symptoms or fatigue prior to advancing to the next phase.

Criteria for Abandoning Nonoperative Treatment and Proceeding to Surgery or More Intensive Intervention

- Unable to perform sport-specific activities or return to preinjury activity level
- Continued pain with activities of daily living
- Failure to restore normal grip strength

Milestones for Progression to Sport-Specific Training and Conditioning

- Able to complete interval tennis program without symptoms
- Maintain normal upper-extremity strength and flexibility

Tips and Guidelines for Transitioning to Performance Enhancement

- When resuming tennis activities, the patient should not try to work through pain or fatigue.
- Use of low-compression tennis balls has been advocated when initiating an interval tennis program. These decrease the amount of stress on the elbow at ball impact.
- The patient's racquet should be evaluated for string tension and grip size. These can also be valuable in avoiding reinjury.
- Adequate rest and recovery are important to avoiding and minimizing fatigue and reducing the chances of reinjury.

Performance Enhancement and Beyond Rehabilitation: Training/Trainer and Optimization of Athletic Performance

- When returning to tennis activities, supervision by a professional to improve mechanics can enhance performance and prevent reinjury.
- Learning to weight-shift properly, use the core and lower extremities, and avoid hitting too late with the leading elbow posture can be very valuable.
- Upon returning to tennis, a program for full-body strength, flexibility, and endurance should be maintained. This will also reduce the risk of reinjury.

Specific Criteria for Return to Sports Participation: Tests and Measurements

- Normal grip strength on dynamometer
- Shoulder strength greater than contralateral side
- Normal upper-extremity flexibility
- Completion of full-interval tennis program

Evidence

Struijs PAA, Damen PJ, Bakker EWP, et al: Manipulation of the wrist for management of lateral epicondylitis: a randomized pilot study. *Phys Ther* 83:608–616, 2003.

In this randomized pilot study, two protocols were compared for patients with lateral epicondylitis. One was wrist manipulation, and the other consisted of ultrasound, friction massage, stretching, and strengthening. Follow-up was at 3 and 6 weeks. Manipulation of the wrist appeared to be more effective for the short-term.

Tanaka Y, Aoki M, Izumi T, et al: Effect of elbow and forearm position on contact pressure between the extensor origin and the lateral side of the capitellum. *J Hand Surg [Am]* 36:81–88, 2011.

In this cadaveric study, contact pressure between the origin of the common extensor tendons and the lateral side of capitellum was measured with a pressure sensor. Bone-to-tendon contacts is considered to be a cause of lateral epicondylitis with elbow extension, forearm pronation, and varus stress to the elbow.

Tyler TF, Thomas GC, Nicholas SJ, et al: Addition of isolated wrist extensor eccentric exercise to standard treatment for chronic lateral epicondylosis: A prospective randomized trial. *J Surg Shoulder Elbow* 19:917–922, 2010.

In this prospective randomized study, 21 patients with lateral epicondylosis were treated with eccentric strengthening for the wrist extensors using an inexpensive rubber bar. All outcome measures were found to have markedly improved with eccentric training on the basis of the Disabilities of the Arm, Shoulder, and Hand questionnaire; visual analogue scale measurement; and strength testing.

Vincenzino B, Smith D, Cleland J, et al: Development of a clinical prediction rule to identify initial responders to mobilisation with movement and exercise for lateral epicondylalgia. *Man Ther* 14:550–554, 2009.

In this post hoc analysis, 64 patients with lateral epicondylalgia were treated with standardized physical therapy. After

3 weeks, patients were categorized as improving or not improving. Factors with relationships to improvement were entered into a logistic regression model. Probability of improvement rose from 79% to 100% if all three factors were positive (Identify what the three factors were).

Wen DY, Schultz BJ, Schaal B, et al: Eccentric strengthening for chronic lateral epicondylosis: a prospective randomized study. *Sports Health* 3:500–503, 2011.

In this prospective randomized study, 28 patients with lateral epicondylosis were treated with eccentric strengthening or stretching. Pain scores rated with a visual analogue scale were used. Both groups had improved at 4 weeks, but there was no significant difference between groups at any follow-up time point.

Multiple-Choice Questions

QUESTION 1. Which cannot be utilized for protection and symptom reduction during the initial phase of nonoperative treatment?

A. Sling
B. Elbow counterforce brace
C. Activity modification
D. Wrist cockup splint

QUESTION 2. Which would not be considered a criterion for return to sport?

A. Normal shoulder forearm and shoulder flexibility
B. Completion of a sport-specific plyometric program
C. Interval tennis program with only minimal to moderate symptoms
D. Shoulder strength greater than contralateral side

QUESTION 3. Which position allows the most bone-to-tendon contact for the extensor tendons?

A. Elbow flexion and forearm supination
B. Elbow extension and forearm pronation
C. Elbow extension and forearm supination
D. Elbow flexion and forearm pronation

QUESTION 4. Which of the following should one do when returning to tennis activities?

A. Use tennis balls with high compression
B. Hit unsupervised
C. Play through fatigue to build endurance
D. Learn to weight-shift properly and avoid hitting too late with leading elbow

QUESTION 5. When should isolated strengthening of the wrist and finger extensors be initiated?

A. When a proximal strength base has been established
B. When forearm flexibility is restored
C. When the patient is asymptomatic
D. All of the above

Answer Key

QUESTION 1. Correct answer: **D** (see Phase I: Protection)

QUESTION 2. Correct answer: **C** (see Specific Criteria for Return to Sports Participation)

QUESTION 3. Correct answer: **B** (see Evidence)

QUESTION 4. Correct answer: **D** (see Performance Enhancement and Beyond)

QUESTION 5. Correct answer: **D** (see Phase II)

POSTOPERATIVE REHABILITATION AFTER OPEN OR ARTHROSCOPIC SURGERY FOR LATERAL EPICONDYLITIS

Michael Levinson, PT, CSCS, and David Altchek, MD

Indications for Surgical Treatment

- Failure of conservative treatment, which may include nonsteroidal antiinflammatory drugs, cortisone injections, splinting, and physical therapy and activity modification for a minimum of 6 months
- Persistent pain that interferes with activities of daily living
- Pain that prevents an athlete from returning to sport
- Clear localization of pain at the anatomic areas of the extensor carpi radialis brevis (ECRB) and extensor digitorum communis
- Tear of the extensor tendon diagnosed

Brief Summary of Surgical Treatment

Major Surgical Steps

- Supine position on the operating table
- Extensor carpi radialis longus (ECRL) is split longitudinally and retracted medially and laterally.
- The ECRB is exposed.
- Fibrinous material is debrided.
- Mini-Mitek suture anchor (De Puy Synthes, West Chester, Pennsylvania) is inserted into the lateral epicondyle.
- Two limbs of suture are passed through the ECRL and ECRB and reattached to the lateral epicondyle.
- Placed in posterior splint

Other Surgical Techniques and Options

- Major differences in other surgical techniques (if not covered in other sections)
- The ECRB can be debrided and released arthroscopically.
- The arthroscope is used to identify the location of the ECRB tendon and identify any other elbow joint pathologies, such as loose bodies.
- Any variance from rehabilitation guidelines would result from any postoperative joint effusion that might interfere with restoring range of motion (ROM) and strength.
- The clinician should be cognizant of any posterolateral instability that may result from this procedure.

Before Surgery: Overview of Goals, Milestones, and Guidelines[1]

GUIDING PRINCIPLES OF POSTOPERATIVE REHABILITATION

- Understand the surgical procedure performed and healing rates of the tissues involved
- Understand the positions and activities that stress the wrist and finger extensors and their attachment at the lateral epicondyle
- Minimize active wrist and finger extension during the early phases of rehabilitation
- Avoid painful ROM and strengthening
- Understand the criteria for returning to functional and athletic activities

Phase I: Immediate Postoperative Period (days 0 to 14)

Clinical Pearls

- Early range of motion is important. It should be performed actively or actively with assistance.
- Aggressive passive range motion should be avoided to allow optimal soft-tissue healing.
- A brace is generally not required. However, it may be indicated if patient activity modification is a concern.

Goals

- Patient education
- Activity modification to avoid stressing the repair
- Protect the surgical repair
- Minimize swelling, pain, and inflammation
- Avoid contracture

[1]*Prehabilitation, if appropriate, is described in the Nonoperative Rehabilitation section of this chapter.*

Protection

- A posterior splint is used for 1 week. As mentioned above, a brace is generally not indicated.

Management of Pain and Swelling

- Oral pain medications are prescribed.
- Cryotherapy is used for pain and inflammation.
- Activity modification to avoid pain is also critical. Minimizing activities that stress the wrist and finger extensors will help to reduce postoperative pain.
- For swelling, cryotherapy and activity modification

Techniques for Progressive Increase in Range of Motion

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Codman exercises are used to increase blood flow into the entire upper extremity and maintain flexibility of the glenohumeral joint.
- Scapular retraction exercises are used to maintain posture and begin to restore proximal strength.
- Elbow active range of motion (AROM) and active assisted range of motion (AAROM) exercises are initiated. The therapist should not engage the patient with passive range of motion (PROM).

Other Therapeutic Exercises

- Once the sutures are removed, the patient may begin to use a stationary bicycle, but should avoid gripping the handle with the surgically treated hand.

Milestones for Progression to the Next Phase

- Minimal pain and swelling

Phase II (weeks 2 to 6)

Clinical Pearls

- The therapist should continue to avoid engaging the patient with aggressive PROM to allow optimal soft-tissue healing.
- Elbow extension should be restored by a low-intensity/long-duration stretch in supine.
- Patients should be advised to perform activities with their surgically treated arm with the elbow in flexion to reduce stress to the repair.

Goals

- Protect surgical repair
- Minimize pain, swelling, and inflammation
- Continue to modify activities of daily living (computer use, handshaking, carrying, and lifting)
- Avoid painful exercises.

Protection

- No protection is needed if the patient is compliant.

Management of Pain and Swelling

- Continue cryotherapy and oral pain medications as indicated.
- Continue cryotherapy and activity modification to control swelling.

Techniques for Progressive Increase in Range of Motion

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Continue AROM and AAROM of the elbow.
- Low-intensity/long-duration stretch for elbow extension if needed; performed while supine with a towel roll under the humerus
- Gentle wrist ROM is initiated to avoid forearm stiffness and promote healing. This should be performed with the elbow in flexion.
- AROM of the shoulder is performed to maintain glenohumeral ROM and flexibility.

Other Therapeutic Exercises

- Continue stationary bicycle while avoiding gripping with the surgically treated hand.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Begin manual sidelying scapular stabilization exercise with resistance proximal to the elbow to continue to establish proximal strength (Figure 9-8).

Milestones for Progression to the Next Phase

- Minimal pain or swelling



FIGURE 9-8. Manual sidelying scapular stabilization exercises with proximal resistance.

Phase III (weeks 6 to 10)

Clinical Pearls

- When initiating isotonic exercises for the shoulder, scapula, and elbow, the patient should avoid end ranges of elbow extension. This will avoid excessive stress to the surgically repaired extensor tendon.
- Strengthening of the wrist and finger extensors should begin with the elbow supported and flexed. This will decrease bone-to-tendon contact pressure at the origin of the common extensor tendon at the lateral epicondyle.

Goals

- Continue to avoid excessive stress to the surgical repair.
- No pain with exercise or activities of daily living
- Full elbow ROM
- Begin to restore shoulder and scapular strength/flexibility.
- Begin to restore elbow and forearm strength.

Management of Pain and Swelling

- Cryotherapy is continued, and oral pain medication should be discontinued.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- In cases where extension is not full by 6 to 10 weeks, joint mobilization, such as joint distraction and posterior gliding of the ulna on the humerus, should be utilized.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- If full extension has not been restored, a low-intensity/long-duration stretch should continue to be used. A weight or elastic resistance may be added.

Other Therapeutic Exercises

- Sport-specific core and lower-extremity strengthening may be introduced. However, holding heavy weights in the hands while performing these exercises should be avoided.
- Proximal strengthening should be introduced for the shoulder and scapula, including the rhomboids; serratus; upper, middle, and lower trapezius; and latissimus dorsi and rotator cuffs.
- All exercises should be performed while avoiding the end range of elbow extension (Figures 9-9 to 9-11).
- Begin biceps and triceps strengthening while avoiding the end stage of elbow extension.

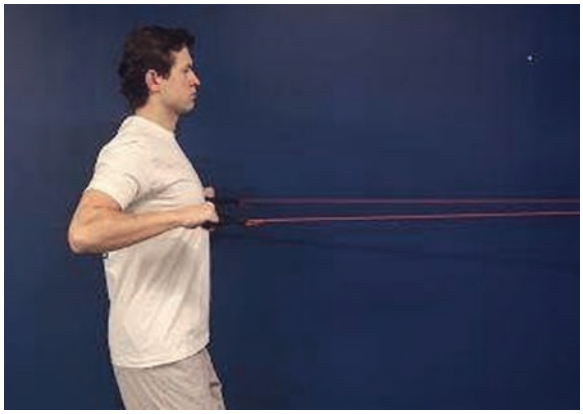

FIGURE 9-9. Scapula retraction with elastic resistance.



FIGURE 9-10. Serratus punch.

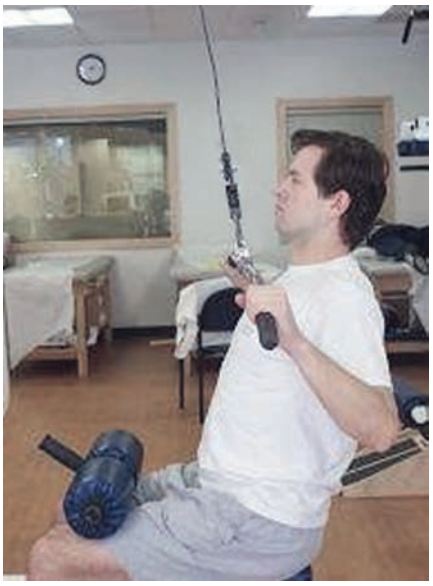

FIGURE 9-11. Latissimus dorsi pull-down.

Activation of Primary Muscles Involved in Injury Area or Surgical Structure

- Isotonic exercises for the wrist and finger extensors are initiated with the elbow supported and in flexion.

Open and Closed Kinetic Chain Exercises

- Most closed kinetic chain exercises put significant stress on the lateral epicondyle and common extensor tendon.

TIMELINE 9-2: **Postoperative Rehabilitation after Open or Arthroscopic Surgery for Lateral Epicondylitis**

PHASE I (weeks 1 to 2)	PHASE II (weeks 3 to 6)	PHASE III (weeks 6 to 10)
• Posterior splint for 1 week • Physical therapy (PT) modalities • Elbow AROM and AAROM • Codman's exercises	• PT modalities • Elbow AROM and AAROM • Low-intensity/long-duration stretch for extension (LILD) • Wrist AROM with elbow in flexion • Full elbow ROM • Manual sidelying scapular stabilization	• PT modalities as needed • Full AROM • Mobilization as needed • LILD as needed • Scapular exercises: progressive resistive exercises (PREs) • TAS: biceps and triceps PREs • Glenohumeral exercises: PREs • Rotator cuff exercises: PREs • Wrist flexor exercises • Wrist and finger extensor exercises with elbow in flexion • Rhythmic stabilization exercises proximal to the elbow • Closed kinetic chain exercises



FIGURE 9-12. Rhythmic stabilization with proximal resistance.

Neuromuscular Dynamic Stability Exercises

- Rhythmic stabilization exercises for the shoulder can be initiated with resistance proximal to the elbow (Figure 9-12).

Milestones for Progression to the Next Phase

- Full elbow ROM. Using standard goniometry, average elbow ROM is 0° internal and 140° external. However, it should be compared with the nonoperative side.
- Pain free with exercises and activities of daily living
- Good proximal strength base. All shoulder strength should be 5/5 using standard manual muscle testing. Scapulothoracic function should be within normal limits based on observation and comparison to the nonoperative side.
- Good shoulder flexibility determined using standard goniometry and compared with the nonoperative side. For shoulder internal rotation, vertebral level may be used.

Phase IV (weeks 10 to 14)

Clinical Pearls

- Elbow pathology in the athletic population is often associated with a selective loss of shoulder flexibility.
- In preparing for athletic activities, begin to restore proximal flexibility, especially in the posterior structures of the shoulder.
- The common extensor tendon often undergoes significant eccentric stresses. Eccentric training should begin to be incorporated into the program.

Goals

- Restore normal shoulder and scapular strength
- Restore normal shoulder flexibility
- Begin to restore forearm flexibility
- Progress to overhead activities

Management of Pain and Swelling

- Cryotherapy is continued to prevent any muscle soreness.
- Any significant pain in this phase indicates that the patient's activity level should be reduced.
- The surgeon should address any significant swelling in this phase.

TIMELINE 9-2: **Postoperative Rehabilitation after Open or Arthroscopic Surgery for Lateral Epicondylitis** (Continued)

PHASE IV (weeks 10 to 14)	PHASE V (weeks 14 to 24)	PHASE VI (weeks 24 to 52)
• PT modalities as needed • Full AROM • Mobilization as needed • Forearm stretching • Posterior shoulder stretching • TBS, TAS, and TLS activities as recommended and tolerated • Scapular exercises: PREs • TAS: biceps and triceps PREs • Glenohumeral exercises: PREs • Rotator cuff exercises: PRE progression to 90° internal and 90° external position • Eccentric wrist and finger extensor exercises • Proprioceptive neuromuscular facilitation (PNF) exercises • Rhythmic stabilization exercises distal to elbow and overhead position • Upper-body ergometry	• AROM: Maintain full motion • Mobilization as needed • Full upper-extremity flexibility exercises • Total body strengthening (TBS), total arm strengthening (TAS), and total leg strengthening (TLS) activities as recommended and tolerated • Scapular exercises: PREs • TAS: biceps and triceps PREs • Glenohumeral exercises: PREs • Rotator cuff exercises: PREs • Forearm exercises with elbow extension: PREs • Isokinetics if available • PNF exercises • Rhythmic stabilization exercises • Bodyblade when available • Deceleration exercises • Plyometrics: Two-arm progressing to one arm • Interval tennis or sport-specific program begins • Full lower-extremity and core strength and flexibility	• AROM: maintain full motion • Maintain full-body flexibility • TBS, TAS, and TLS activities as recommended and tolerated • Scapular exercises: PREs • TAS: biceps and triceps PREs • Glenohumeral exercises: PREs • Rotator cuff exercises: PREs • Internal rotation/external rotation exercises at 90° • Core and lower-extremity PREs • PNF exercises • Forearm exercises: PREs • Progress sport-specific program • Return to play



FIGURE 9-13. Posterior shoulder stretch.

Techniques for Progressive Increase in Range of Motion

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Forearm stretching for both the lateral and medial side should be performed. Posterior shoulder flexibility exercises should be initiated (Figure 9-13).

Other Therapeutic Exercises

- Scapula, shoulder, and elbow strengthening should be progressed as tolerated.
- Rotator cuff strengthening should be progressed to the 90° internal and 90° external position (Figure 9-14).

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Wrist and finger extension strengthening should begin to emphasize the eccentric activity of muscle contraction.

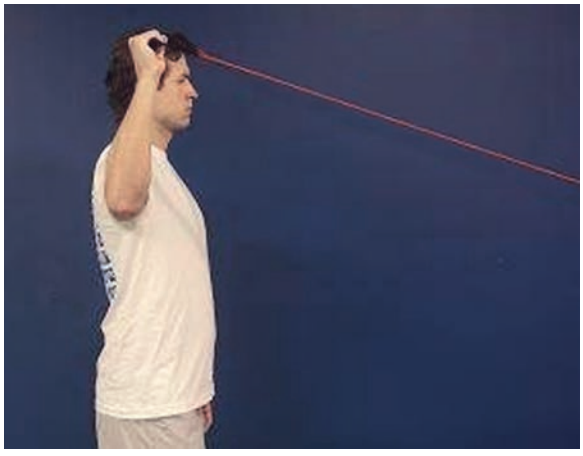

FIGURE 9-14. Rotator cuff strengthening in the 90° internal and 90° external position.



FIGURE 9-15. Upper-body ergometry

Sensorimotor Exercises

- Proprioceptive neuromuscular facilitation patterns are initiated.

Techniques to Increase Muscle Strength, Power, and Endurance

- Upper-body ergometry may be initiated to improve general upper-extremity endurance (Figure 9-15).

Neuromuscular Dynamic Stability Exercises

- Rhythmic stabilization exercise should be progressed to resistance distal to the elbow and to the overhead position.

Phase V (weeks 14 to 24)

Clinical Pearls

- Sport- or work-specific programs should be initiated only after the patient has demonstrated normal strength, flexibility, and endurance.
- The patient should have tolerated all neuromuscular drills, including plyometrics, prior to beginning a sport- or work-specific program.
- For the tennis player, problems are often initiated by strength and flexibility deficits at more proximal points in the chain, such as the trunk and hips.

Goals

- Restore normal neuromuscular function
- Begin sport- or work-specific activities without pain
- Restore full-body strength, ROM, flexibility, and endurance

Management of Pain and Swelling

- Cryotherapy

Techniques for Progressive Increase in Range of Motion

Stretching and Flexibility Techniques for the Musculotendinous Unit

- A full upper-extremity flexibility program should be continued for the shoulder, elbow, wrist, and forearm.

Other Therapeutic Exercises

- For the athlete, a full core and lower-extremity strengthening and flexibility program should be incorporated.
- For the tennis player, emphasis on hip and trunk flexibility and strength is critical.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Wrist and finger extensor strengthening should be performed with the elbow in extension if tolerated.
- Forearm pronation and supination exercises should be incorporated to improve total forearm function. Heavy resistance is not required and, in most cases, is contraindicated.

Techniques to Increase Muscle Strength, Power, and Endurance

- When available, isokinetics can be utilized to build endurance and simulate the speeds and loading rates of functional activities, such as tennis.

Neuromuscular Dynamic Stability Exercises

- Rhythmic stabilization may be progressed to all functional positions.
- The patient may be progressed to the Bodyblade if one is available.
- A functional progression should be followed from the patient's side to external rotation, then to the 90° internal and 90° external position, and then to follow-through (Figure 9-16).

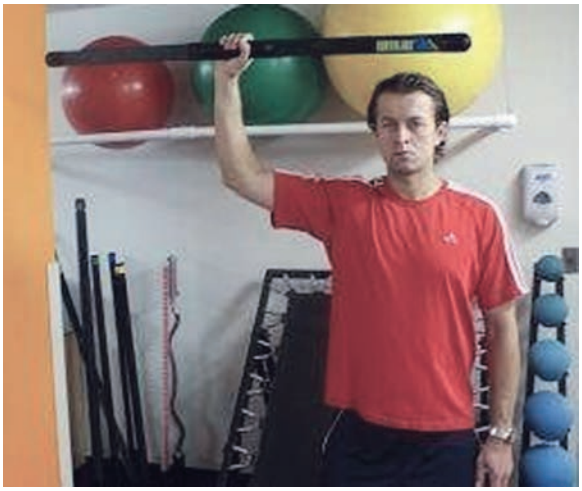

FIGURE 9-16. Bodyblade.

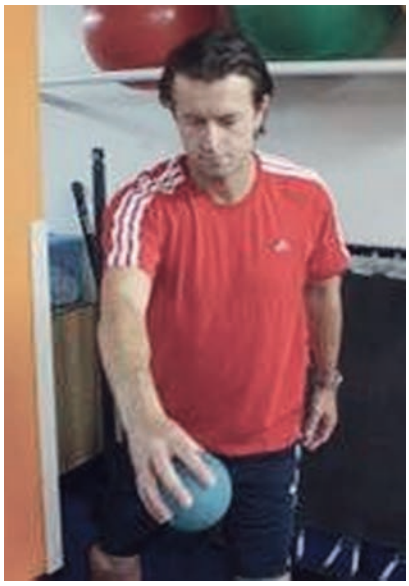

FIGURE 9-17. Deceleration exercises using a Plyoball.

Plyometrics

- When the patient is asymptomatic and with a normal strength base and upper-extremity flexibility within normal limits, a plyometric program should be initiated.
- Progression: Chest pass, side-to-side wood chops, overhead soccer pass, one-handed external rotation with arm at side, one-arm external rotation in 90° internal and 90° external position.

Functional Exercises

- Deceleration exercises are performed first in a kneeling position. Tossing a Plyoball over the shoulder and catching it and decelerating the arm.
- This should be progressed to a standing position where the patient trains the larger body parts to absorb stress from the upper extremity during a serve (Figure 9-17).

Sport-Specific Exercises

- For the tennis player, an interval tennis program should be initiated after completing several weeks of plyometrics without symptoms.
- Any sport-specific interval program should progress the intensity and volume of work.

Milestones for Progression to the Next Phase

- Normal grip strength
- Normal upper-extremity flexibility
- Normal upper-extremity strength, power, and endurance
- Completion of a sport-specific interval program.

Phase VI (weeks 24 to 52)

Goals

- Return to play
- Avoid reinjury
- Maintain strength and flexibility
- Maintain general fitness and improved posture

Management of Pain and Swelling

- Cryotherapy after activity or exercise

Techniques for Progressive Increase in Range of Motion

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Maintain full upper-body, lower-body, and core flexibility program during play.

Other Therapeutic Exercises

- Continue full upper-body, lower-body, and core strengthening as they play.

Plyometrics

- Plyometrics should be phased out as the volume of play increases.

Sport-Specific Exercises

- Return to play.

Criteria for Return to Sport

General

- Pain free
- Normal grip strength with handheld dynamometer. Comparison with nonoperated side. There are also normative values for dominant and nondominant hands for various age groups.
- Normal rotator cuff ratio. Isokinetic dynamometer. External rotation/internal rotation is 66% in the normal population.
- Scapular symmetry. Observational comparison to the nonoperative side.
- Normal shoulder flexibility comparable to the contralateral side. Standard goniometry or vertebral level for shoulder internal rotation.

Sport-Specific

- See above.

After Return to Sport

Continuing Fitness or Rehabilitation Exercises

- Lower-extremity and core strengthening and flexibility training
- Full upper-extremity strengthening and flexibility training
- General conditioning

Exercises and Other Techniques for Prevention of Recurrent Injury

- Improve mechanics (emphasis on the backhand) to use the larger body parts more and improve weight shifting (for example, the trunk and lower extremities)
- Adjust racquet grip size
- Adjust racquet tension

Evidence

Baker CL, Jr, Baker CL, 3rd: Long-term follow-up of arthroscopic treatment of lateral epicondylitis. *Am J Sports Med* 36:254–260, 2008.

In this case series, 30 patients were located for follow-up after being treated for lateral epicondylitis with arthroscopic resection of pathologic tissue. A numeric pain scale and the Mayo Clinic Elbow Performance Index were used. The rate of success was maintained after a mean follow-up of 130 months. (Level IV evidence).

Dunn JH, Kim JJ, Davis L, et al: Ten- to 14-year follow up of the Nirschl surgical technique for lateral epicondylitis. *Am J Sports Med* 36:261–266, 2008.

Eighty-three patients with a mean follow-up of 12.6 years underwent the mini-open surgical technique for resection of tendinosis tissue. On the basis of the Numeric Pain Intensity Scale, the Nirschl and Verhaar tennis elbow scoring systems, and the American Shoulder and Elbow Surgeons elbow form, the surgery was successful. (Level IV evidence).

Rosenberg N, Henderson I: Surgical treatment of resistant lateral epicondylitis: follow-up study of 19 patients after excision, release and repair of proximal common extensor tendon origin. *Arch Orthop Trauma Surg* 122:514–517, 2002.

In this study, the researchers reported on 19 patients treated by excision, release, and repair of the common extensor tendon. Eighteen patients reported recovery from pain and a satisfactory regaining of forearm strength 3 to 4 months after surgery. (Level IIc evidence).

Szabo SJ, Savoie FH, Field LD, et al: Tendinosis of the extensor carpi radialis brevis: an evaluation of three methods of operative treatment. *J Shoulder Elbow Surg* 15:721–727, 2006.

In this retrospective review, outcomes were evaluated for 109 patients with lateral epicondylitis who had undergone open, arthroscopic, or percutaneous surgery. Outcomes were evaluated with the visual analogue scale and the Andrews-Carson score. At a mean follow-up of 47.8 months, there was no significant difference between the three procedures. All were considered effective. (Level IIb evidence).

Zingg PO, Schneeberger AJ: Debridement of extensors and drilling of the lateral epicondyle for tennis elbow: a retrospective follow-up study. *J Shoulder Elbow Surg* 15:347–350, 2006.

In this retrospective follow-up study, 21 patients treated for tennis elbow with extensor debridement without repair and with decortication drilling were reviewed after a mean follow-up of 15 months. Ninety-five felt they had improved; however, they reported that recovery was slow and painful. (Level IIb evidence).

Multiple-Choice Questions

QUESTION 1. When is AROM of wrist extension safe with the elbow in flexion?

A. 0 to 2 weeks
B. 3 weeks
C. 6 weeks
D. 8 weeks

QUESTION 2. In the initial postoperative phase, which of the following should be excluded?

A. Scapula retraction
B. Elbow AROM
C. Codman exercises
D. Elbow PROM

QUESTION 3. If there is difficulty in restoring elbow extension ROM, which of the following therapeutic techniques should be employed?

A. Aggressive PROM by the clinician
B. Manipulation
C. Low-intensity long-duration stretch and joint mobilization
D. Deep-tissue massage

QUESTION 4. When is it safe to initiate eccentric strengthening of the extensors?

A. 3 to 6 weeks
B. 6 to 10 weeks
C. 10 to 14 weeks
D. 14 to 24 weeks

QUESTION 5. Which of the following would not be an indication for surgical intervention for lateral epicondylitis?

A. Failure of at least 3 months of conservative treatment
B. Tear of the extensor tendon
C. Pain with activities of daily living
D. Unable to return to sport

Answer Key

QUESTION 1. Correct answer: **B** (see Phase II, 3 to 6 weeks)

QUESTION 2. Correct answer: **D** (see Phase I, 0 to 2 weeks)

QUESTION 3. Correct answer: **C** (see Phases II and III, 3 to 10 weeks)

QUESTION 4. Correct answer: **C** (see Phase IV, 10 to 14 weeks)

QUESTION 5. Correct answer: **A** (see Indications for Surgical Treatment)

BEYOND BASIC REHABILITATION: RETURN TO TENNIS AFTER TREATMENT FOR LATERAL EPICONDYLITIS

Jamie Osmark, CSCS, Michael Levinson, PT, CSCS, and David Altchek, MD

Introduction

- This injury is more common in the novice tennis player. It is not often seen in competitive tennis players.
- It is often related to poor mechanics in the tennis backhand, but it also can be related to trying to create topspin on a serve or forehand.
- Returning to tennis can be challenging. However, success can be correlated with becoming asymptomatic, restoring strength and flexibility and improving mechanics.

Aspects of Tennis that Require Special Attention in Rehabilitation

- Repetitive activities
- Rapid development of muscular activity, short bursts, and high intensity

- Strength, speed, power, flexibility, muscular endurance, and muscular balance
- Velocity, spin, and placement
- Number of strokes
- Anaerobic and aerobic activity

Phase I: Advanced Strength and Conditioning Programs

Periodization

- Linear
- Macrocycles
- Mesocycles
- Microcycles

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- Training continuum
- Flexibility and joint mobility for joint stability
- Training with optimum posture
- Sensorimotor and balance training
- Core training
- Cardiorespiratory training
- Multiplanar training activities
- Training for optimum muscle balance
- Training for optimum muscle functional strength
- Training for optimum muscle functional power
- Neuromuscular dynamic stability exercises
- Training for speed, agility, and quickness (SAQ)
- Functional training

Olympic Lifts Used in the Training Program

- Clean and jerk
- Power clean

Training Principles Used in the Design of the Program

- Principle of progression
- Principle of overload
- Principle of variation
- Principle of individualization
- Principles of specificity: Specific adaptation to imposed demands (SAID)

Application of Acute Training Variables

- When returning to tennis, a linear periodized program consisting of endurance, hypertrophy, strength, and power phases should be implemented for a safe, strong return.
- Repetitions
  - Endurance phase: 12 to 20 repetitions
  - Hypertrophy phase: 7 to 12 repetitions
  - Strength phase: Four to six repetitions
  - Power phase: Two to five repetitions
- Sets
  - Endurance phase: Two or three sets
  - Hypertrophy phase: Three to six sets
  - Strength phase: Three to five sets
  - Power phase: Three five sets
- Rest interval
  - Endurance phase: 30 to 45 seconds
  - Hypertrophy phase: 45 to 60 seconds
  - Strength phase: 120 seconds
  - Power phase: 120+ seconds

TIMELINE 9-3: **Postoperative Rehabilitation After Open or Arthroscopic Posterior Shoulder Stabilization**

PHASE I (weeks 1 to 2)	PHASE II (weeks 3 to 6)	PHASE III (weeks 7 to 10)
• Sling • PT modalities • ROM: Scapular plane elevation to 90° • Active assisted Codman's exercises • TBS, TAS, and TLS activities as recommended and tolerated	• Sling • PT modalities • ROM during Wk 4: Scapular plane elevation to 120° • ROM during Wk 6: Scapular plane elevation to 160° • ROM during Wk 4: Start flexion to 90° • ROM during Wk 6: ER to 30° • ROM during Wk 6: Internal rotation (IR) to 0° • TBS, TAS, and TLS activities as recommended and tolerated • Scapular exercises • Wk 4: Active assisted range of motion exercises • Wk 4: Submaximal isometrics for glenohumeral joint muscles • Wk 4: Submaximal isometrics for external rotation (ER)	• DC sling • PT modalities as needed • PROM: Full • Mobilization as needed • TBS, TAS, and TLS activities as recommended and tolerated • Scapular exercises: Progressive resistive exercises (PREs) • TAS, biceps, and triceps PREs • Glenohumeral exercises: PREs • Rotator cuff exercises: PREs • Limit IR exercises to minimize strain to posterior capule • Proprioceptive neuromuscular facilitation (PNF) exercises • OKC rhythmic stabilization exercises • CKC exercises • Wk 10: Seated press-ups and increased weight-bearing through joint • CKC manual perturbation exercises

- Intensity
  - Endurance phase: <67% of 1RM
  - Hypertrophy phase: 67% to 85% of 1RM
  - Strength phase: >85% of 1RM
  - Power phase: 75% to 85% of 1 RM
- Repetition tempo
  - Endurance: 2/1/2
  - Hypertrophy: 2/0/2
  - Strength: 2/0/1
  - Power: 1/0/X
- Training frequency
  - 3 or 4 days
- Training duration
  - 60 minutes per session
  - 3 to 5 weeks per mesocycle
- Training volume
  - Endurance: 12 to 60 repetitions per exercise
  - Hypertrophy: 18 to 72 repetitions per exercise
  - Strength: 12 to 30 repetitions per exercise
  - Power: 6 to 25 repetitions per exercise
- Specific exercises used in the training
  - Clean and jerk
  - Clean
  - Squat
  - Dumbbell overhead press
  - Dead lift
  - Push press
  - Row
  - Lat pull-down
  - Pushup
  - Serratus punch
  - Chest fly
  - Prone Y's and T's
  - Plank
  - Side plank
  - Palloff press (Figure 9-18)
  - Stability chop and lift
  - Bridge
  - Dead bug (Figure 9-19)
  - Russian twist
  - Wrist extension and flexion
  - Wrist pronation and supination
  - Shoulder external rotation
  - Shoulder internal rotation
  - Quadruped thoracic rotation (Figure 9-20)
  - Hip airplane
  - Wall slide stretch
  - Sleeper stretch



FIGURE 9-18. Palloff press.

TIMELINE 9-3: **Postoperative Rehabilitation After Open or Arthroscopic Posterior Shoulder Stabilization** (Continued)

PHASE IV (weeks 11 to 14)	PHASE V (weeks 15 to 24)	PHASE VI (weeks 25 to 52)
• Physical therapy (PT) modalities as needed • PROM: Full • Mobilization as needed TBS, TAS, and TLS activities as recommended and tolerated • Scapular exercises: PREs • TAS, biceps, and triceps PREs • Glenohumeral exercises: PREs • Rotator cuff exercises: PREs • Thrower's Ten • Limit IR exercises to minimize strain to posterior capsule • PNF exercises • Open kinetic chain (OKC) rhythmic stabilization exercises • Closed kinetic chain (CKC) exercises • CKE manual perturbation exercises	• Passive range of motion (PROM): Maintain full motion • Mobilization as needed • TBS, TAS, and TLS activities as recommended and tolerated • Scapular exercises: PREs • TAS, biceps, and triceps PREs • Glenohumeral exercises: PREs • Rotator cuff exercises: PREs • Thrower's Ten progress intensity • PNF exercises • OKC rhythmic stabilization exercises • CKC exercises • CKC manual perturbation exercises • Plyometrics: Two- arm progressing to one-arm • Overhead strengthening exercises • Sport-specific exercises begin • Overhead throwing athletes can begin an easy interval throwing program • 20 wks: Begin full-windup throwing	• PROM: Maintain full motion • Mobilization as needed • Total body strengthening (TBS), total arm strengthening (TAS), and total leg strengthening (TLS) activities as recommended and tolerated • Scapular exercises: PREs • TAS, biceps, and triceps PREs • Glenohumeral exercises: PREs • Rotator cuff exercises: PREs • IR/ER exercises at 90° • Thrower's Ten progress intensity • PNF exercises • OKC rhythmic stabilization exercises • CKC exercises • CKC manual perturbation exercises • Plyometrics: Two-arm chest passes progressing to 90° internal and 90° external one-arm plyometrics • Overhead strengthening exercises • Sport-specific exercises progressed • Overhead throwing athletes progress through an interval throwing program



FIGURE 9-19. Dead bug.

Application of Chronic Training Variables

- The first phase, endurance, helps acclimate the player back to strength training by preparing the muscles, tendons, and overall joint stability for more volume and intensity. This phase also helps reestablish the neuromuscular connection to maximize muscular recruitment.
- The second phase, hypertrophy, is aimed to build muscular size.
- The third phase, strength, focuses on gaining maximal functional strength.
- The final phase, power, ties the prior phases together. Its focus is on the transfer and development of power through the legs, torso, and upper body.

Phase II: Performance Enhancement Training Techniques

Periodization

- Linear
- Macrocycles
- Mesocycles
- Microcycles

Program Design and Performance Training Program

Sport-Specific Concepts of Integrated Training

- Training continuum
- Flexibility and joint mobility for joint stability



FIGURE 9-20. Quadruped thoracic rotation.

- Training with optimum posture
- Sensorimotor and balance training
- Core training
- Cardiorespiratory training
- Multiplanar training activities
- Training for optimum muscle balance
- Training for optimum muscle functional strength
- Training for optimum muscle functional power
- Neuromuscular dynamic stability exercises
- Training for SAQ
- Plyometric training
- Functional training
- Sport-specific training
- Power training
- Speed agility training

Training Principles Used in the Design of the Program

- Principle of progression
- Principle of overload
- Principle of variation
- Principle of individualization
- Principles of specificity: SAID

Application of Acute Training Variables

- Repetitions
  - Plyometrics: 8 to 12 repetitions
  - Rotational power: 3 to 12 repetitions
  - Core strength: 1 to 12 repetitions
- Sets
  - Plyometrics: Two or three sets
  - Power: Three to five sets
  - Strength: One or two sets
- Rest interval
  - Plyometrics: 1 to 3 minutes
  - Rotational power: 3 to 5 minutes
  - Core strength: 1 to 2 minutes
- Intensity
  - Plyometrics: Body weight, medicine ball, dead ball, near-maximal effort (>90% of maximal effort)
  - Rotational power: 67% to 85% of 1RM
  - Strength: Body weight and weighted vest
- Repetition tempo
  - Plyometrics: Maximal effort
  - Rotational Power: Maximal effort
  - Strength: Controlled 3/1/2
- Training frequency
  - Two or three times per week
- Training duration
  - 60 minutes
  - 3 to 4 weeks
- Training volume
  - Plyometrics: 16 to 36 repetitions per exercise
  - Rotational power: 9 to 60 repetitions per exercise
  - Strength: 1 to 24 repetitions per exercise
- Specific exercises used in the training
  - Plyometrics
    - Bounding
    - 90°, 180° jumping exercise
    - Lateral bounding with resistance



FIGURE 9-21. Medicine ball rotational throw.

- Lateral bounding progression
- Box jumps
- Medicine ball squat thrust
- Medicine ball slam
- Medicine ball rotational throw (Figure 9-21)
- 90°/90° wall plyometrics
- Straight-arm ball dribbling on wall
- Medicine ball squat to rotational chest pass
- Medicine ball sit-up overhead throw
- Reaction/response training
- Rotational power
  - Squat to rotational press (Figure 9-22)
  - Rotational row (Figure 9-23)
  - Rotational push–pull
  - Rotational snatch
  - Explosive torso-and-hip rotation
  - Chop and lift
- Strength
  - Single-leg squat
  - Mini band lateral walk



FIGURE 9-22. Squat-to-rotational press.



FIGURE 9-23. Rotational throw.

- Single-leg Romanian dead lift
- Walking lunge with mini band rotation
- Triplanar lunge
- Pull-down
- Pushup
- Wrist extension and flexion
- Wrist pronation and supination
- Plank
- Side plank
- Quadruped thoracic rotation
- Hip airplane
- Wall slide stretch

Application of Chronic Training Variables

- During this phase of training, plyometrics are included in order to utilize the stretch-shortening cycle so that force production can be maximized. The typical focus in tennis is the development and transfer of lower-body power to upper-body rotational strength and stability. In this training phase, emphasis is placed on development of rotary power. The force delivered to the tennis ball from the tennis racket will be evenly distributed throughout the kinetic chain when rotational sequencing becomes more efficient. Additionally, stabilization exercises will complement the power movements and build the neuromuscular control required in tennis.

Phase III: Sport-Specific Training

Periodization

- Linear
- Macrocycles
- Mesocycles
- Microcycles

Program Design and Performance Training Program

Sport-Specific Concepts of Integrated Training

- Training continuum
- Flexibility and joint mobility for joint stability
- Training with optimum posture
- Sensorimotor and balance training
- Core training
- Cardiorespiratory training
- Multiplanar training activities
- Training for optimum muscle balance
- Training for optimum muscle functional strength
- Training for optimum muscle functional power
- Neuromuscular dynamic stability exercises
- Training for SAQ
- Plyometric training
- Functional training
- Sport-specific training

Training Principles Used in the Design of the Program

- Principle of progression
- Principle of overload
- Principle of variation
- Principle of individualization
- Principles of specificity: SAID

Application of Acute Training Variables

- Repetitions
  - Sport-specific agility: 8 to 20 repetitions
- Sets
  - Three or four sets
- Rest interval
  - 1:4 work-to-rest ratio
- Intensity
  - Maximal effort
- Training frequency
  - Two or three times per week
- Training duration
  - 60 to 90 minutes
  - 3 to 4 weeks
- Training volume
  - 24 to 80 repetitions per exercise
- Specific exercises used in the training
  - Medicine ball ground strokes
  - Lateral intervals
  - Linear intervals
  - Multidirectional intervals
  - Side shuffle
  - Crossover
  - Backpedal

Application of Chronic Training Variables

- In order to simulate the feeling of playing a match, sport-specific training will take place on the tennis court. Interval training should be implemented in order to exhaust the anaerobic system. As training progresses, rest time may be shortened to increase the conditioning

of the athlete. During this phase, the focus should be on improving response time, footwork, lateral speed, and overall conditioning.

Sports Performance Testing

General Information

- General history
- Subjective questionnaires
- Medical history
- Sports injury history
- Surgical history
- Chronic conditions and/or medications

Objective tests

- Physiological assessments
  - Lactate
    - Before, during, and after training
  - Heart rate
    - Throughout training
  - Rate of perceived exertion
    - Immediately after interval training
- Body composition tests: Body composition can be measured by using hydrostatic weighing, whole-body plethysmography (BOD POD), dual X-ray absorptiometry scan, or skin-fold measurements.
  - Preseason
  - End of preseason
  - Periodically through competition
- Static and dynamic postural assessments. Static posture can be assessed with the use of an AlignaBod (Dallas, TX) or a gridline, and dynamic posture can be observed on the tennis court by a coach.
  - Through preseason and competition
- Movement performance testing
  - Functional Movement Screen (FMS): The FMS is a great tool to use for looking at the athlete's overall movement strategy. It is a quick and easy way to screen the athlete for faulty movement patterns that potentially could lead to injury.
    - Periodically through preseason
  - Single-leg squat
    - Periodically through preseason
- Sport-specific testing: A tennis coach performs this type of testing by observing the overall form in real time or on two-dimensional videotape analysis.
  - Stroke analysis
    - Periodically through preseason and competition
  - Serve velocity
    - Periodically through preseason and competition
  - Ground stroke velocity
    - Periodically through preseason and competition

Specific Criteria for Progression to the Next Stage to Determine Readiness for Tennis

- The athlete is pain-free through all movements with symmetrical range of motion.
- Athlete has achieved increases in load, intensity, and volume and shows a strong adaptation to the current training phase.

Specific Criteria for Release to Unsupervised Complete Participation in Tennis

- There is no pain or tenderness in the affected area.
- The athlete presents symmetrical strength and range of motion through all strokes and can maintain adequate strength and symmetry as he or she fatigues.
- The athlete displays strong scapular and wrist stability and maintains proper form throughout a full match. Both can be observed and assessed by a skilled coach as the player transitions back to a full match.

Recommended Ongoing Exercises

- Wrist extension
- Wrist flexion
- Ball dribbling on wall
- Plank
- Side plank
- External rotation
- Internal rotation
- Prone T and Y
- Serratus punch

Evidence

Ellenbecker TS, Pluim B, Vivier SV, et al: Common injuries in tennis players: exercises to address muscular imbalances and reduce injury risk. *Strength Cond J*. 31:50–58, 2009.

This article explains common injuries presented in tennis and the muscle imbalances that may cause these injuries. Specific exercises are suggested to restore balance and improve performance and prevent injury.

Fernandez-Fernandez J, Sanz-Rivas D, Mendez-Villanueva A: A review of the activity profile and physiological demands of tennis match play. *Strength Cond J*. 31:15–26, 2009.

This review gives insight into the physical demands of a competitive tennis match. It also provides information that will help strength and conditioning coaches implement training protocols to improve performance.

Kovacs MS: Movement for tennis: the importance of lateral training. *Strength Cond J*. 31:77–85, 2009.

Tennis involves many different movement changes throughout a match with an emphasis on lateral movement. This article explains the importance of lateral movement training and offers exercises that train the lateral movements specific to tennis.

Kovacs MS: Tennis physiology: training the competitive athlete. *Sports Med* 37:189–198, 2007.

This article outlines the physiological changes that have occurred through the evolution of tennis. It illustrates how these physiological changes affect the way tennis performance and injury prevention programs are designed and implemented.

Lorenz DS, Reiman MP, Walker JC: Periodization: current review and suggested implementation for athletic rehabilitation. *Sports Health*. 2:509–518, 2010.

The authors review of 91 articles related to periodization, methods of periodization, and periodization program outcomes. They conclude that despite the evidence in the strength training literature supporting periodization programs, there is a considerable lack of data in the rehabilitation literature about program design and successful implementation of periodization in rehabilitation programs.

Roetart EP, Ellenbecker TS, Reid M: Biomechanics of the tennis serve: implications for strength training. *Strength Cond J*. 31: 35–40, 2009.

In this review, the authors discuss the biomechanics of the tennis serve and offer specific training exercises to optimize performance.

Roetart EP, Kovacs M, Knudson D, et al: Biomechanics of the tennis groundstrokes: implications for strength training. *Strength Cond J*. 31:41–49, 2009.

This article summarized recent research related to the biomechanics of tennis technique in groundstrokes and offers specific strength and conditioning exercises to improve performance and prevent injury.

Wakeham TR, Jacobs R: Preseason strength and conditioning for collegiate tennis players. *Strength Cond J*. 31:86–93, 2009.

In this article, the authors outline the requirements of tennis and how to achieve these outcomes by adhering to an annual plan consisting of different phases. The authors' objective is to review off-season strength and power training as well as preseason general and sport-specific conditioning.

Multiple-Choice Questions

QUESTION 1. Which of the following is the appropriate intensity for an athlete in the endurance phase of strength and conditioning program?

A. 60% to 67% of 1 RM
B. 85% to 95% of 1 RM
C. 75% to 85% of 1 RM
D. 10% of body weight

QUESTION 2. Which of the following is the result when rotational sequencing becomes more efficient?

A. Loss of energy transfer
B. Increase in upper-body dominance
C. Even force distribution through kinetic chain
D. Decrease in racket velocity

QUESTION 3. Which of the following is an example of a rotational power exercise?

A. Snatch
B. Chop and lift
C. Power clean
D. Side Plank

QUESTION 4. If an athlete continues to participate in tennis, which of the following exercises should he or she do indefinitely?

A. Pull-over
B. Ball-dribbling on wall
C. Snatch
D. Push press

QUESTION 5. In Phase I of strength and conditioning, which of the following is the correct order of mesocycles?

A. Sport-specific, endurance, power, strength
B. Strength, endurance, power, sport-specific
C. Endurance, hypertrophy, strength, power
D. Hypertrophy, endurance, strength, power

Answer Key

QUESTION 1. Correct answer: **A** (see Phase I)

QUESTION 2. Correct answer: **C** (see Phase II, Chronic training variables applied)

QUESTION 3. Correct answer: **B** (see Phase II, Specific exercises used)

QUESTION 4. Correct answer: **B** (see Phase III, Exercises to continue)

QUESTION 5. Correct answer: **C** (see Phase I, Training variables)

NONOPERATIVE REHABILITATION OF GOLFER'S ELBOW

Steven Michael Scher, MSPT, ATC, CSC, PES, TPI, Stacie Christine Graves, MS, PA-C, Beth E. Richardson, DPT, and Kyle Anderson, MD

GUIDING PRINCIPLES OF NONOPERATIVE REHABILITATION

- Minimize pain and edema
- Minimize formation of scar tissue
- Restore range of motion (ROM) and strength of both wrist and elbow
- Treat and correct areas of compensatory motions and restrictions and impairments above and below the elbow
- Increase strength to fair to good in wrist, elbow, and shoulder
- Full participation in sport without residual pain

Phase I (weeks 2 to 4)

Goals

- Reduce pain and edema
- Reduce the load and pull demands on the medial epicondyle
- Restore pain-free ROM to passive ROM (PROM) between 90° flexion and 80° extension of the wrist with cessation at comfortable stretch
- Minimize excessive loads and pull demands at the elbow by bracing at the wrist during the day and splinting at night
- Active rest

Protection

- Temporary cessation of the offending activity is often required, but immobilization or inactivity is not recommended because of the possibility of disuse atrophy or elbow stiffness.
- Icing for 20 minutes three to four times daily should be the first-line antiinflammatory treatment.
- Oral nonsteroidal antiinflammatory medications (NSAIDs) may be helpful for analgesia; however, because medial epicondylitis is a degenerative rather than an inflammatory process, the benefit of NSAIDs is debatable.
- Physical therapy modalities such as ultrasound, electrical stimulation, and iontophoresis can be useful for relieving pain due to medial epicondylitis.
- Counterforce bracing may be beneficial for pain in activities of daily living and also for return to sport.
- Compression neuropathies of the anterior interosseous nerve and posterior interosseous nerve have been reported with use of these braces; therefore, patients should be made aware of the risks, and instruction in proper application should be given.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Functional massage to the involved wrist, forearm, and/or shoulder
- Astym (regenerative medicine therapy for the stimulation and regeneration of damaged tissues and resorption of fibrosis) to the affected upper extremity (UE), followed by soft-tissue mobilization/massage (STM) and manual stretches
- Grade II joint mobilization for pain or grade III joint mobilization at the wrist, carpals (improve wrist flexion/extension), and proximal or distal radial/ulnar joints (forearm pronation/supination) as restrictions are noted
- Mobilization with motion (MWM) for restrictions and/or pain during wrist flexion and/or extension as well as at the elbow.
- Because forces produced by the wrist flexor muscles affect the attachment point at the tendons, which have a small cross-sectional area, these muscles are vulnerable to injury if high and sustained forces are repetitively applied, such as during the golf swing.
- Given the decreased blood supply to the area of insertion, there is a slower healing time. This should be addressed during the rehabilitation process with any of the aforementioned manual and soft-tissue techniques as appropriate.
- The body regenerates connective tissue largely as a result of an inflammatory response consisting of three main phases (inflammation, proliferation, and remodeling), which begins with the release of inflammatory mediators and ends with remodeling of the repaired tissue.
- During maturation, the injured tissue is reshaped and strengthened by internal and external mechanical stress applied to the tissue. If left to immobilization secondary to pain, those tissues will rearrange in unorganized bundles oriented in various directions and not necessarily in the direction of the original, normally functioning tissue. Therefore, the body needs a stimulus for regeneration and also needs to be subjected to normal stresses using appropriate movement patterns for the given tissues, as with functional massage and a specific and individualized exercise program.
- Cross-friction massage (CFM) and other types of STM may assist in preventing adhesion formation and mobilize the cross-links between the collagen fibers, stimulating the regeneration phases at a localized region (wrist flexor origin)
  - Functional massage is a biomechanical soft-tissue technique that combines conventional massage and stretching. This is an appropriate technique to utilize following Astym or CFM followed by a specific and



FIGURE 9-24. Kinesiotaping for wrist flexor inhibition with fascial correction.

individualized exercise program for appropriate loading and tissue regeneration.
  - Neural mobilization: Median, ulnar, or radial as noted. Typically, however, ulnar nerve restriction and involvement occur due to the location in the ulnar groove, near the medial epicondyle.
  - Kinesiotaping (KT) for wrist flexor inhibition with fascial correction and/or space correction to decompress the tissues around the medial epicondyle (Figure 9-24)
- KT is a popular taping method that can gather and align the fascia into its desired position and lift the skin over areas of inflammation, pain, and edema, which then decreases the pressure over the lymphatic channels to provide a path for removal of exudates and provides a positional stimulus to the skin by activating mechanoreceptors to either stimulate or limit movement. Kinesiotape is an elastic tape that does not necessarily restrict muscular or blood flow movements as conventional athletic tape does.
- Modalities: Pulsed ultrasound (US), ice massage, or cold pack (Game Ready, a cold pack with compression; CoolSystems, Concord, California) to the tissues around the medial epicondyle, and H-wave therapy to increase blood flow, decrease muscle spasms, and/or decrease chronic intractable pain
  - H-wave utilizes electrodes around a specific area to activate muscles and can be used at a low frequency to promote local circulation around the medial epicondyle or at a high frequency for pain control.
- Interferential current for pain control

Stretching and Flexibility Techniques for the Musculotendinous Unit

Wrist flexor and other appropriate stretches
- Myofascial release (MFR): Mini foam self-rolling to affected forearm
- Trunk rotation stretches (Figures 9-25 and 9-26)
- Upper trapezius, pectoral, or hip stretches as limitations are noted, such as hip external and internal rotation, prone quadriceps length, and hip flexor ROM

Other Therapeutic Exercises

- Initiate HEP (home exercise program): Self-stretches as limitations are noted with gentle stretching of wrist flexors, active ROM (AROM), and closed kinetic chain (CKC) exercises

TIMELINE 9-4: **Rehabilitation Timeline for Medial Epicondylitis (Golfer's Elbow)**

PHASE I (weeks 1 to 4)
- Brace for wrist stabilization during day and positional night splinting
- PT modalities for pain and edema: H-wave, ultrasound, Hivolt, interferential current, ice 15 to 20 min
- Rest with complete cessation of wrist and elbow stress–related activities
- PROM and AROM of hand and wrist
- Joint and neural mobilization as appropriate
- Upper-body ergometer for ROM stimulus
- Soft-tissue techniques: Astym, functional massage, CFM
- Kinesiotaping for muscle inhibition and pain relief (space correction)
- Oral NSAIDs administered (10–14-d course)
- Consider local cortisone injection
- Stretching program including MFR mini-foam-rolling, trunk rotation stretches, upper trapezius, pectoral, or hip stretches as limitations are noted
- Sensorimotor and kinesthesia: Ball draw, supine alphabet for scapular stabilization
- Activation of wrist flexor and extensor mass, biceps and triceps, abdominal obliques, erector spinae muscles, gluteals
- Mobilization, submaximal isometrics for wrist
- Strengthening of shoulder and trunk
- Sensorimotor and kinesthesia
- Closed chain kinetics: Thera-Band wall two-point weight-bearing, straight-arm diagonals

PHASE II (weeks 4 to 6)
- Initiate pain-free wrist and elbow AROM
- Continue modalities for pain and inflammation control
- Astym and functional massage as appropriate
- Wrist isometrics: Increased resistance and repetitions
- Exercises performed in elbow flexion to minimize load on muscles
- D/C splint and bracing
- Gripping and pronation–supination exercises
- Shoulder program: IR, ER, low rows, and alternate rows, half-roll Thera-Band shoulder horizontal abduction, and PNF D2 pattern with the wrist in neutral
- Closed chain activities: Four-point BOSU rocks, fingertip pushups, walk out on Swiss ball with pushups with a plus, seated on Swiss ball, straight-arm trunk rotation with unilateral knee extension
- Plyometrics: Wrist flips with plyoball, wall dribble, IR rebounder eccentric loading



FIGURE 9-25. Sidelying trunk rotation, hips and knees 90° internal and 90° external.



FIGURE 9-26. Prayer stretch "thread the needle" arm reach-through.

- Wrist isometrics and progressive resisted exercises (PREs) as tolerated
- Power grip web
- Gripping and pronation–supination with power bar and/or towel roll
- Pronation–supination with weight
- Upper-body ergometer for upper-body ROM stimulus
- Shoulder isometrics: External rotation, internal rotation, extension, and abduction

Activation of Primary Muscles Involved

- Wrist flexor mass: The flexor carpi radialis and pronator teres at the insertion of the medial epicondyle are most likely to be involved, owing to the noted consistent burst of activity during the contact phase[1]
  - Occasionally, involvement of the flexor carpi ulnaris and flexor digitorum superficialis may be found. This may be due to the findings of a study on which electrode electromyography (EMG) recordings of the flexor muscles from symptomatic players are of greater magnitude during other phases of the golf swing, showing biomechanical differences between symptomatic and asymptomatic players.[1]
- Wrist extensor mass, because both wrist flexor and extensor muscles play a role in stabilization of the club during the contact phase
- Biceps and triceps

Activation of secondary muscle groups

- Abdominal obliques and erector spinae muscles show significant activity during the forward swing phase.[2]
- Shoulder ER/IR, scapula stabilizers, and abductors during backswing and follow-through

TIMELINE 9-4: **Rehabilitation Timeline for Medial Epicondylitis (Golfer's Elbow)** (Continued)

PHASE III (weeks 6 to 8)	PHASE IV (weeks 8 to 12)
• Full AROM restored • Continue modalities and soft-tissue techniques when necessary • Continue with scapular and core program: Half-roll alternating SASH series, upper-extremity step-ups, walk out on ball with fishtail • Neurodynamic stability, plyometrics and functional sport-specific exercises: Standing torso twists with partner, medicine ball pass, medicine ball tosses with release at deceleration/impact position, transverse plane lunges, single-leg balance, Thera-Band to golf swing impact position	• Goals: Return to sport using a functional exercise program and ensure independence with HEP • Continue with previous stretching, including thoracic rotation stretches • Sport-specific training: Single-leg reaches on half-foam roll and with one-arm row (woodpecker), single-leg PNF standing with 4- or 5-lb kettle ball, two-handed torso rotation kneeling on Swiss ball • Impact program for UE/elbow/wrist: Seated boat toss with medicine ball, four-point plank ball roll side to side • Address equipment issues to reduce stress on medial elbow



FIGURE 9-27. Standing ball draw (clockwise, counterclockwise, side to side, superior/inferior).

- Gluteals, especially the high activity of the gluteus maximus, is noted during the forward swing and initiation of power into the acceleration phase and hip abductors to stabilize the pelvis as that weight-shift occurs.[2]

Sensorimotor Exercises

- Ball draw: Straight arm, open palm: small superior/inferior and circles: clockwise/counterclockwise (CW/CCW) (Figure 9-27)
- Supine alphabet with or without weighted ball for scapular stabilization during UE activity

Closed Kinetic Chain Exercises

- Standing weight shifts on table and/or wall pushups
- Prone weight-shift/walk-out on therapeutic ball to tolerance
- Thera-Band (TB) around both arms and straight-arm star pattern reaches

Milestones for Progression to the Next Phase

- Full, pain-free AROM and PROM at the wrist
- Pain during palpation of the medial epicondyle reduced by 50%
- Elimination of edema: girth measurement compared to involved side

Phase II (weeks 4 to 8)

- Upon relief of symptoms, Phase II is initiated and a guided rehabilitation program is started.
- Stretches for the wrist and elbow are initiated, followed by progressive isometric exercises.
- Gradual progression to more resistive exercises and increasing duration results in resumption of sport.
- It is crucial to instruct the athlete to maintain a flexibility and strengthening program to reduce the possibility of reinjury.
- Injected corticosteroids have been shown to improve symptoms in the short term, but have not been proven efficacious in the long term. Stahl et al. reported significantly less pain at 6 weeks but no significant difference in pain scores compared with the placebo group at 3 months and 1 year follow-up examinations.[3] These may have a role in management between Phases I and II, but their use is controversial.

Goals

- Restore active assisted ROM and AROM
- Pain-free during palpation of the medial epicondyle and flexor muscle mass
- Improve strength
- Address and correct kinetic chain deficits to prevent future injury

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Functional massage per prior phase
- Joint mobilization and mobilization with motion

Soft-Tissue Techniques

- MFR skin-rolling
- MFR mini-roll as previously shown
- Continue with Astym as appropriate
- Modalities per Phase I

Other Therapeutic Exercises

2 sets, 10 repetitions each
- Anterior hip capsule and psoas stretching (3 × 30 seconds each)
- Wrist dumbbell series: 2 or 3 lb, 2 × 10 seconds each; increase weight as appropriate
  - Wrist flexion, extension, supination, pronation
- Wrist straight-arm TB: Straight-arm pull-downs/shoulder extension, rows, alternating rows, shoulder IR/ER
- Half-roll TB with shoulder in horizontal abduction, proprioceptive neuromuscular facilitation (PNF) D2 flexion with wrist in neutral (Figure 9-28)
- Four-way weighted-ball pass to partner (seated on Swiss ball): 2 × 10 in each direction
- For other components of kinematic chain, anterior hip capsule and psoas stretching: 3 × 30 seconds each

Open and Closed Kinetic Chain Exercises

2 sets, 10 repetitions each
- Four-point BOSU rocks (no side-to-side)
- Fingertip pushups
- Walk out on ball with pushup plus scapular protraction

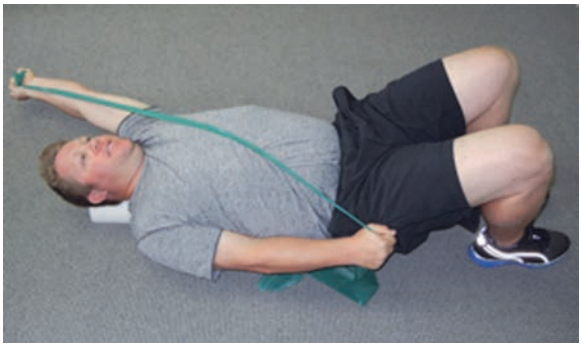

FIGURE 9-28. Half-roll supine Thera-Band shoulder PNF D2.

- Seated on Swiss ball, straight-arm trunk rotation with unilateral knee extension (Figure 9-29)

Plyometrics

2 sets, 10 repetitions each
- Wrist flips with plyoball (Figure 9-30)
- Wall dribble
- IR rebounder eccentric loading

Milestones for Progression to the Next Phase

- Full, pain-free AROM (especially gripping)
- Minimal to zero pain during palpation at the medial epicondyle
- Able to tolerate manual resistance testing of the wrist flexors
- Able to tolerate gripping objects and resisted supination/pronation

Phase III (weeks 6 to 8)

- Initial guidelines: ROM performed pain-free with zero pain at end-range wrist flexion and extension, zero tenderness over the medial epicondyle with stretching or resistance of the wrist flexor muscle group



FIGURE 9-29. Seated Swiss ball straight trunk rotation with unilateral knee extension.

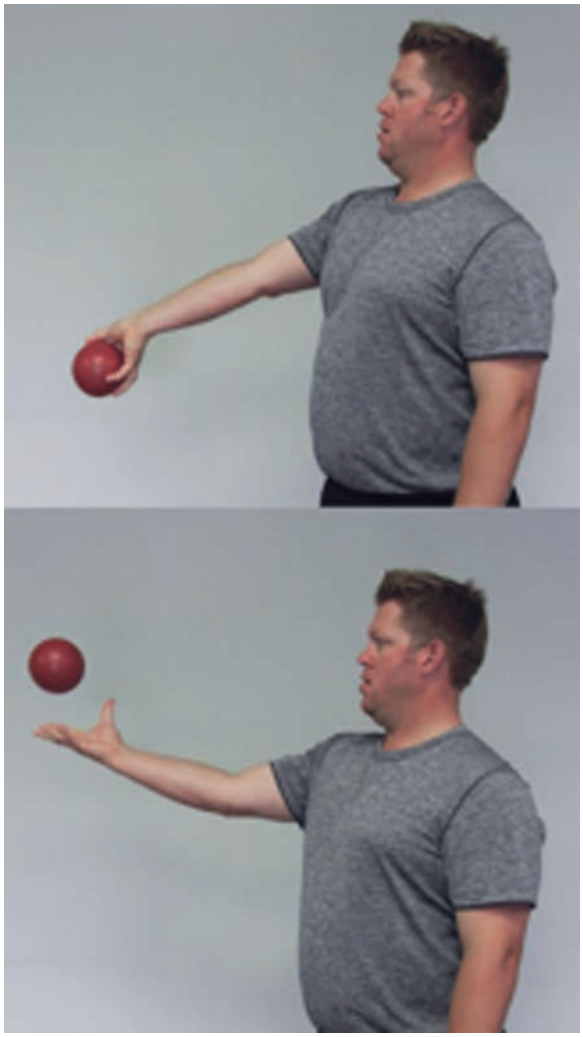

FIGURE 9-30. Wrist flips with plyoball.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Functional massage and joint mobilization per prior phase as appropriate

Soft-Tissue Techniques

- Continue Astym as appropriate

Stretching and Flexibility Techniques for the Musculotendinous Unit

Backswing
- Hip ER walk 3×20 feet, side-stepping with feet outward
- Hamstring stretches, 3 × 30 seconds
- Hip swings ×30
- Latissimus dorsi stretch with hip ER 3 × 30 seconds (Figure 9-31)

Other Therapeutic Exercises

3 sets, 12 repetitions each
- Wrist pulses (fast twitches flexion and extension) with TB



FIGURE 9-31. Standing Latissimus dorsi and hip external rotation combination stretch.

- Wrist eccentrics: Start with 2 or 3 lb and increase 1 lb at a time as appropriate
- Bucket dig: 5-lb bucket filled with long grain rice, pronate/supinate to bottom of bucket ×10
- Pull the curtain (wrist flexion): TB wrist flexion
- Half-roll SASH, a/k/a PNF D1/D2 series, three-way (Figure 9-32)

Open and Closed Kinetic Chain Exercises

- UE step-ups
- Walk out on ball with fishtail (prone on ball bilateral lower extremities move side-to-side on ball)



FIGURE 9-32. Half-roll SASH series.

- Alternating rows with alternating staggered stance position

Techniques to Increase Muscle Strength, Power, and Endurance

- See "Other Therapeutic Exercises" in this phase

Neuromuscular Dynamic Stability Exercises

3 sets, 12 repetitions each
- Four-point foam wrist-rolling
- Bodyblade wrist flicks
- Bodyblade shoulder three-way: sagittal and frontal

Plyometrics

Three sets, 12 repetitions each
- Chest pass, over head, side-to-side
- Hay toss: Stride stance throwing a weighted ball from one side of the body to the other
- Standing torso twists with partner and medicine ball pass
- Medicine ball toss with release at deceleration/impact position (Figure 9-33)

Functional Exercises

- Transverse plane lunges with supination to pronation bar
- Single-leg balance Thera-Band to golf ball impact position (Figure 9-34)
- Single-leg balance TB pulses at golf ball impact position (Figure 9-35)

Milestones for Progression to the Next Phase

- Good overhead squat performed with zero or minimal heel raise; overhead squat shows overall functional strength
- Can hold single-leg stance with eyes closed for 10 seconds. Golf swing is needed with single-leg balance in both legs, from backswing to finish.
- 4/5 strength manual muscle testing: Wrist flexion/extension and elbow flexion/extension



FIGURE 9-33. Medicine ball tosses (release at golf ball impact position).



FIGURE 9-34. Single-leg balance Thera-Band to golf ball impact position.

Phase IV (weeks 8 to 12)

Goals

- Full AROM and end-range stretching of the wrist in all directions tolerated without pain
- Pain-free loading of wrist flexors during multiple repetitions
- Initiate eccentric loading and begin sport training

Techniques for Progressive Increase in Range of Motion

Stretching and Flexibility Techniques for the Musculotendinous Unit

Three times for 30 seconds each
- Thoracic rotation stretches: Prayer position reach through and sidelying with hips and knees at 90° IR and 90° ER
- Continue with previous stretches



FIGURE 9-35. Single-leg balance Thera-Band pulses (club or stick oscillation).

Other Therapeutic Exercises

CKC: 3 sets, 15 repetitions each
- Four-point plank pass of ball to each UE
- Single-leg balance: One-arm rebounder throw
- Stool prone wrist pulls and pushes
- Four-point plank ball roll side-to-side

Open and Closed Kinetic Chain Exercises

- Stool-walk, forward and backward propelled heel drives to move the stool, three times at 20 feet
- Bridge-walk over cones and hurdles, three times at 20 feet

Neuromuscular Dynamic Stability Exercises

- Single-leg reaches on a one-half foam roll: Multidirectional

Plyometrics

Three sets, 15 repetitions
- Seated boat position (seated long-sitting with B legs flexed off the ground) toss with medicine ball (Figure 9-36)

Functional Exercises

Three sets, 15 repetitions
- Single-leg PNF standing with 4- or 5-lb kettle ball

Sport-Specific Exercises

Three sets, 15 repetitions
- Pelvic tilts in golf posture on Bosu
- Two-handed torso rotation while kneeling on Swiss ball (Figure 9-37)

Milestones for Progression to Advanced Sport-Specific Training and Conditioning

- 4+/5 manual muscle test for strength of major muscle groups



FIGURE 9-36. Seated boat toss with medicine ball.



FIGURE 9-37. Kneeling on Swiss ball with two-handed torso rotation.

- Ability to load the elbow joint with wrist flexors activated, ability to lift 5 lb or more while keeping elbow flexed and extended.
- Absorbing impact position, the ability to swing a golf club and hit the ground or ball with no pain
- Ability to use the core to provide good energy transfer to the UE, complete planks series (prone plank, side plank, supine plank)

Criteria for Abandoning Nonoperative Treatment and Proceeding to Surgery or More Intensive Intervention

- Failed conservative management for a minimum of 3 to 6 months
- Poor progression in rehabilitation along with tendon avulsion or tear seen on magnetic resonance imaging scan in a high-demand athlete
- Continued or worsening objective changes, such as swelling, atrophy, and weakness
- Pain persisting past Phase III or interference with daily activities or sleep

Tips and Guidelines for Transitioning to Performance Enhancement

- Once rehabilitation is complete and the athlete is back to preinjury status, begin to evaluate the athlete's sport-specific demands
- Begin with a fitness examination with the goal of maximizing athletic potential. Prior medical history and injury history are ideal bases for developing a training program for the athlete.
- Posture and body mechanics are important to determining whether the athlete needs basic correction of alignment before performance training.
- The fitness examination or dynamic movement analysis allows determines if the athlete can move and perform according to the physical demands of the sport (Functional Movement Screen score of 14 or better).
- Correcting the athlete's imbalances will allow proper training and avoid injury. This means that the key is optimal body movement without weight before weight or resistance is added.
- Prevention of injuries and proper posture throughout movement-specific tasks allows the stage to be set for performance training.
- The goal is functional training—multiplanar movement involving acceleration, deceleration, and stabilization.

Performance Enhancement and Beyond Rehabilitation: Training/Trainer and Optimization of Athletic Performance

- Typically, the golf swing is described as a pendulum with the shoulders and arms taken as a single, rigid unit hinged to the golfer's body or trunk and the golf club hinged at the wrists and hands.
- It has been noted that the downswing motion can be initiated at the legs and hip muscles, followed by the upper-body muscles, and that the trunk is the body segment that connects the legs to the arms.[4] This supports the concept that trunk rotation, hip torque, and weight transfer provide the force and torque to the shoulders and arms.
- EMG-based studies have shown high levels of gluteus maximus and hip stabilizer activity as well as high erector spinae and abdominal oblique activity during certain phases of the golf swing.[2] Therefore, simple physics can connect the kinetic chain during a golf swing to address forces that the elbow sustains as a result of inadequacies or limitations (ROM, strength and/or neuromuscular control) at the hip, trunk, and shoulder. This is the rationale behind optimizing athletic performance and avoiding future injury during the rehabilitation process by addressing hip, trunk, shoulder, elbow, and wrist strength; AROM; and neuromuscular control.
- The stored power accumulated during the backswing is applied to the golf ball at impact in a specific and sequential order:
  - Uncocking of the left wrist at release, followed by straightening of the right arm, thus applying forces at the right arm
  - Rolling of the hands to maintain rhythm, followed by contact of the upper left arm, thus adding the force of the rotating trunk
- A good golf swing has been noted to apply almost no torque to the grip of the club. Furthermore, those with injuries have been shown to be clinically weaker and less mobile than asymptomatic golfers.[5] Therefore, appropriate wrist strength and control for stabilization during impact could prevent premature wrist flexor muscle activation, saving it for the flexor burst that typically occurs at ball impact to counter the energy transference (equal and opposite reaction), as seen in asymptomatic golfers.[1] This may assist in protecting

the tendon attachment site at the medial, and occasionally lateral, epicondyles.

Specific Criteria for Return to Sports Participation: Tests and Measurements

- Athlete is pain-free
- No swelling or edema
- Full active ROM compared to opposite side
- Athlete has within 80% strength (manual muscle-testing) compared to opposite side
- Perform proper movement patterns during sport specific activities
- The ability to load body weight through the upper extremities and complete pushup

Evidence

Cahalan TD, Cooney WP, 3rd, Tamai K, et al: Biomechanics of the golf swing in players with pathologic conditions of the forearm, wrist, and hand. *Am J Sports Med* 19:288–293, 1991.

Twenty subjects with a variety of upper-extremity disorders participated in the study to quantitate wrist motion and club head and ball impact force in a controlled environment. Although it was understandable that the involved group was clinically weaker, it was noted that they used more motion during their swings. This may have been due to the theory that the motion required for a full swing may stress the wrist beyond its limits, and, due to the weakness, they may not be able to resist the forces the wrist endures, allowing excessive motion. Therefore, good concentric and eccentric control, as well as mobility and strength, in not only the wrist but also the kinetic chain may be necessary to avoid injury. (Level II evidence).

Glazebrook MA, Curwin S, Islam MN, et al: Medial epicondylitis: an electromyographic analysis and an investigation of intervention strategies. *Am J Sports Med* 22:674–679, 1994.

An EMG study performed to compare the amount and/or timing of muscle activity in the common flexor and extensor muscles during the golf swing of symptomatic and asymptomatic subjects of low and high golf-scoring ability. Although the study did find biomechanical alterations when subjects used a club with an enlarged grip, it did show that both groups utilize significant amounts of flexor muscle activity during the contact phase, with higher amounts in the symptomatic group. This may indicate that more muscles of that group are utilized more often and therefore could cause damage to more muscles in the flexor group. (Level II evidence).

Gosheger G, Liem D, Ludwig K, et al: Injuries and overuse syndromes in golf. *Am J Sports Med* 31:438–443, 2003.

An epidemiologic study of 24 randomly selected golfers to uncover associations in age, sex, body mass index, warm-up routines, and playing-level data with occurrence of reported injuries. It was discovered that 82.6% of reported injuries involved overuse with typical injuries in the back, wrist, and shoulder, providing further support for the inclusion of hip, back, shoulder, and wrist in a good rehabilitation program. (Level III evidence).

Okuda I, Gribble P, Armstrong C: Trunk rotation and weight transfer patterns between skilled and low skilled golfers. *J Sports Sci Med* 9:127–133, 2010.

The full-shot golf swings of 13 skilled golfers and 17 low-skilled golfers were studied via three-dimensional videography and force plates to examine trunk rotational patterns and weight transfer patterns between skilled and low-skilled golfers. It was shown that skilled golfers had significantly less upper trunk horizontal rotation, which was explained with the notion that it may have been due to purposeful eccentric control earlier in the swing to transfer momentum to either the club or the distal body. This provides support for addressing trunk mobility, neuromuscular control, and strength of the hips, pelvis, and trunk during the rehabilitation process. (Level III evidence).

Stahl S, Kaufman T: The efficacy of an injection of steroids for medial epicondylitis: a prospective study of sixty elbows. *J Bone Joint Surg Am* 24:535–538, 1996.

A randomized, double-blind, prospective study in which the short-term and long-term effects of a local steroid injection to treat medial epicondylitis were analyzed. The investigators concluded that these injections offer only short-term relief of 6 weeks to 3 months. (Level II Evidence).

Watkins R, Uppal J, Pink M, et al: Dynamic electromyographic analysis of trunk musculature in professional golfers. *Am J Sports Med* 24:535–538, 1996.

A prospective study performed to uncover the high rate of back injury in golfers. Using EMG the muscle activity of bilateral abdominal obliques, gluteus maximus, erector spinae, and upper and lower rectus abdominal muscles was evaluated during various phases of the golf swing in 13 male professional golfers. The findings showed consistent patterns of trunk muscle activity throughout all phases of the golf swing, providing a basis for addressing deficits in those areas in a rehabilitation program. (Level III evidence).

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3. Stahl S, Kaufman T: The efficacy of an injection of steroids for medial epicondylitis: a prospective study of sixty elbows. *J Bone Joint Surg Am* 24:535–538, 1996.
4. Okuda I, Gribble P, Armstrong C: Trunk rotation and weight transfer patterns between skilled and low skilled golfers. *J Sports Sci Med* 9:127–133, 2010.
5. Cahalan TD, Cooney WP, 3rd, Tamai K, et al: Biomechanics of the golf swing in players with pathologic conditions of the forearm, wrist and hand. *Am J Sports Med* 19:288–293, 1991.

Multiple-Choice Questions

QUESTION 1. Which one of the statements is correct about Phase I?

A. Protection of healing tissues
B. Rest
C. Pain-free PROM
D. All of the above

QUESTION 2. Which nerve is most involved and best for neural glides for treatment of golfers elbow?

A. Musculocutaneous
B. Axillary
C. Median
D. Ulnar

QUESTION 3. Which phase is best to start plyometrics?

A. Phase I
B. Phase II
C. Phase III
D. Phase IV

QUESTION 4. Which muscles are most appreciated in the diagnosis of medial elbow pain (golfer's elbow)? (Circle all that apply)

A. Flexor carpi ulnaris
B. Pronator teres
C. Flexor carpi radialis
D. Flexor digitorum

QUESTION 5. Please circle all that apply to the following statement: The manual techniques will help increase blood flow to the medial epicondyle.

A. Astym
B. Cross-friction massage
C. Functional massage
D. All of the above

Answer Key

QUESTION 1. Correct answer: **D** (Phase I)

QUESTION 2. Correct answer: **D** (Manual Therapy Techniques)

QUESTION 3. Correct answer: **C** (Phase III)

QUESTION 4. Correct answer: **A** and **B** (Phase I: Muscle Activation)

QUESTION 5. Correct answer: **D** (Manual Therapy Techniques)

BEYOND BASIC RECOVERY: RETURN TO GOLF AFTER TREATMENT FOR MEDIAL EPICONDYLITIS (GOLFER'S ELBOW)

Steven Michael Scher, MSPT, ATC, CSCS, PES, TPI, Stacie Christine Graves, MS, PA-C, Beth E. Richardson, DPT, and Kyle Anderson, MD

ASPECTS OF GOLF THAT REQUIRE SPECIAL ATTENTION IN REHABILITATION

- Although medial epicondylitis is termed "golfer's elbow," lateral epicondylitis is still more common in golfers.
- Golf club grip: Size of grips, position of hands, tension placed on club
- Proper swing mechanics: Medial elbow pain seen most often when golf club deviates from proper plane on the backswing, resulting in compensatory movements and injury
- Inflexibility or improper technique
- Even minor deviations in technique can be magnified with extreme overuse and practice regimens.

Phase I: Advanced Strength and Conditioning Programs (weeks 1 to 3)

- Preparation phase: correct movement pattern

Week 1

Flexibility/Warmup

- Arm circles
  - 50 big and 50 small
- Lunge walk to trunk rotation 3 × 30 ft
- High-step karaoke walk 3 × 30 ft
- Single-leg toe-touch reaches for hamstring ×10 each leg, hold stretch for 30 seconds each
- Stride lunge buddy latissimus dorsi stretch 3 × 30 seconds (Figure 9-38)

Joint Stability/Strength Program

- Rhythmic stabilization (RS)
  - Tubing shoulder horizontal adduction and abduction: Three times to fatigue
- Wall-draws on ball
  - Three times to fatigue (forward–back, side to side)
- Proprioceptive neuromuscular facilitation (PNF) chops seated on ball
  - 3 sets of 8
- Straight arm: Resisted Thera-Band (TB) one-handed supination to pronation (Figure 9-39)
  - TB/tubing: Three sets of eight

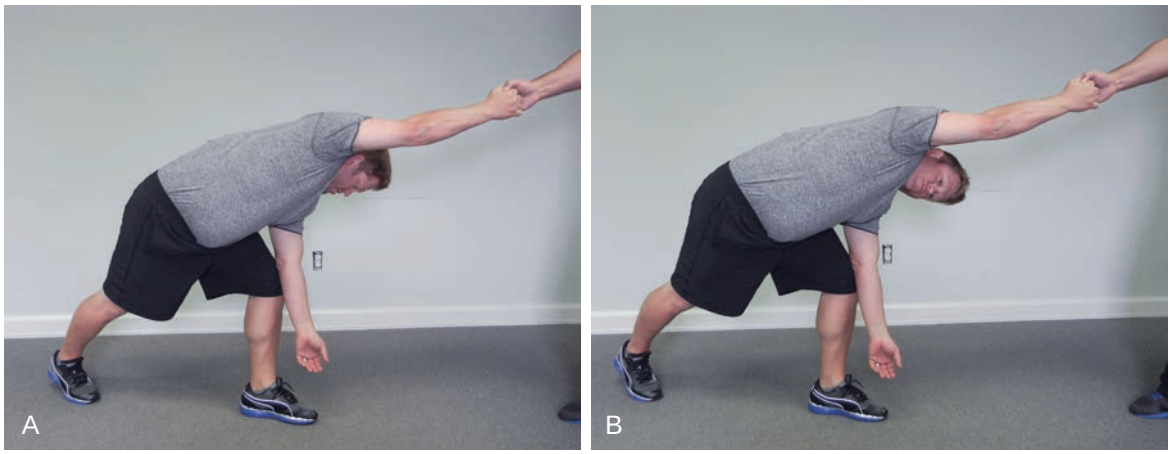


FIGURE 9-38. A, B, Stride lunge buddy latissimus dorsi stretch.

- Single-arm row (tubing/band/cable column)
  - Short arm, 3 sets of 10
  - Long arm, 3 sets of 10
- Prone Swiss ball (W, Y, and T): Lying flat, face down on ball, make W, Y, and T shapes with both arms. The exercise will start below body plane/top of ball, and each position will finish at body plane.
  - 3 × 10, arm weight
  - Proper upper- and lower-body form observed
- Body-weight squat: Overhead bar
  - Correct posture and form, 3 × 10
- Closed chain
  - BOSU rocks: Forward and back, side to side, three sets of eight
  - Pushup walk-up, 2-inch box, three sets of eight
- Trunk/core stabilization: Abdominal drawing-in maneuver (transverse abdominus)
  - Supine draw-in, three sets of eight (Figure 9-40)
  - Bridge draw-in, three sets of eight
  - Four-point/quadruped, three sets of eight
- Foam-rolling: Dynamic myofascial release/cool-down program
  - Hip external rotation (ER)/piriformis, gluteus (full pass on foam-roll from iliac crest to ischial tuberosity)
  - Iliotibial band (ITB) (Figure 9-41)
  - Rectus femoris
  - Hamstrings

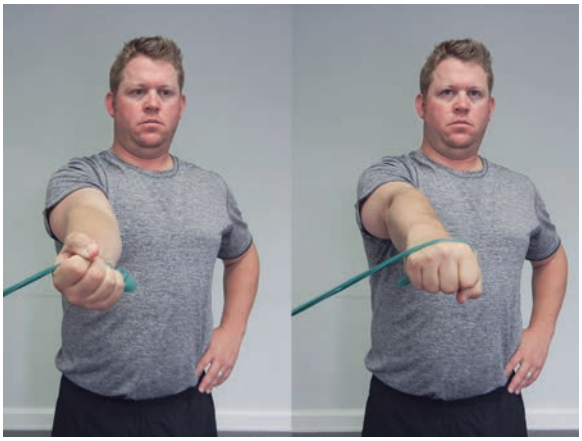


FIGURE 9-39. Straight-arm one-handed supination to pronation resisted Thera-Band.

Week 2

Flexibility/Warmup

- Arm circles
  - 50 big and 50 small
- Lunge walk to trunk rotation 3 × 30 ft



FIGURE 9-40. Supine draw-in (transverse abdominus muscle).



FIGURE 9-41. Iliotibial band foam-rolling (myofascial release).

- High-step karaoke walk 3 × 30 ft
- Latissimus dorsi stride-step buddy stretch, 3 × 30 seconds in stride step (reach and grasp hands of buddy (or golf cart)). To reference, the back leg is the same side of arm being stretched. Look under armpit of the stretched-out arm and simultaneously lean back.
- Single-leg toe-touch reaches for hamstring ×10 each leg, hold stretch for 30 seconds
- Foam-rolling: Dynamic myofascial release/cool-down program
  - Hip ER/piriformis, gluteus
  - Iliotibial band (ITB)

TIMELINE 9-5: **Rehabilitation of Medial Epicondylitis (Golfer's Elbow)**

PHASE I Preparation (weeks 1 to 3)

week 1

- Warmup: Arm circles, lunge walk to trunk rotation and high-step carioca 3 × 30 ft
- Flexibility/stretching and dynamic myofascial release
  - Stride lunge buddy latissimus dorsi stretch 3 × 30 s
  - Foam-rolling: Hip ER, piriformis, gluteal muscles, ITB, rectus femoris, hamstrings 3 × 30 s
- Joint stability and rhythmic stabilization: Wall-draws, PNF chops on ball, single-arm row, prone Swiss ball (W, T, Y), body weight squat: 3 sets of 10 repetitions

week 2

- Same warmup, flexibility, and foam-rolling as wk 1
- Joint stability and rhythmic stabilization: Wall-draws, tubing pulses with shoulder horizontal adduction and abduction six times to fatigue
- PNF chops on ball, single-arm row, prone Swiss ball (W, T, Y), body weight squat: 3 sets of 10 repetitions
- Hip rotation: Kneeling hip Thera-Band resisted rotation: IR and ER, 3 × 10
- Single-arm row: Short-arm and long-arm, 3 × 10 each
- Straight-arm supination to pronation, Thera-Band: 3 sets of 10
- Closed chain: BOSU rocks and pushup walk, 6-inch box, 3 sets of 10
- Trunk and core stabilization: Transverse abdominus draw-in, seated horizontal chops, standing single-leg chops/lawnmower: All for 3 sets of 10 repetitions

week 3

- Use prior warmup from wk 1 and 2 plus 15 upper body ergometer
- Foam-rolling, rhythmic stabilization, and wall-draws on ball
- Joint stability/strength: Tubing pulses, shoulder horizontal adduction and abduction, and wall-draws on ball: 8× to fatigue
- PNF chops seated on ball, add 3–5 lb, supination to pronation, single-arm row in opposite direction, single-leg balance short and long arm: 3 × 12
- Closed chain: BOSU rocks and pushup walk 6-in box: 3 × 12
- Trunk/core stabilization: Transverse abdominus, single-leg bridge draw-in, seated horizontal chops, standing single-leg chops/lawnmower, add 3–5 lb: All for 3 ×12
- Kneeling hip Thera-Band-resisted rotation, ER and IR: 3 × 12

PHASE II (weeks 4 to 6)

week 4

- Continue warmup and foam-rolling from preparation phase
- Dynamic trunk: Lunge walks, backward dive, supine-lying trunk twists, single-leg crossover latissimus stretches, hip flexor sleeper stretches
- Upper-extremity-specific: Dumbbell training with large grips performed in golf iron posture (supination and pronation, wrist extension and flexion, elbow flexion and extension): Three sets of eight repetitions with 5 lb
  - Bicep curl single-leg squats: 5–10 lb
  - X-outs with tubing, alternate arm, 3×8
  - Overload training with Bodyblade: Wrist 3× to fatigue
- Sensorimotor: Single-leg balance on foam pad with opposite Thera-Band hip abduction, 3 × 8
- Core training: Side plank series with windmill, ball bridge to alternate leg drop-off, both 3 × 8
- Torso rotations with lunge walk with 5-lb weighted ball, 3 × 8
- Plyometric: Trunk rotation development
  - Seated boat rotation, Russian twist, front twist throw, side throw, backward twist throw, all 3 × 8 with 5-lb weighted ball
- Multiplanar: Diagonal dumbbell press with squat and lunge, 3 × 8, 5-lb dumbbells
  - Transverse lunge with supination/pronation, 3 × 8 with 5-lb dumbbells

week 5

- Follow week 4, 3 × 10, increase weight by 3–5 lb per exercise

week 6

- Follow weeks 4 and 5, 3 × 10, increase weights by 3–5 lb per exercise

PHASE III (weeks 7 to 8)

week 7

- Two-handed powerball decelerations: Stop at impact position, start at impact position to follow-through, single-leg deadlift row, all 3 × 8
- Core resisted Thera-Band bird dog (quadruped): Opposite arm and leg, 3 × 8
- Eccentric backswing Thera-Band on BOSU, BOSU squat alternate trunk rotations, 3 × 8
- Single-leg balance golf stance Bodyblade, 3× to fatigue
- Squat weighted ball rotation raise: Double-leg, single-leg: 3 × 8, 20 lb
- Alternate dumbbell dynamic side plank, 3 × 8

week 8

- Warmup 15-minute jog
- Foam-rolling: Continued prior to and following training session
- Flexibility: Same as previous week with increase in repetitions to 3 × 10

- Rectus femoris
- Hamstrings

Joint Stability/Strength Program

- RS
  - Tubing shoulder horizontal adduction and abduction six times to fatigue
- Wall-draws on ball
  - Six times to fatigue (forward–back, side to side)
- PNF chops seated on ball
  - 3 sets of 10
- Straight arm: Two-handed supination to pronation
  - Thera-Band/tubing: 3 sets of 10
- Single-arm row
  - Short arm, 3 sets of 10
  - Long arm, 3 set of 10
- Prone Swiss ball (W, Y, and T)
  - 3 × 10, 3lbs
- Closed chain
  - Bosu rocks: Forward and back, side to side, 3 sets of 10
  - Pushup walk-up, 4-inch box, 3 sets of 10
- Trunk/core stabilization: Draw-in (transverse abdominus)
  - Single-leg bridge draw-in, 3 sets × 10
  - Seated horizontal chops, 3 ×10
  - Standing single-leg chops/lawnmower, 3 × 10 (Figure 9-42). This exercise replicates a pull of a lawnmower. By facilitating the hips to lead to upper-extremity (UE) movement. This allows contralateral hip to ipsilateral hip movement to the involved UE by performing diagonal pattern and ER of the glenohumeral joint.
- Hip rotation
  - Kneeling hip TB resisted rotation
    - ER and internal rotation (IR), 3 × 10

Week 3

- Use prior warmup from weeks 1 and 2, plus 15 upper-body ergometer



FIGURE 9-42. Standing single-leg chops/lawnmower.

- Foam-rolling: Dynamic myofascial release/cool-down program
  - Hip ER/piriformis, gluteus
  - ITB
  - Rectus femoris
  - Hamstrings

Joint Stability/Strength Program

- RS
  - Tubing pulses: Shoulder horizontal adduction and abduction
  - Eight times to fatigue (forward–back, side to side)
- Wall-draws on ball
  - Eight times to fatigue (forward–back, side to side)
- PNF chops seated on ball, add 3 to 5 lb
  - 3 sets of 12
- Straight arm: Two-handed supination to pronation
  - Thera-Band/tubing 3 sets of 12, increase resistance
- Single-arm row in opposite single-leg balance: Opposite side single-leg balance facilitates gluteus and core stabilization of the trunk, also activates the latissimus dorsi muscle. Perform a single-arm straight low row while standing on single leg of contralateral side.
  - Short arm, 3 sets of 12
  - Long arm, 3 sets of 12
- Prone Swiss ball (W, Y, and T)
  - 3 × 12 (5 lb)
- Closed chain
  - BOSU rocks: Forward and back, side to side, 3 sets of 12
  - Pushup walk 6-inch box, 3 sets of 12
- Trunk/core stabilization: Draw-in (transverse abdominus)
  - Single-leg bridge draw-in, 3 sets × 12
  - Seated Horizontal Chops, 3 x 12
  - Standing single-leg chops/lawnmower, 3 × 12, add 3 to 5 lb
- Hip rotation
  - Kneeling hip TB resisted rotation
    - ER and IR, 3 × 12

Phase II: Performance Enhancement Training Techniques (weeks 4 to 6)

- Continue warmup from preparation phase
- Foam-rolling from preparation phase

Week 4

Performance-Specific Flexibility Program: Anterior Hip/Psoas and Dynamic Trunk

- Lunge walks
- Backward dive (Figure 9-43)
- Supine trunk twists
- Latissimus dorsi buddy stretch
- Hip sleeper stretches while in sidelying with involved side down and hip and knee at 90°. Place a large towel or belt around foot, and pull foot, pulling hip, into IR. The increase stretch can be intensified by the pull or by



FIGURE 9-43. Backward dive (dynamic psoas stretch).

the body rolling toward the involved side being stretched.

Upper-Extremity-Specific

- Dumbbell training with large grips performed in golf iron posture:
  - Supination and pronation, 3 × 8, 5 lb
  - Wrist extension and flexion, 3 × 8, 5 lb
  - Elbow flexion and extension, 3 × 8, 5 lb
- Bicep curl single leg Squats, three sets of eight, 5 to 10 lb
- X-outs with tubing: Alternate arm, three sets of eight (Figure 9-44).
  - Position both hands inside tubing, so tubing is around both wrists.
  - Perform an X pattern with both arms, one arm at a time or at the same time.
- Overload training, Bodyblade (wrist): Three times to fatigue



FIGURE 9-44. X-outs with Thera-Band.

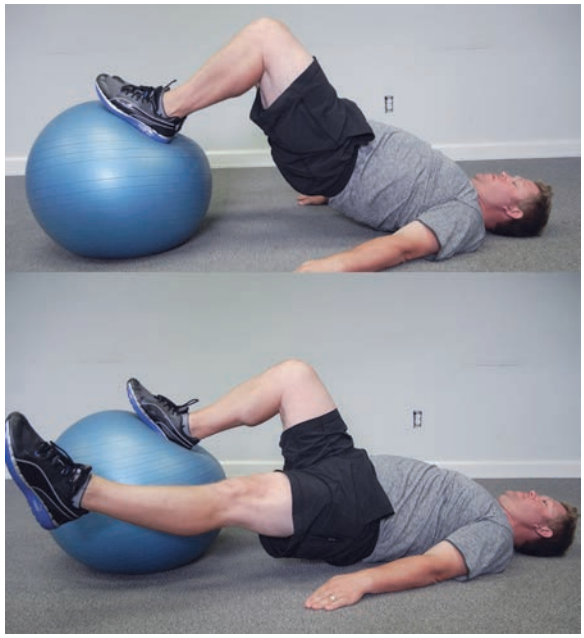


FIGURE 9-45. Ball bridge to alternate leg drop-off.

Sensorimotor

- Single-leg balance on foam pad with opposite TB: Hip abduction, three sets of eight

Core Training

- Side plank series with windmill, three sets of eight in side plank position reach with opposite arm to the ceiling, then switch to other side and repeat, making a windmill.
- Torso rotations with lunge walk, three sets of eight, weighted ball 5 pounds
- Ball bridge to alternate-leg drop-off, three sets of eight (Figure 9-45). Perform a bridge on stabilization ball (pelvis off ground), drop off one leg and lower slowly to the ground.

Plyometric: Trunk Rotation Development

- Seated boat rotation, three sets of eight, 5-lb weighted ball: Side to side in a "boat" or "V" position (low back or legs off ground). Take a weighted ball and rotate side to side of the abdomen.
- Russian twist, three sets of eight, 5-lb weighted ball (Figure 9-46)
- Front twist throw, three sets of eight, 5-lb weighted ball
- Side throw, three sets of eight, 5-lb weighted ball
- Backward twist throw, three sets of eight, 5-lb weighted ball

Multiplanar

- Diagonal dumbbell press, three sets of eight, 5-lb dumbbells
  - With squat
  - With lunge
- Transverse lunge with supination–pronation (elbow specific, three sets of eight, 5 lb)



FIGURE 9-46. Russian twist with weight ball.

Week 5

- Follow week 4, 3 sets of 10, increase weight 3 to 5 lb per exercise

Week 6

- Follow weeks 4 and 5, 3 sets of 10, increase weights 3 to 5 lb per exercise
- During performance enhancement phase, the weeks can be altered to focus more on endurance, strength, or power.
- For endurance, increase sets to four to six with rest 30 seconds between sets, low intensity, and high volume.
- For strength focus, sets of three to five, rest phase 30 to 60 seconds, intensity moderate with high volume.
- Last, power sets three to five, rest 120 to 240 seconds between sets, intensity high, and volume moderate to low.

Phase III: Sport-Specific Training (weeks 7 and 8)

- 15-minute warmup jog
- Foam-rolling: Continued, prior, and after training session
- Flexibility: Same as Phase II

Week 7

- Two-handed powerball decelerations with a powerball or weighted ball in both hands, throw down to waist height while stopping the ball before it gets to the waist.
  - Stop at impact position, three sets of eight
  - Start at impact to follow-through, three sets of eight
- Single-leg deadlift row (hamstring focus), three sets of eight
- Core-resisted TB bird dog (quadruped) (Figure 9-47) in a four-point position. Place TB around left foot and right hand. With the TB attached, lift the left foot and right hand to straight-arm position, applying resistance to the Thera-Band and controlling a two-point position.
  - Opposite arm and leg, three sets of eight, tubing/band
- Eccentric backswing TB on bosu, three sets of eight
- Single-leg balance golf stance bodyblade, three sets to fatigue
- Torso rotation: Single-leg, three sets of eight, TB resistance
- BOSU squat alternate trunk rotations, three sets of eight
- Squat weighted ball rotation raise, three sets of eight, 20 lb (Figure 9-48)
  - Double-leg
  - Single-leg
- Alternate dumbbell dynamic side plank, three sets of eight

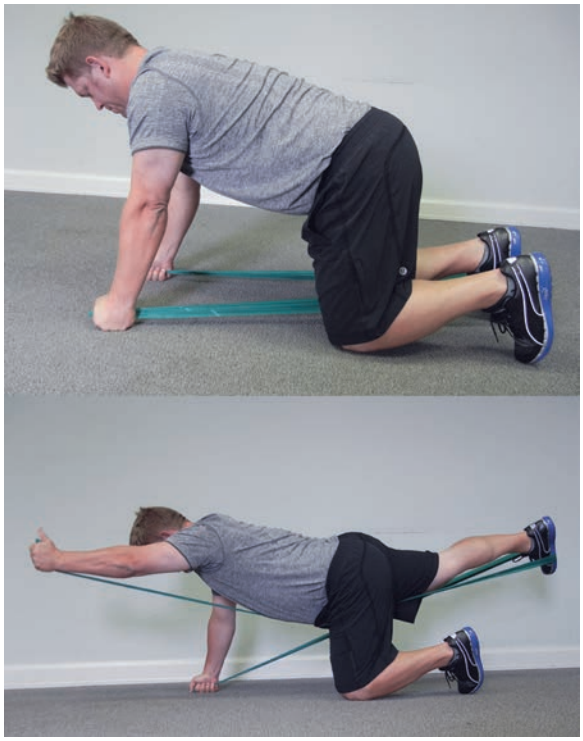


FIGURE 9-47. Thera-Band bird dog (quadruped opposite arm and leg).



FIGURE 9-48. Squatted medicine ball rotation raise.

Week 8

- Warmup 15-minute jog
- Foam-rolling: Continued, prior and after training session
- Flexibility: Same as prior phase
- Two-handed powerball decelerations
  - Stop at impact position, 3 × 10
  - Start at impact to follow-through, 3 × 10
- Single-leg deadlift row, 3 × 10
- Core-Resisted
  - TB Bird Dog (quadruped)
    - Opposite arm and leg, 3 × 10, tubing/band
- Eccentric backswing TB on BOSU, 3 × 10
- Single-leg balance golf stance Bodyblade, 3 x fatigue
- Torso rotation single-leg, 3 × 10, TB resistance
- BOSU squat alternate trunk rotations, 3 × 10
- Squat weighted ball rotation raise, 3 × 10, 20 lb
  - Double-leg
  - Single-leg
- Alternate dumbbell dynamic side plank, 3 × 10

Sports Performance Testing

History

- General history: Age, height, weight, prior injuries
- Medical history: Differential diagnosis, lateral epicondylitis, autoimmune diseases, diabetes, and circulation difficulties
- Surgical history: Prior capsular release of the medial or lateral elbow, shoulder or cervical disc pathology C5-C7
- Sports injury history: triangular fibrocartilage complex (TFCC) injury, back injury, lead shoulder problems, posterior shoulder hypermobility, anterior hip injury
- Chronic conditions/medications: Osteoarthritis, diabetes, total joint replacement

Sport-Specific Testing

- Golf posture: Two main posture types
  - S-posture: Excessive lumbar lordosis
  - C-posture: Excessive thoracic kyphosis
- Both of these common golf postures at address can cause major swing faults and lead to back and sport injury. In order to observe these faults, specific testing is needed to evaluate the body's capability to move, coordinate, and sequence a series of defined movements that make a golf swing.
- Refer to Table 9-1 for a list of the standard sport-specific tests for golf.

Specific Criteria for Progression from Advanced Strength Phase to Performance Enhancement

- Learn basic movement for each exercise, especially in preparation phase (observed with proper form and good posture).
- Body weight resistance first with good form and body mechanics
- Simple weight before complex/multidirectional movement patterns
- Resistance to fatigue completing third set of RS: Golfer can complete 3 sets of RSs, with each set lasting 20 to 30 seconds.
- Able to maintain golf/optimal posture throughout the advanced strength phase: Observe golf address and swing, looking for breakdown in posture (no C or S posture types).
- Improved flexibility from prescreen examination of hamstrings and hip rotation: Golfer passes the toe-touch test from golf screen.

Specific Criteria for Progression from Performance Enhancement to Readiness for Golf

- Increase flexibility noted by stretches or exercises completed with no loss of balance or lack of coordination: Completion of latissimus dorsi reach test, reach roll and lift test, and toe-touch test.
- All exercises performed in correct form, maintaining posture throughout all sets and repetitions
- Understand the feeling of separation between the trunk and hips to generate and release energy.
  - Completion of pelvic tilt, pelvic rotation, torso rotation, and lower-quarter rotation.
  - Completion of rolling. Rolling establishes coordination between upper and lower body. There are eight types of rolling exercises, four each in supine and prone positions: Initiate in left UE Z, right UE, left lower extremity (LE), and right LE. Repeat the same four in prone position. Observe the ability for the golfer to initiate with the extremity and complete the roll-over.

Table 9-1 Standard for Sport-Specific Testing for Golf: Titleist Performance Institute (TPI) Golf Screen: Identifying Limitations of the Golfer

Pelvic tilt test	Begin with player in stance, normal 5-iron posture (hip hinge as if the athlete is addressing a golf ball), with arms crossed over the chest. Observe standing posture and look for C and S posture. Ask the athlete to tilt the pelvis forward or anteriorly, and backward or posteriorly. Observe the amount of motion and the quality of the motion (a/k/a "shake and bake"). Observe for proper sequence from anterior tilt to posterior tilt. Observe the pelvic movement for quality (smooth or "shake and bake") and quantity of movement. In address positon, check whether the golfer is in neutral, excessive anterior tilt, or posterior tilt. As the golfer performs the tilt test, check for limitation in either anterior or posterior tilt.
Pelvic rotation test	Differentiates the ability of the lower body to rotate from the upper body. Begin in 5-iron posture with arms crossed over the chest. The golfer must keep the upper body still and rotate the lower body. Assess whether this issue is a mobility or stability problem. Observe quality of motion and amount between left and right. Hip rotation and thoracic and lumbar spine mobility can cause a limited pelvic rotation test. Smooth turn is observed without lateral movement or sway. Also, watch for the torso to be stationary during the test. Observe for good mobility: Both limited, limited left, limited right.
Torso rotation test	Assess the ability of the golfer to move the upper body independently of the lower body. In 5-iron posture, the athlete rotates the upper body with arms crossed against chest and keeps the lower body still. Observe the rotation motion side-to-side, assessing mobility and stability between the upper and lower body. Observe the upper body turning while the lower body is still. Observe good mobility: both limited, limited right, or limited left.
Overhead deep squat	A valuable assessment tool, it can be used to assess bilateral mobility and stability of the hips, knees, shoulders, and ankles. If a golfer cannot perform a deep squat, it is impossible for the golfer to maintain posture during the golf swing. Begin standing feet shoulder width apart and toes pointing forward, then grip a dowel rod or golf club overhead with elbows bent. With the shaft overhead and body in line, squat down as far as possible, keeping the club high above the head. Assess for pain, heels coming off the ground, loss of balance, and form. Observe the following criteria: Full deep-squat position, calf flexibility, weight distribution left and right, and limited in hip and knee mobility.
Toe-touch test	Assess for hamstring and low back mobility or flexibility. Look for good hip hinge and forward bend. Have player stand feet together and toes forward. Have them try and touch the tips of their fingers to their toes. Do not let them bend their knees. Unilateral toe touch can be offered for hip joint mobility. (Observe if the golfer can touch both toes (limited or not), and assess unilateral – right versus left. Test will allude to hamstring flexibility or hip mobility concerns.)
90°/90° shoulder test	Demonstrates the mobility of the glenohumeral joint and the stability in the scapulothoracic joint. The athlete can stand tall or in 5-iron posture, looking at the amount of glenohumeral external rotation (ER). The arm is abducted to 90° and elbow flexed at 90°, and the athlete rotates the arm back. This test is measured by less than spine angle, equal to spine angle, or more than spine angle. Limited rotation can lead to shoulder injuries. Measure full ER of the glenohumeral joint and observe if the forearm does not rotate externally past the angle of the spine (less than spine angle, equal to spine angle, or more than spine angle). Compare side to side.
Single leg balance test	Assess overall balance, but also core stability. The athlete stands tall with arms at side. Have one leg lifted until one thigh is parallel to the ground. Once stable, have the golfer close eyes and see how long he or she can maintain balance. Perform a single-leg balance for 25 seconds. If 25 seconds are completed with loss of balance, repositioning of the foot, or sway, the golfer has passed the test. The golfer must keep the opposite hip and knee flexed 90° during the test.
Latissimus dorsi length test	The flexibility of the latissimus dorsi muscle is important in the golf swing. The athlete performs a wall squat with back flat against wall. The back needs to stay flat at all times. The athlete lifts his or her arms up, elbows straight, and tries to touch the thumbs to the wall overhead. The golfer cannot bend the elbows, arch the back, or have pain. Observe whether the arm angle is below 120°, between 120° and 169°, or greater than 169°.
Seated trunk rotation test	The goal of this test is to get an appreciation for how much rotational mobility occurs at the lumbothoracic spine. Ask athlete to sit on a stool in upright position and arms crossed over the chest. Hold a bar/club across the shoulders. Use two clubs on the floor to create 45° degrees angles to assess rotation. The player should rotate as far as possible left and right to observe for quantity of motion keeping knees together and shoulder blade retracted. Observe for the athlete to move past the 45° club angle. Typical range of motion is 45° to 70°. Differences between sides do occur; observe for protraction or retraction of the scapula. Differences between sides are common.
Lower-quarter rotation	In tall stance, with one leg straight and the other up on the toe, rotate around the down leg. Keep hands on hips and hips square. The athlete rotates in ER and IR on the down leg. Assess both sides. Create two angles on the ground by using a 6 iron at approximately 60° to 62°. Many present with less than 40° hip ER and IR. PGA tour average is 60° in both directions. The golfer holds dowel rod or club across the posterior superior iliac spine, and then rotates as far as possible in each direction.
Bridge with leg extension test	Good dynamic movement assessment test for pelvis, lumbar spine, and core stability, specifically the gluteal muscle group. Golfer starts on the floor with knees bent and arms straight at shoulder height. The athlete bridges parallel to the floor, extending right leg from the knee. Hold this position for 10 seconds. Stability on the right side is questioned with left-side hip drop or left-leg shakes. Inhibition of the gluteal muscles can occur with cramping in hamstring or back. Repeat on both sides. Observe if there is cramping down (hamstring) in the leg indicating weakness in the gluteal muscles. Observe pelvic drop between one side and the other. The pelvis must stay level.
Reach, roll, and lift test	Scapular mobility and lower trapezius strength is important for the golf swing. The athlete needs to be in the prayer stretch position, resting backside on the heels and head on one fist. The other arm is reached out as straight as possible palm down, then palm turned up and arm lifted off the ground. Observe the ability of the golfer to keep arm straight and lift it. If the golfer cannot complete the test, evaluate glenohumeral joint mobility, latissimus dorsi flexibility, and upper thoracic kyphosis.

Courtesy of Greg Rose, Dave Phillips, and Lance Gill, Titleist Performance Institute, Oceanside, CA.

- The performance enhancement program must cover the training components of acceleration, deceleration, and change of direction.
- Ability to maintain posture for consistent ball address and posture throughout the swing (observe golf swing for C and S posture)

Specific Criteria for Release to Unsupervised Complete Participation in Golf

- Ability to shock-absorb club impact of the ground, sand, and rough multiple times: Golfer must be able to complete 80 to 100 shots on different surfaces before play without injury. Golfer must be able to complete four rounds before competition.
- Completed golf swings on a variety of different lies and turf conditions, typically three or four practice rounds
- Several pain-free range sessions, 80 to 100 balls hit per session
- No weakness or difficulty felt proximal or distal to the related joint injured. Complete manual muscle testing 4+/5 grade. Golf screen completed without pain.
- Understanding of medial and lateral elbow injuries in golfers and what can be done to help with injury prevention and treatment application. Golfer must understand that stopping the activity with recurrence. Learn stretching of the wrist flexor and extensor mass. Follow rest, ice, compression, and elevation protocol as needed. Learn about appropriate bracing for support.

Recommended Ongoing Exercises

- Squat rotation to overhead press
- Latissimus dorsi and hamstring flexibility
- Trunk rotation lunge walk
- Foam-rolling: ITB, quadriceps, hamstrings, piriformis, gluteal muscles

Evidence

Crossley K, Zhang W, Schache A, et al: Performance on the single-leg squat task indicates hip abductor muscle function. *Am J Sports Med* 39:866–873, 2011.

Panel of five experts rated 34 nonpathological participants performing a single-leg squat. Hip muscle electromyography activation along with compensation faults during the task were evaluated. The experts found that good performers had earlier onset of gluteus medius and greater abduction torque. They suggest that single-leg squat is a good predictor of hip muscle dysfunction. (Evidence for use of single leg tasks during Phases II and III).

Farber A, Smith J, Kvitne R, et al: Electromyographic analysis of forearm muscles in professional and amateur golfers. *Am J Sports Med* 37:396–401, 2009.

Twenty male professional and amateur golfers without history of elbow pathology underwent electromyography of the muscles in the forearm. Amateurs exhibited more pronator muscle activity in trailing arm, in contrast to the professionals, who had more in the lead arm. The authors suggested that, as a result, amateurs should perform stretching and strengthening of the pronator teres. (Evidence for pronator strength in Phase II, Performance enhancement phase).

Koa J, Pink M, Jobe F, et al: Electromyographic analysis of the scapular muscles during a golf swing. *Am J Sports Med* 23:19–23, 1995.

Fifteen competitive male golfers were studied for their scapular muscle involvement during the golf swing. The levator scapulae, trapezius, rhomboids, and serratus anterior were appreciated during the lead and trial arms during the golf swing. Scapular muscle work in synchrony throughout the golf swing and are important to strengthen to prevent injury and increase athletic performance. (Evidence for preparation and sport-specific phase strength foundation for scapular muscle groups).

Kraemer W, Ratamess N, Fry A, et al: Influence of resistance training volume and periodization on physiological and performance adaptations in collegiate women tennis players. *Am J Sports Med* 28:626–633, 2000.

Twenty-four collegiate tennis players were formed randomly into three groups: (1) No resistance training, (2) periodization resistance training, and (3) single-set circuit training program. They found that high-volume, periodized, multiple-set resistance training programs yielded greater results in muscle strength and power. They also suggested there were better long-term gains for the athletes in multiple-set, periodized programs with increases in performance enhancement. (Evidence for design of all three phases: Preparation, Performance, and Sport-Specific).

Vad VB, Bhat AL, Basrai D, et al: Low back pain in professional golfers the role of associated hip and low back range-of-motion deficits. *Am J Sports Med* 32:494–497, 2004.

Forty-two professional golf athletes were measured from hip and lumbar range of motion (ROM) and correlated this to recall of low back pain group and no low back pain group. ROM deficits in lead hip internal rotation and lumbar spine extension were correlated to history of low back pain in golfers. Proper hip lead internal rotation and lumbar spine flexibility is an important component in a return to golf program. (Preparation phase evidence for hip rotation strength).

Multiple-Choice Questions

QUESTION 1. In which training phase are form and correct movement patterns necessary for optimal gain?

A. Preparation
B. Sport-specific
C. Performance enhancement
D. All the above

QUESTION 2. Choose the best statement for increasing power in performance enhancement training:

A. Three to five sets, rest 30 to 60 seconds, intensity moderate, and volume high
B. Rest 30 seconds, intensity low, volume high, and four to six sets

C. Rest 2 minutes, intensity high, volume high, and three to five sets
D. Rest 2 to 4 minutes, three to five sets, intensity high, and volume moderate

QUESTION 3. Which of the following best describes performance enhancement?

A. Acceleration
B. Deceleration
C. Change of directions
D. All the above

QUESTION 4. Which of the following phase(s) is the most important free body squat?

A. Endurance strength phase
B. Preparation phase
C. Power phase
D. Acceleration phase
E. A and B

QUESTION 5. The single-leg deadlift row works on which primary muscle group?

A. Latissimus dorsi
B. Hamstring
C. Erector spinea
D. Piriformis

Answer Key

QUESTION 1. Correct answer: **A** (Preparation phase)

QUESTION 2. Correct answer: **D** (Performance enhancement phase)

QUESTION 3. Correct answer: **C** (Criteria to progress performance enhancement to sport-specific)

QUESTION 4. Correct answer: **B** (Preparation phase)

QUESTION 5. Correct answer: **B** (Phase III: Week 7)

Chapter 10



Epiphyseolysis and Osteochondritis

INTRODUCTION

Rob Hopkins, PT, SCS, and Champ L. Baker, Jr., MD

Epidemiology

- Elbow injuries common in young throwers
- 9 to 14 years old, predominantly male
- Primarily occurs in baseball; can also be seen in softball and volleyball
- Pitchers most often affected followed by catchers and position players

Pathophysiology

Intrinsic Factors

- Open physis at elbow (Figure 10-1)
- Inadequate hip mobility
- Weakness in hips/lower extremity
- Weakness in core



FIGURE 10-1. Open physis.

- Scapular dyskinesis/weakness
- Rotator cuff weakness
- Glenohumeral hypermobility
- Wrist flexor tightness/weakness

Extrinsic Factors

- Pitching too much/overuse
- Pitch selection, throwing curve ball or slider too soon
- Mound height
- Poor mechanics

Traumatic Factors

- Primarily an injury of overuse

Classic Pathological Findings

- Widening of physes on x-ray
- Loose body on x-ray (Figure 10-2)
- MRI demonstrating a nondisplaced osteochondritis dissecans fragment (Figure 10-3)

Clinical Presentation

- Intermittent elbow pain, possibly for years
- Loss of throwing velocity
- Loss of throwing control
- Loss of elbow extension (Figure 10-4)
- History of overparticipation in baseball activities: multiple leagues, travel teams, showcases, specialty coaches
- Pain with pitching or throwing only, hitting and position play do not reproduce pain

Abnormal Findings

- Weakness in core, scapular stabilizers, rotator cuff
- Loss of total arm motion (TAM) secondary to loss of internal rotation



FIGURE 10-2. Loose body on plain radiograph in a 14-year-old patient.

- Tenderness to palpation of medial epicondyle and pain on valgus stress test (Figure 10-5)
- General kyphosis with forward shoulder and head posture and protracted and tilted scapula (Figure 10-6)

Pertinent Normal Findings

- Normal sensation through upper extremity
- No pain at rest
- Full elbow flexion

Imaging Studies

- Plain radiographs
- MRI if patient does not respond to nonoperative management



FIGURE 10-3. Magnetic resonance image in a 14-year-old patient.



FIGURE 10-4. Loss of extension in a patient with Little League elbow.

Differential Diagnosis

- Medial epicondylitis
- Ulnar neuritis

Treatment

Nonsurgical

- Rest
- NSAIDs
- Activity/position modification
- Physical therapy
- Pitching mechanics evaluation
- Interval throwing program (ITP)

Guidelines

- Severity of symptoms
- Patients desire to play
- Time of year/time in season
- Other sports patient participates in

Surgical Indications

- Persistent pain over the medial epicondyle after prolonged rest and attempt to return to throwing
- X-ray/MRI evidence of persistent widening of the medial metaphysis specifically in comparison to contralateral side (Figure 10-7)
- Separation of medial epicondyle epiphysis if acute and retracted
- Persistent pain with activities of daily living even if not attempting sports
- Restricted sports

Aspects of History, Demographics, or Exam Findings That Affect Choice of Treatment

- Age of patient
- Desire to continue playing
- Other sports in which the patient participates
- Response to conservative measures

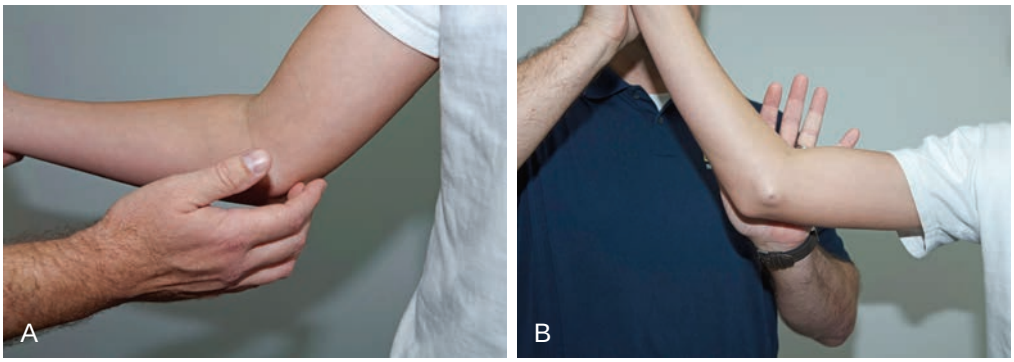


FIGURE 10-5. Physical findings include tenderness to palpation of the medial epicondyle (**A**) and pain on valgus stress (**B**).

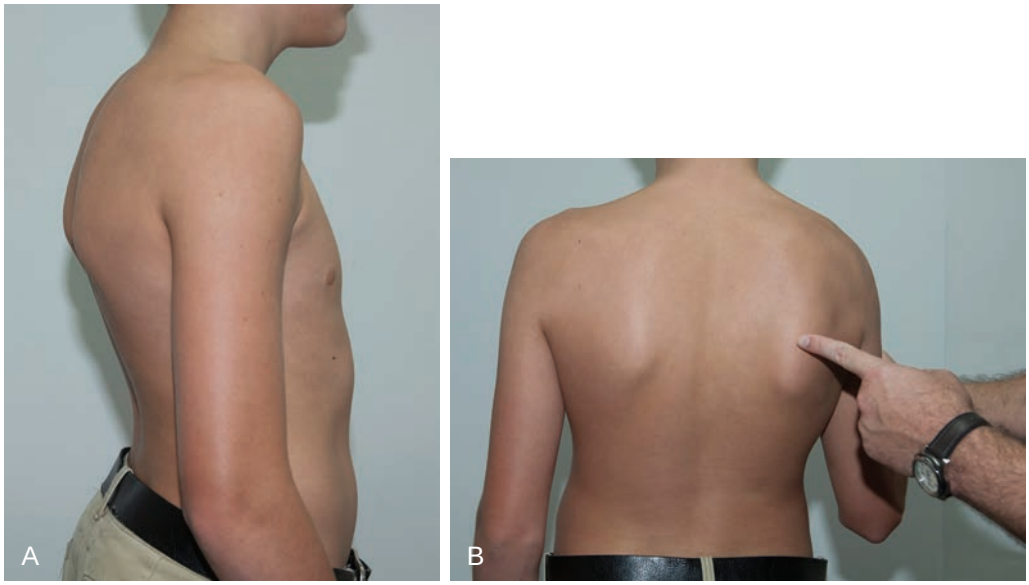


FIGURE 10-6. Patient's posture shows weak core and thoracic kyphosis (**A**) and malpositioned winging scapula (**B**).

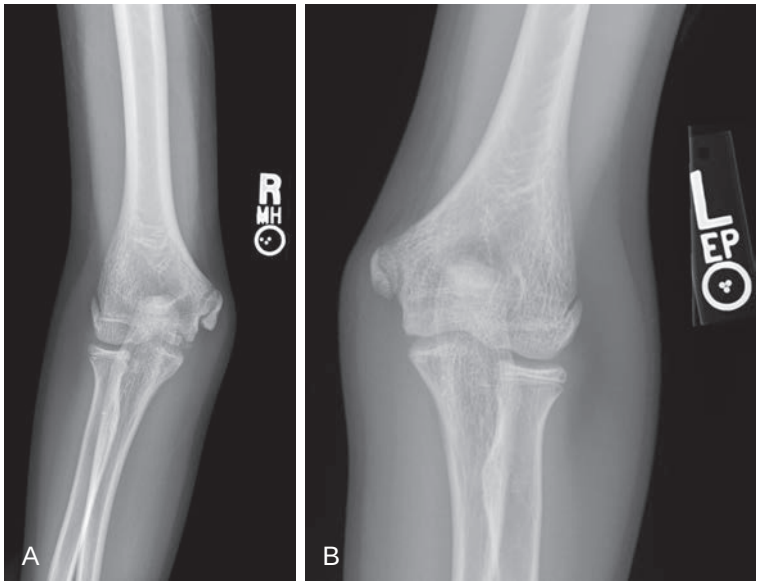


FIGURE 10-7. Plain radiograph of affected elbow (**A**) shows widening of medial metaphysis when compared with contralateral elbow (**B**).

Aspects of Clinical Decision Making When Surgery Is Indicated

- Age of the patient and desire to return to throwing sport are important.
- Skeletal maturity age should be determined by skeletal films of the hand.
- Radiographic comparison with the contralateral elbow should be made.
- Surgeon should be prepared to address ulnar nerve symptoms at the time of surgery.
- Patients must be advised that it can be as long as 3 months before bony closure is achieved and return to throwing is possible. Although it may require less time, it may be up to 6 months before full release to return to sports is possible.

Evidence

Axe MJ, Hurd W, Snyder-Mackler L: Data-based interval throwing programs for baseball players. *Sports Health* 1:145–152, 2009.

The authors developed data-driven programs based on the number, type, distance, and intensity of throws for baseball athletes at all levels of play. They recommend medical professionals use these programs for safe training, conditioning, and return to play. (Level of evidence NA)

Dines JS, Frank JB, Akerman M, et al: Glenohumeral internal rotation deficits in baseball players with ulnar collateral ligament insufficiency. *Am J Sports Med* 37:566–570, 2009.

In this case-control study of baseball players with and without ulnar collateral ligament insufficiency, investigators measured passive glenohumeral internal and external rotation, elbow flexion and extension, and forearm pronation and supination to determine the association between pathologic glenohumeral internal rotation deficit and elbow valgus instability. (Level III evidence)

Fleisig GS, Andrews JR, Cutter GR, et al: Risk of serious injury for young baseball pitchers: A 10-year prospective study. *Am J Sports Med* 39:253–257, 2011.

In this study, 481 youth pitchers were followed for 10 years to determine whether increased amount of pitching, throwing curveballs at a young age, and concomitantly playing catcher increased a young pitcher's risk of injury. (Level III evidence)

Marsh D: Little League elbow: Risk factors and prevention strategies. *Strength Cond J* 32:22–37, 2010.

The article discusses the risk factors and prevention strategies for Little League elbow in youth athletes. (Level of evidence NA)

Nissen CW, Westwell M, Ounpuu S, et al: A biomechanical comparison of the fastball and curveball in adolescent baseball pitchers. *Am J Sports Med* 37:1492–1498, 2009.

In this controlled laboratory study, 33 adolescent baseball pitchers with a minimum of 2 years of pitching experience underwent three-dimensional motion analysis using reflective markers aligned to bony landmarks. The authors looked for an association between pitch techniques and shoulder and elbow injuries. (Level of evidence NA)

Reinold MM, Escamilla RF, Wilk KE: Current concepts in the scientific and clinical rationale behind exercises for glenohumeral and scapulothoracic musculature. *J Orthop Sports Phys Ther* 39:105–117, 2009.

The authors of this paper provide the clinician with a thorough overview of the available literature relevant to develop safe, effective, and appropriate exercise programs for injury rehabilitation and prevention of the glenohumeral and scapulothoracic joints. (Level V evidence)

Multiple Choice Questions

QUESTION 1. What is the age range of most patients with Little League elbow?

A. 5 to 8 years
B. 9 to 14 years
C. 15 to 18 years
D. All ages are equal.

QUESTION 2. Which of the following is an extrinsic factor in the pathophysiology?

A. Overuse
B. Pitch selection
C. Pitching mechanics
D. All of the above

QUESTION 3. Which of the following is not in the normal clinical presentation?

A. Night pain
B. Loss of velocity
C. Loss of control
D. Loss of total arm motion
E. Night pain

QUESTION 4. The following are nonsurgical treatments except

A. change positions.
B. increase volume of throwing.
C. rest.
D. NSAIDs.

QUESTION 5. Which of the following findings will affect the choice of treatment?

A. Age
B. Desire to keep playing
C. Other sports played
D. Response to conservative management
E. All of the above

Answer Key

QUESTION 1. Correct answer: **B** (see Epidemiology)

QUESTION 2. Correct answer: **D** (see Extrinsic Factors)

QUESTION 3. Correct answer: **B** (see Clinical Presentation)

QUESTION 4. Correct answer: **A** (see Treatment)

QUESTION 5. Correct answer: **E** (see Findings That Affect Choice of Treatment)

NONOPERATIVE REHABILITATION OF EPIPHYSIOLYSIS OF THE MEDIAL EPICONDYLE (LITTLE LEAGUE ELBOW)

Rob Hopkins, PT, SCS, and Champ L. Baker, Jr., MD

Phase I (weeks 0 to 2)

Protection

- No sports activities
- A sling is rarely, if ever, needed. A sling may be used when necessary for elbow pain. Discontinue as soon as patient is pain free at rest.

Treatment for Pain/Swelling

- Ice, compression
- Over-the-counter pain medication/NSAIDs

Techniques for Progressive Increase in Range of Motion

Manual Therapy

- Joint mobilization of shoulder, primarily posterior capsule if glenohumeral internal rotation deficit (GIRD) is present

Soft Tissue Techniques

- Massage to facilitate edema reduction and release adhesions

Stretching/Flexibility Techniques

- Proprioceptive neuromuscular facilitation (PNF) muscle energy techniques and self-stretching to gain full elbow and shoulder range of motion (ROM)

Other Therapeutic Exercises

- Lower extremity strength and flexibility
- Core strength/stability
- Maintain cardiovascular endurance

Muscle Activation of Primary Muscles Involved

- Concentric activation of elbow flexors and extensors, wrist supination and pronation, wrist flexion and extension

Sensorimotor Exercises

- Manual joint replication activities at wrist and elbow

Open (OKC) and Closed (CKC) Kinetic Chain Exercises

- OKC exercises at this time

Techniques to Increase Muscle Strength, Power, and Endurance

- No activities for primary injury site
- Continue to maintain or increase lower body and core power and endurance.

Neuromuscular Dynamic Stability Exercises

- None at this time

Plyometrics

- None at this time

Functional Exercises

- Patient is encouraged to use upper extremity for all activities of daily living (ADLs). Patient is restricted from sports activities only at this time.

Sports-Specific Exercises

- None at this time

Milestones to Progress to Next Phase

- Pain free at rest
- Normal elbow ROM
- Nontender to palpation

TIMELINE 10-1: **Nonoperative Rehabilitation of Epiphysiolysis of the Medial Epicondyle (Little League Elbow)**

PHASE I (weeks 0 to 2)	PHASE II (weeks 2 to 6)
• Sling, if needed • Modalities to control pain and swelling • Restore full A/PROM to elbow • Evaluate throwing shoulder girdle (hyper/hypo mobility, scapular stability, etc.) • Core and lower-extremity strength and endurance training	• Elbow ROM WNL • Rotator cuff, deltoid, and scapular stabilization exercises, begin UBE • Proprioception exercises at shoulder and elbow • Continue core and lower-extremity strength and endurance training

Phase II (weeks 2 to 6)

Protection

- None

Treatment for Pain/Swelling

- Ice, compression, over-the-counter pain medication/NSAIDs

Initial Guidelines for Progressive Increase in ROM

Patient should have normal elbow ROM at this time.

Manual Therapy Techniques

- Joint mobilization of shoulder, primarily posterior capsule if GIRD is present

Soft Tissue Techniques

- Massage to facilitate edema reduction and release adhesions at elbow

Stretching/Flexibility Techniques for the Musculotendinous Unit

- PNF/muscle energy techniques and self-stretching to gain full shoulder ROM

Other Therapeutic Exercises

- Lower extremity strength and flexibility, focus on hips
- Core strength/stability
- Rotator cuff, deltoid, and scapular stabilization
- Maintain cardiovascular endurance

Muscle Activation of Primary Muscles Involved in Injury Area

- Concentric activation of elbow flexors and extensors, wrist supination and pronation, wrist flexion and extension progressing to eccentric as able

Sensorimotor Exercises

- Manual joint replication activities at wrist and elbow

Open (OKC) and Closed (CKC) Kinetic Chain Exercises

- OKC exercises for upper extremity
- CKC exercises for scapular stabilization and core

Increase Muscle Strength, Power, and Endurance

- Upper body exercises (UBE)
- Begin resisted activities for entire upper extremity, Thera-Band, free weights, etc
- Continue to maintain or increase lower body and core power and endurance

Neuromuscular Dynamic Stability Exercises

- None at this time

Plyometrics

- None at this time

Functional Exercises

- Patient should have no functional limitations. Patient is restricted form sports activities only at this time.

Sport-Specific Exercises

- None at this time

Milestones/Criterion-Based Rehabilitation Guidelines to Progress to Next Phase

- Pain free at rest
- Normal elbow ROM
- Nontender to palpation
- Complete Phase II exercises without increase in symptoms

Phase III (weeks 6 to 12)

Protection

- None

Treatment for Pain/Swelling

- Ice, compression
- Over-the-counter pain medication/NSAID

Techniques for Progressive Increase in ROM

Patient should have normal elbow ROM at this time.

Manual Therapy Techniques

- Joint mobilization of shoulder, primarily posterior capsule if GIRD is present

TIMELINE 10-1: **Nonoperative Rehabilitation of Epiphysiolysis of the Medial Epicondyle (Little League Elbow)** (Continued)

PHASE III (weeks 6 to 12)	PHASE IV (weeks 12+)
• Continue above exercises • Begin closed chain upper-extremity exercises • Begin PNF • Plyoball throws; two-hand progressing to one-hand • Return to hitting activity • Position play as indicated	• Continue to progress all above exercises • Pitching mechanics evaluation • Begin interval throwing program



FIGURE 10-8. Sleeper stretch for stretching posterior capsule is begun during Phase II.

Soft Tissue Techniques

- Massage to facilitate edema reduction and release adhesions at elbow

Stretching/Flexibility Techniques for the Musculotendinous Unit

- PNF/muscle energy techniques and self-stretching to gain full shoulder ROM (Figure 10-8)

Other Therapeutic Exercises

See Figure 10-9.
- Lower extremity strength and flexibility, focus on hips
- Core strength/stability
- Rotator cuff, deltoid and scapular stabilization
- Maintain cardiovascular endurance



FIGURE 10-9. Posterior shoulder stretching on BOSU Trainer for core, cuff, and scapula strengthening.

Muscle Activation of Primary Muscles Involved in Injury Area

- Concentric/eccentric activation of elbow flexors and extensors, wrist supination and pronation, wrist flexion and extension

Sensorimotor Exercises

- Manual joint replication activities at wrist, elbow, shoulder

Open (OKC) and Closed (CKC) Kinetic Chain Exercises

- OKC exercises for upper extremity at this time
- CKC exercises for lower extremity, scapular stabilization, core, upper extremity

Techniques to Increase Muscle Strength, Power, and Endurance

- Upper body exercises
- Begin resisted activities for entire upper extremity, Thera-Band, free weights, and so on.
- Continue to maintain or increase lower body and core power and endurance.

Neuromuscular Dynamic Stability Exercises

- Begin PNF patterns, concentric progressing to eccentric.

Plyometrics

- Begin two-handed Plyoball throws progressing to one.

Functional Exercises

- Patient should have no functional limitations at this time.

Sport-Specific Exercises

- Patient is allowed to hit off tee and progress to live batting. Patient may return to playing field position (noncatcher) if cleared by physician.

Milestones/Criterion-Based Rehabilitation Guidelines to Progress to the Next Phase

- Pain free at rest
- Normal elbow ROM
- Nontender to palpation
- Complete phase III exercises without increase in symptoms
- Able to hit without pain
- Pain free with all Plyoball exercises

Phase IV (weeks 12+)

Protection

None

Treatment for Pain/Swelling

- Ice, compression, over-the-counter pain medication/NSAID

Initial Guidelines and Guidelines for Progressive Increase in ROM

Patient should have normal elbow ROM at this time.

Manual Therapy Techniques

- Joint mobilization of shoulder, primarily posterior capsule if GIRD is present

Soft Tissue Techniques

- Massage to facilitate edema reduction and release adhesions at elbow

Stretching/Flexibility Techniques

- PNF/muscle energy techniques and self-stretching to gain full shoulder ROM

Other Therapeutic Exercises

- Lower extremity strength and flexibility exercises, focus on hips
- Core strength/stability
- Rotator cuff, deltoid and scapular stabilization
- Maintain cardiovascular endurance

Muscle Activation of Primary Muscles Involved in the Injury Area

- Concentric/eccentric activation of elbow flexors and extensors, wrist supination and pronation, wrist flexion and extension

Sensorimotor Exercises

- Manual joint replication activities at wrist, elbow, shoulder

Open (OKC) and Closed (CKC) Kinetic Chain Exercises

- OKC exercises for upper extremity
- CKC exercises for lower extremity, scapular stabilization, core, upper extremity

Techniques to Increase Muscle Strength, Power, and Endurance

- UBE
- Continue resisted activities for entire upper extremity, Thera-Band, free weights, etc.
- Continue to maintain or increase lower body and core power and endurance.

Neuromuscular Dynamic Stability Exercises

- PNF patterns, concentric progressing to eccentric

Plyometrics

- Two-handed and one-handed Plyoball throws

Functional Exercises

- Patient should have no functional limitations at this time.

Sport-Specific Exercises

- Continue hitting and playing field positions (non-catcher).
- Evaluate pitching mechanics.
- Begin interval throwing program (ITP).

Milestones/Criterion-Based Rehabilitation Guidelines to Progress to Next Phase

- Completion of ITP
- Faulty mechanics corrected
- Patient can return to pitching in 8 to 12 months pending physician clearance.

Criteria for Abandoning Nonoperative Treatment and Proceeding to Surgery

- Inability to return to pitching
- Pain with activities of daily living
- Loss of motion affecting performance

Milestones/Criterion-Based Rehabilitation Guidelines to Progress to Sport-Specific Training and Conditioning

- Completion of nonoperative rehabilitation
- No pain with ITP
- No pain with hitting
- Appropriate age to benefit from advanced training

Transition to Performance Enhancement: Tips and Guidelines

- Patients (and parents) need to be involved at young ages.
- Beware of compensatory movements after an injury.
- Patients have a tendency to overtrain after an injury.
- Patient must demonstrate correct form before increasing resistance.

Performance Enhancement and Beyond Rehab

- Performance enhancement improves an athlete's ability to succeed at his or her sport. It requires an understanding of the demands of the sport and the position being played by the athlete. This understanding must be coupled with the knowledge of human anatomy, physiology, psychology, and kinesiology. Putting these elements together gives the athlete the best opportunity to optimize his or her abilities and to perform at the highest level.

Criteria for Return to Sports Participation

- Completion of ITP
- Normal physical exam findings
- No pain with throwing

Evidence

Aguinaldo AL, Chambers H: Correlation of throwing mechanics with elbow valgus load in adult baseball pitchers. *Am J Sports Med* 37:2043–2048, 2009.

In this laboratory study, the authors analyzed the associations of 13 biomechanical variables with elbow valgus overload in 69 adult baseball pitchers. Their findings offer feedback for developing methods to minimize the effects of valgus load on elbow injuries. (Level of evidence NA. Descriptive laboratory study.)

Davis JT, Limpisvasti O, Fluhme D, et al: The effect of pitching biomechanics on the upper extremity in youth and adolescent baseball pitchers. *Am J Sports Med* 37:1484–1491, 2009.

Baseball pitchers aged 9 to 18 were studied in the laboratory while throwing fastballs to compare five pitching parameters with the pitcher's age, humeral internal rotation torque, elbow valgus load, and calculated pitching efficiency. The authors attempted to show how improper pitching mechanics adversely affected the upper extremity. (Level of evidence, NA. Descriptive laboratory study.)

Ogard WK: Proprioception in sports medicine and athletic conditioning. *Strength Cond J* 33:111–118, 2011.

This article discusses terminology and concepts of proprioceptive function and how it is addressed in the context of sports medicine and athletic conditioning. (Level of evidence NA)

Oliver JL, Lloyd RS, Meyers RW: Training elite child athletes: Promoting welfare and well-being. *Strength Cond J* 33:73–79, 2011.

The authors of this article identified risks to provide recommendations to help coaches promote the welfare and well-being of elite child athletes during training. (Level of evidence, NA)

Olsen SJ, 2nd, Fleisig GS, Dun S, et al: Risk factors for shoulder and elbow injuries in adolescent baseball pitchers. *Am J Sports Med* 34:905–912, 2006.

The authors make recommendations based on the results of this study comparing adolescent pitchers who had shoulder or elbow surgery with those who had never had a significant pitching-related injury. (Level III evidence)

Multiple Choice Questions

QUESTION 1. Which of the following is NOT a guiding principle of rehabilitation?

A. Patient and family education
B. Continue playing
C. Stopping stressful activity
D. Active rest

QUESTION 2. Which of the following should be examined on a pitcher with Little League elbow?

A. Elbow range of motion
B. Core strength
C. Shoulder mobility
D. All of the above

QUESTION 3. When should a patient expect to return to hitting?

A. 0 to 2 weeks
B. 2 to 6 weeks
C. 6 to 12 weeks
D. 12+ weeks

QUESTION 4. When should a patient expect to return to pitching?

A. 2 months
B. 4 months
C. 6 months
D. 8+ months

QUESTION 5. When transitioning from rehabilitation, a therapist/trainer should be aware of which of the following?

A. Overtraining
B. Overbearing parents
C. Substitution patterns/movements
D. All of the above

Answer Key

QUESTION 1. Correct answer: **B** (see Guiding Principles)

QUESTION 2. Correct answer: **D** (see Phase I)

QUESTION 3. Correct answer: **C** (see Phase III)

QUESTION 4. Correct answer: **D** (see Phase IV)

QUESTION 5. Correct answer: **D** (see Transition to Performance Enhancement)

POSTOPERATIVE REHABILITATION AFTER TREATMENT OF OSTEOCHONDRITIS DISSECANS OF THE CAPITULUM

Rob Hopkins, PT, SCS, and Champ L. Baker, Jr., MD

Indications for Surgical Treatment

- Displaced medial epicondylar fracture in acute injury as shown on plain radiographs (x-ray) and/or MRI
- Chronic pain with delayed closure of medial humeral epiphysis
- Nonoperative management is recommended for 3 to 6 months.

Brief Summary of Surgical Treatment

Major Surgical Steps

- Ensure adequate x-ray and/or fluoroscopic support.
- Create limited medial incision.
- Expose the medial epicondyle.
- Under fluoroscopic control, control insertion of cancellous screw fixation of the nondisplaced fragment (Figure 10-10). Countersink the screw to prevent postoperative discomfort.
- If the fragment is small, two parallel pins can be used instead of cancellous screw.
- Epiphysis does not need to be exposed.
- Nerve does not need to be exposed.

Factors That May Affect Details of Rehabilitation

- Surgery may be done using general anesthetic or nerve block, but choice should not affect rehabilitation.

Phase I: Immediate Postoperative Period (days 1 to 14)[1]

Goals

- Protect healing tissues.
- Decrease pain and inflammation.
- Decrease swelling.
- Increase range of motion (ROM) as tolerated at the elbow and wrist.

Clinical Pearl

Correct sling fit in the immediate postoperative phase is important in reducing the patient's pain. Slings that are the wrong size or applied incorrectly can generate pain, which will encourage the patient to remove the sling prematurely.

Protection

- Sling as needed for comfort for 2 to 6 weeks

Management of Pain and Swelling

- Pain medications
- Ice/cryotherapy
- Electrical stimulation

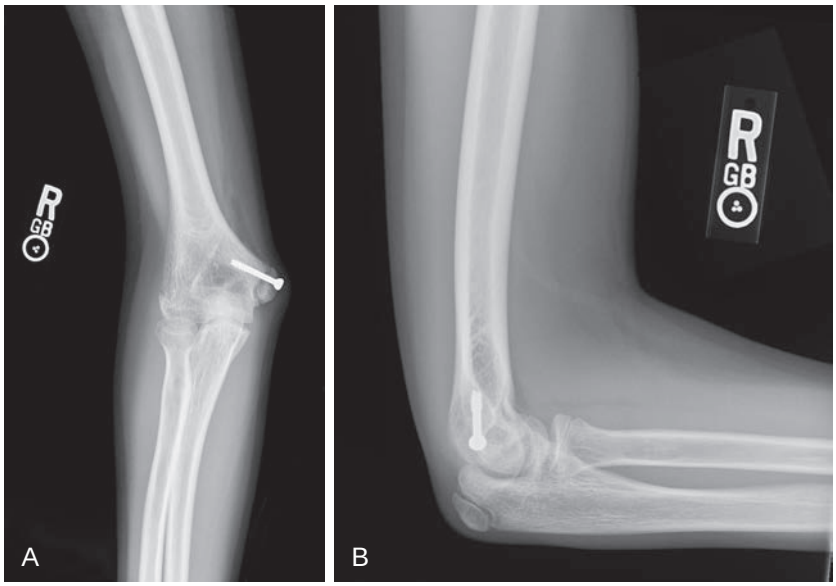


FIGURE 10-10. Anteroposterior (**A**) and lateral (**B**) radiographs show placement of cancellous screw used for fixation of fragment.

Techniques for Progressive Increase in Range of Motion

Manual Techniques

- Massage to reduce edema
- Scar massage

Stretching/Soft Tissue Techniques for the Musculotendinous Unit

- Avoid wrist flexion stretching.

Other Therapeutic Exercises

- Stationary bike or elliptical may be used to maintain cardiovascular endurance.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Encourage active movement of fingers, wrist, and elbow of involved arm, no resistance.
- Active ROM (AROM) of shoulder and scapula on involved side

Milestones for Progression to the Next Phase

- Incision healed, no signs/symptoms of infection

Phase II (weeks 2 to 6)

Goals

- No pain
- No swelling
- Full PROM

Protection

- Discontinue sling as able

Treatment for Pain and Swelling

- Pain medications
- Ice/cryotherapy
- Electrical stimulation

Techniques for Progressive Increase in Range of Motion

Manual Techniques

- Massage to reduce edema
- Joint mobilizations to facilitate full ROM
- Scar massage

Stretching/Soft Tissue Techniques for the Musculotendinous Unit

- Avoid wrist flexion stretching.

Other Therapeutic Exercises

- Stationary bike or elliptical may be used to maintain cardiovascular endurance

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Encourage active movement of fingers, wrist, elbow of involved arm, no resistance.
- AROM of shoulder and scapula on involved side

Milestones for Progression to the Next Phase

- Pain free
- Full AROM
- No swelling

Phase III (weeks 6 to 10)

Goals

- Avoid overstressing repair.
- Maintain activity restrictions.
- Begin shoulder/scapula strengthening.

Treatment for Pain and Swelling

- Ice/cryotherapy post rehab

Therapeutic Exercises (Figure 10-11)

- Stationary bike or elliptical may be used to maintain cardiovascular endurance
- Shoulder and scapular strengthening exercises (Thrower's 10 program)
- Core strengthening

TIMELINE 10-2: **Postoperative Rehabilitation After Treatment of Osteochondritis Dissecans of the Capitulum***

PHASE I (weeks 0 to 2)	PHASE II (weeks 2 to 6)
• Sling as needed • Modalities as needed for pain • AROM elbow/wrist hand • Massage for edema	• Discontinue sling • Modalities as needed • Full P/A ROM at elbow • AROM scapula and glenohumeral joint exercises • Bike/elliptical for conditioning

*Prehabilitation, if appropriate, is described in the Nonoperative Rehabilitation section of this chapter.



FIGURE 10-11. Scaption on Swiss ball for rotator cuff, scapular, and core strengthening.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Begin upper body exercises
- Isotonic elbow, wrist, and hand strengthening

Sensorimotor Exercises

- Rhythmic stabilization for elbow, and shoulder in OKC (open kinetic chain) only

Open and Closed Kinetic Chain Exercises

- Thrower's 10 (OKC)

Neuromuscular Dynamic Stability Exercises

- Begin PNF patterns for the upper extremity

Milestones for Progression to the Next Phase

- Good proprioception in shoulder and elbow
- 70% strength in shoulder and elbow

Phase IV (weeks 10 to 14)

Goals

- No pain with weight bearing through upper extremity

Treatment for Pain and Swelling

- Ice/cryotherapy post rehab



FIGURE 10-12. Prone plank (**A**) and side plank (**B**) for core strengthening and scapular stabilization.

Therapeutic Exercises (Figure 10-12)

- Stationary bike, elliptical, or running may be used to maintain cardiovascular endurance
- Shoulder and scapular strengthening exercises (Thrower's 10 program)
- Core strengthening

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- UBE
- Isotonic elbow, wrist, and hand strengthening

Sensorimotor Exercises

- Rhythmic stabilization for elbow, and shoulder

Open (OKC) and Closed (CKC) Kinetic Chain Exercises

- Thrower's 10 (OKC)
- Begin closed chain stabilization exercises, stable surfaces, progressing to unstable surfaces (CKC)

Neuromuscular Dynamic Stability Exercises

- PNF patterns for the upper extremity

TIMELINE 10-2: Postoperative Rehabilitation After Treatment of Osteochondritis Dissecans of the Capitulum* (Continued)

PHASE III (weeks 6 to 10)	PHASE IV (weeks 10 to 14)	PHASE V	
		(weeks 14 to 24)	(weeks 24+)
• Begin UBE • Rhythmic stabilization exercises for upper extremity • Begin core strengthening • Throwers 10 for rotator cuff and scapula strengthening • Isotonic elbow/wrist/hand exercises	• Begin PNF • Progress throwers ten to include 90/90 exercises • Begin closed chain stabilization exercises • Begin upper extremity Plyoball exercises (two hand progressing to one hand)	• Continue above exercises • Begin interval throwing program	• Return to pitching when interval throwing program is completed



FIGURE 10-13. Patient progresses from two-handed Plyoball toss exercise (**A**) to one-handed wall dribble (**B**) and wrist flips (**C**).

Plyometrics

- Begin upper extremity Plyoball exercises using two hands, progressing to one hand (Figure 10-13).

Milestones for Progression to the Next Phase

- 80% shoulder and elbow strength

Phase V (weeks 14 to 24)

Goals

- Completion of interval throwing program

Treatment for Pain and Swelling

- Ice/cryotherapy post rehab

Therapeutic Exercises

- Stationary bike, elliptical, or running may be used to maintain cardiovascular endurance.
- Shoulder and scapular strengthening exercises (Thrower's 10 program)
- Core strengthening

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- UBE
- Isotonic elbow, wrist, and hand strengthening

Sensorimotor Exercises

- Rhythmic stabilization for elbow, and shoulder

Open (OKC) and Closed (CKC) Kinetic Chain Exercises

- Thrower's 10 (OKC)
- Closed chain stabilization exercises, stable surfaces, progressing to unstable surfaces (CKC)

Neuromuscular Dynamic Stability Exercises

- PNF patterns for the upper extremity

Plyometrics

- Upper extremity Plyoball exercises using two hands, progressing to one hand (see Figure 10-13).

Sport-Specific Exercises

- Interval throwing program

Criteria for Return to Play at 6 Months

- Normal upper extremity strength (90% of uninvolved side)
- Normal ROM
- Normal scapulothoracic mechanics
- Patient must have completed interval throwing program

After Return to Sport

- Athlete should maintain arm and body conditioning as described in the nonoperative section of this chapter.

Evidence

Cain EL, Dugas JR, Wolf RS, et al: Injuries in throwing athletes: A current concepts review. *Am J Sports Med* 27:621–635, 2003.

In this review of the diagnosis and treatment of overhead throwing injuries, the authors discuss anatomy and function of the elbow, biomechanics, mechanism of injury, and recent advances in surgical techniques used to treat the motivated athlete and return the athlete to competition. (Level V evidence)

Kibler WB: The role of the scapula in athletic shoulder function. *Am J Sports Med* 26:325–337, 1998.

Knowledge of the role and function of the scapula in shoulder function, injury, and rehabilitation helps the physician to provide more comprehensive care for the athlete. In this review, the author addresses those roles and functions. (Level V evidence)

Pabian PS, Kolber MJ, McCarthy JP: Post rehabilitation strength and conditioning of the shoulder: an interdisciplinary approach. *J Strength Cond Res* 33:42–54, 2011.

The authors' intent is to link the entire spectrum of the recovery process from common shoulder injuries for the understanding of the numerous professionals whom injured individuals will encounter. (Level of evidence NA)

Reinold MM, Escamilla RF, Wilk KE: Current concepts in the scientific and clinical rationale behind exercises for glenohumeral and scapulothoracic musculature. *J Orthop Sports Phys Ther* 39:105–117, 2009.

The authors of this paper provide the clinician with a thorough overview of the available literature relevant to develop safe, effective, and appropriate exercise programs for injury rehabilitation and prevention of the glenohumeral and scapulothoracic joints. (Level V evidence)

Wilk KE, Arrigo CA, Andrews JR: Current concepts: The stabilizing structures of the glenohumeral joint. *J Orthop Sports Ther* 25:364–379, 1997.

The authors of the review discuss concepts related to the anatomic stabilizing structures of the shoulder joint complex and their clinical relevance to shoulder instability. (Level V evidence)

Multiple Choice Questions

QUESTION 1. How long should a sling be worn postoperatively?

A. Never
B. 1 week
C. 2 to 6 weeks
D. 6 to 8 weeks

QUESTION 2. When should active range of motion of the hand begin?

A. 1 week
B. 2 weeks
C. 3 weeks
D. 4 weeks

QUESTION 3. When should the patient have full AROM of the involved elbow?

A. 2 weeks
B. 4 weeks
C. 6 weeks
D. 8 weeks

QUESTION 4. When should plyometrics be introduced into the rehab program?

A. Weeks 2 to 6
B. Never
C. Weeks 24+
D. Weeks 10 to 14

QUESTION 5. When should a patient be cleared to return to throwing?

A. Never
B. After completing the interval throwing program
C. 6 to 10 weeks
D. 10 to 14 weeks

Answer Key

QUESTION 1. Correct answer: **C** (see Phase II)

QUESTION 2. Correct answer: **A** (See Phase I)

QUESTION 3. Correct answer: **C** (See Phase II)

QUESTION 4. Correct answer: **D** (See Phase IV)

QUESTION 5. Correct answer: **B** (See Criteria for Return to Play at 6 Months)

BEYOND BASIC REHABILITATION: RETURN TO PITCHING AFTER OSTEOCHONDRITIS DISSECANS OF THE CAPITULUM

Rob Hopkins, PT, SC, and Champ L. Baker, Jr., MD

Introduction

KEY ASPECTS OF PITCHING THAT REQUIRE SPECIAL ATTENTION IN REHABILITATION

- Little League baseball has a high participation nationally.
- Overuse is the cause of most injuries.
- Pitching is a highly skilled activity and one of the most demanding of an individual's upper extremity.
- Pitching requires precise timing of multiple links in the kinetic chain.
- Pitching requires both upper and lower extremity flexibility, strength, and endurance.

Why Is Osteochondritis Dissecans of the Capitulum Being Reviewed?

- Elbow and shoulder injuries are common among young throwers.
- Many coaches and parents are ill informed as to the cause of injuries and the best techniques of injury prevention.
- Athletes are skeletally immature and are at a higher risk of injury than adults.
- There is often a desire to "play through the pain" among athletes, parents, and coaches.

Phase I: Advanced Strength and Conditioning Program[1]

Periodization

- Linear
- Undulating

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- Training with optimum posture
- Sensorimotor and balance training
- Core training
- Cardiorespiratory training
- Multiplanar training activities
- Training for optimum muscle balance
- Training for optimum muscle functional strength
- Training for optimum muscle functional power
- Neuromuscular dynamic stability exercises

Olympic Lifts Used in the Training Program

- Squat
- Power clean

Training Principles Used in the Design of the Program

- Progression
- Overload
- Variation
- Individualization
- Specific adaptations to imposed demands (SAID)

Application of Acute Training Variables

- Repetitions: rotate between 5-10-15 reps
- Sets: two to four
- Rest: 30 sec to 2 min
- Intensity: low to high
- Repetition tempo: slow to fast
- Frequency: two to four times per week
- Duration: 45 to 60 min
- Volume: varies with intensity
- Specific exercises: body weight exercises focusing on form, rotator cuff strengthening, plank exercises for core

Application of Chronic Training Variables

- Sets, repetitions, and rest time are changed at each training session. This also changes volume and intensity and prevents chronic adaptations.

Phase II: Performance Enhancement Training Techniques

Periodization

- Linear
- Undulating

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- Training with optimum posture
- Sensorimotor and balance training
- Core training
- Cardiorespiratory training
- Multiplanar training activities

- Training for optimum muscle balance
- Training for optimum muscle functional strength
- Training for optimum muscle functional power
- Neuromuscular dynamic stability
- Training for speed agility and quickness
- Plyometrics training
- Sport-specific training
- Single leg lunges
- BOSU and Swiss ball used when able
- Plyoball for upper extremity plyometrics

Olympic Lifts Used in the Training Program

- Squat
- Power clean

Training Principles Used in the Design of the Program

- Progression
- Overload
- Variation
- Individualization
- Specific adaptations to imposed demands

Application of Acute Training Variables

- Repetitions: rotate between 5-10-15 reps
- Sets: two to four
- Rest: 30 sec to 2 min
- Intensity: low to high
- Repetition tempo: slow to fast
- Frequency: two to four times week
- Duration: 45 to 60 min
- Volume: varies with intensity
- Specific exercises: single leg activities, use of BOSU and Core Board for standing upper extremity exercises, Swiss ball for seated exercises

Application of Chronic Training Variables

- Sets, repetitions, and rest time are changed at each training session. This also changes volume and intensity and prevents chronic adaptations.

Phase III: Sport-Specific Training

Periodization

- Linear
- Undulating

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- Training with optimum posture
- Sensorimotor and balance training
- Core training
- Cardiorespiratory training
- Multiplanar training
- Training for optimum muscle balance
- Training for optimum muscle functional strength
- Training for optimum muscle functional power
- Neuromuscular dynamic stability
- Training for speed agility and quickness
- Plyometrics training
- Sport-specific training
- Single leg exercises versus double
- BOSU and Core Board used for standing exercises, Swiss ball used for seated and prone exercises
- Plyoball for upper extremity plyometrics

Olympic Lifts Used in the Training Program

- None

Training Principles Used in the Design of the Program

- Progression
- Overload
- Variation
- Individualization
- Specific adaptations to imposed demands

Application of Acute Training Variables

- Repetitions: rotate between 5-10-15 reps
- Sets: two to four
- Rest: 30 sec to 2 min
- Intensity: low to high
- Repetition tempo: slow to fast
- Frequency: two to four times week
- Duration: 45 to 60 min
- Volume: varies with intensity
- Specific exercises: Interval throwing program/long toss program. Pitching mechanics evaluation

Application of Chronic Training Variables

- Sets, repetitions, and rest time are changed at each training session. This also changes volume and intensity and prevents chronic adaptations.

Sports Performance Testing

General Information

- Medical history
- Injury history
- Throwing history (number of pitches per outing, season, year and what types of pitches thrown)

Specific Tests for Determining Readiness to Pitch

- Functional movement screen
- Hand held dynamometer for strength
- Physiological assessments
- Pitching mechanics evaluation (video)

Specific Criteria for Determining Readiness to Pitch

- Able to complete exercises with correct form/no substitution
- Pain free with all activities/exercises
- Athlete beginning to plateau with current program

Specific Criteria for Release to Unsupervised Complete Participation in Pitching

- Normal physical exam
- Completed interval throwing program
- Cleared by MD

Recommended Ongoing Exercises

- Posterior capsule stretching (sleeper stretch/cross-body stretch)
- Throwers 10 cuff program

Evidence

Axe MJ, Hurd W, Snyder-Mackler L: Data-based interval throwing programs for baseball players. *Sports Health* 1:145–152, 2009.

The authors developed data-driven programs based on the number, type, distance, and intensity of throws for baseball athletes at all levels of play. They recommend medical professionals use these programs for safe training, conditioning, and return to play. (Level of evidence NA.)

Fleisig GS, Andrews JR, Cutter GR, et al: Risk of serious injury for young baseball pitchers: A 10-year prospective study. *Am J Sports Med* 39:253–257, 2011.

In this study, 481 youth pitchers were followed for 10 years to determine whether increased amount of pitching, throwing curveballs at a young age, and concomitantly playing catcher increased a young pitcher's risk of injury. (Level III evidence)

Granacher U, Muehlbauer T, Maestrini L, et al: Can balance training promote balance and strength in prepubertal children. *J Strength Cond Res* 25(6):1759–1766, 2011.

The authors investigated the impact of balance training followed by detraining on postural control, plantar flexor strength, and jumping height in 30 prepubertal children. (Level of evidence NA.)

Marsh D: Little League elbow: Risk factors and prevention strategies. *Strength Cond J* 32:22–37, 2010.

The article discusses the risk factors and prevention strategies for Little League elbow in youth. (Level of evidence NA.)

Oliver JL, Lloyd RS, Meyers RW: Training elite child athletes: Promoting welfare and well-being. *Strength Cond J* 33:73–79, 2011.

Elite child athletes can be exposed to potentially large volumes of specialized training and early competition at a time when they are still maturing, thus exposing them to a variety of risks. This article identifies risks and provides recommendations to help coaches promote the welfare and well-being of elite child athletes during training. (Level of evidence NA.)

Multiple Choice Questions

QUESTION 1. Which one of the following is not an Olympic lift?

A. Deadlift
B. Snatch
C. Curl
D. Squat

QUESTION 2. Which of the following is not a reason returning an athlete to pitching is difficult?

A. Pitching is a highly skilled activity and one of the most demanding you can do with your upper extremity.
B. Pitching requires precise timing of multiple links in the kinetic chain.
C. Good pitchers only use their arms.
D. Most pitchers tend to throw too much.

QUESTION 3. Why is this topic being reviewed?

A. Most coaches are ill informed as to the causes of elbow injuries.
B. Young throwers are at a higher risk of injury.
C. Most young athletes want to play through the pain.
D. All of the above

QUESTION 4. Which of the following is an acute training variable?

A. Sets
B. Music playing
C. Temperature
D. Time of day

QUESTION 5. Which of the following is not a sports performance test used in sports-specific training?

A. Functional movement screen
B. 40-yard dash
C. Physiological assessments
D. Pitching mechanics evaluation (video)

Answer Key

QUESTION 1. Correct answer: **C** (see Phase I, Advanced Strength and Conditioning)

QUESTION 2. Correct answer: **C** (see Introduction)

QUESTION 3. Correct answer: **D** (see Introduction)

QUESTION 4. Correct answer: **A** (see Phase II: Performance Enhancement Training Techniques)

QUESTION 5. Correct answer: **B** (see Sports Performance Testing)

Chapter 11



Ulnar Collateral Ligament Injuries

INTRODUCTION

E. Lyle Cain, Jr., MD

Epidemiology

- Most common in young amateur or professional athletes, ages 15 to 40 years
- Most common in males, with 9:1 ratio male:female
- Most common in baseball, with occasional occurrence in other overhead sports (football, javelin throwing, softball, tennis, wrestling, soccer, gymnastics, cheerleading, and pole vaulting)
- Baseball pitchers make up 89%, followed by catchers
- Incidence evenly distributed among high school, collegiate, and professional levels
- Incidence of UCL injury requiring surgery in high school and adolescent athletes has risen dramatically in the past 5 years.

Pathophysiology

Intrinsic, Extrinsic, and Traumatic Factors

- Injury generally occurs during the acceleration phase of the throwing motion (Figure 11-1).
- Biomechanical factors resulting in poor power transfer from the trunk to the arm may predispose the athlete to UCL injury.
- Based on cadaveric testing, UCL tensile failure is approached with every throw, especially in high-velocity throwers.
- Overuse-type throwing habits result in repeated microtrauma to the static restraints of the throwing elbow, without adequate time for healing.

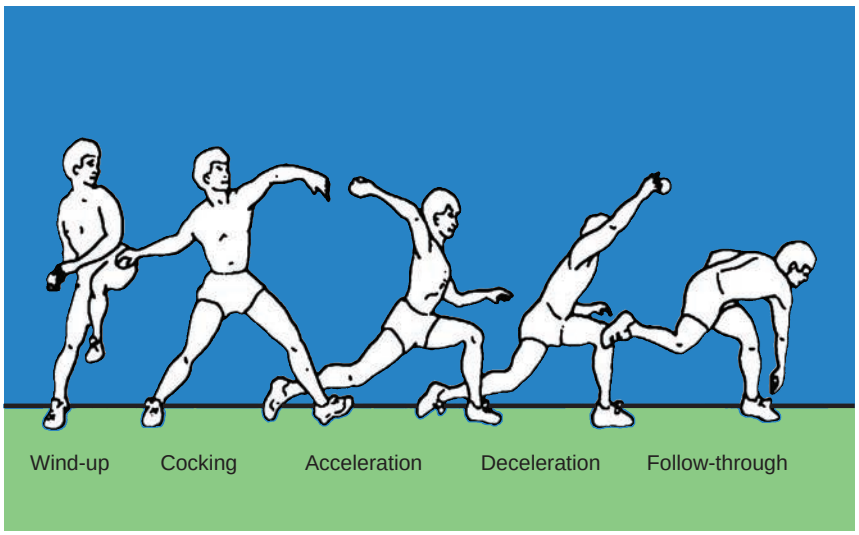


FIGURE 11-1. Phases of the overhead throwing motion.

- Accumulation of elbow microtrauma causes the UCL to become weakened and prone to catastrophic failure.
- The failure process is exacerbated by high pitch velocity, the throwing of breaking pitches, and inadequate warm-ups.

Classic Pathological Findings

- Anterior bundle of the ulnar collateral ligament (UCL) is the primary restraint to valgus stress at the elbow during functional range of motion between 20° and 120° of flexion.
- Dr. Frank Jobe pioneered surgical reconstruction of the UCL in 1974, often referred to as "Tommy John Surgery" in reference to the first recipient of the reconstruction procedure.

Clinical Presentation and Examination

- All patients report elbow pain while athletically active (throwing, tennis).
- Baseball players primarily (96%) complained of pain during the late cocking and acceleration phase of throwing.
- Half report an acute onset of pain at the medial elbow, whereas half cannot identify a single inciting event.
- For those athletes who can identify the onset of symptoms, three out of four report that the onset occurred during a game, 10% during practice, 10% during the preseason, 4% during the off-season, and 1% while playing recreationally.
- Decreased velocity and/or loss of control is a common complaint.

Abnormal Findings

- The primary exam finding is tenderness to palpation of the anterior band of the UCL.
- Pain with valgus stress (milking maneuver) and active valgus stress are common.
- Preoperatively one in four athletes has neurological symptoms, most commonly intermittent paresthesias in the ulnar nerve distribution (ring and small fingers) during throwing.

Pertinent Normal Findings

- Elbow range of motion is generally full, although many overhead athletes have a flexion contracture of about 5°.
- Only one in four patients demonstrates valgus instability to manual testing at 30° elbow flexion.

Imaging Studies

- Radiographic examination is normal in half, whereas half have assorted radiographic abnormalities, most commonly olecranon osteophyte formation and ectopic calcification within the UCL substance.
- Magnetic resonance arthrography (MRA) with intraarticular contrast is the gold standard diagnostic test.
- MRA may show complete tearing or a partial undersurface tear of the anterior band of the UCL.
- CT arthrogram is useful in patients who cannot undergo MRA
- Ultrasound may be useful in diagnosis and may be helpful to allow some level of reparative process of the ligament with nonsurgical treatment.

Differential Diagnosis

- Flexor pronator tendinitis: tenderness anterior to the UCL along the medial epicondyle, pain with resisted wrist pronation
- Ulnar neuritis: sensory disturbance to the ring and small fingers, positive Tinel's at the cubital tunnel, normal imaging
- Olecranon osteophyte/valgus extension overload: posterior medial pain along the olecranon tip with extension, pain during ball release or follow-through, osteophyte on radiographs

Treatment

Nonsurgical Options

- Rest: cessation from throwing or any valgus producing stress to the elbow
- NSAIDs
- Physical therapy to maintain elbow motion, decrease pain, strengthen both the shoulder and elbow musculature
- Injection of corticosteroids or platelet rich plasma: *controversial*

Guidelines for Choosing among the Nonsurgical Treatment Options

- Level of play: Higher level of play (major league) is more likely to have successful outcomes than lower level (high school, recreational).
- Degree of injury (partial vs. complete): Complete tears are more likely to lead to chronic symptoms.
- Timing of season: Return to play generally takes approximately 1 year.
- Position (pitcher vs. fielder): Pitcher and catcher require more elbow endurance, and may take longer to return after surgery.
- Acute versus chronic injury: Chronic ligament insufficiency is less likely to respond favorably to nonsurgical treatment.
- Symptom magnitude: Some athletes can participate at various levels (i.e., fielding but not pitching) despite ligament damage.

Surgical Indications

- Absolute: complete tear in pitcher who has failed nonoperative treatment and is unable to participate at the desired level of play

- Relative: any degree of tear in any sport or position that is unable to return to the desired level of competition after appropriate nonsurgical treatment, and is willing to participate in a minimum 1 year rehabilitation period
- Most UCL injuries in nonoverhead athletes (e.g., football, gymnastics, soccer) do not require surgery for continued participation.

Aspects of History, Demographics, or Exam Findings That Affect Choice of Treatment

- Age
- Level of play
- Degree of injury (partial vs. complete)
- Timing of season
- Position (pitcher vs. fielder)
- Acute versus chronic injury
- Symptom magnitude

Aspects of Clinical Decision Making When Surgery Is Indicated

- Graft choice: palmaris longus versus gracilis tendon (autografts)
- Additional procedures as indicated: ulnar nerve transposition, olecranon osteophyte excision, loose body removal
- Muscle-splitting versus modified Jobe (muscle elevation)
- Graft fixation: suture fixation versus interference screw versus docking

Evidence

Azar FM, Andrews JR, Wilk KE, et al: Operative treatment of ulnar collateral ligament injuries of the elbow in athletes. *Am J Sports Med* 28:16–23, 2000.

The authors evaluated the first large series of ulnar collateral ligament reconstructions (78) or repairs (13) by one surgeon (JRA). Thirty-seven patients (41%) were professional baseball players, 41 (45%) were collegiate baseball players, and 7 (7.7%) were high school or recreational players. Subcutaneous ulnar nerve transposition with stabilization of the nerve with fascial slings of the flexor pronator mass was performed in all patients. Reconstruction of the ulnar collateral ligament was found to be effective in correcting medial instability of the elbow and allowed most athletes (79%) to return to previous levels of play in less than 1 year. (Level IV evidence)

Cain EL, Andrews JR, Dugas JR, et al: Outcome of ulnar collateral ligament reconstruction of the elbow in 1281 athletes: Results in 743 athletes with minimum 2-year follow-up. *Am J Sports Med* 38:2426–2434, 2010.

The authors report follow-up data on a large case series of ulnar collateral reconstruction (1266) or repair (15) performed in 1281 patients over a 19-year period using a modification of the Jobe technique. Seven hundred forty-three patients (79%) were contacted for follow-up evaluation and/or completed a questionnaire at an average of 37 months postoperatively. Six hundred seventeen patients (83%) returned to the previous level of competition or higher. The average time from surgery to the initiation of throwing was 4.4 months and the average time to full competition was 11.6 months after reconstruction. Complications occurred in 148 patients (20%), including 16% considered minor and 4% considered major. (Level IV evidence)

Conway JE, Jobe FW, Glousman RE, et al: Medial instability of the elbow in throwing athletes. Treatment by repair or reconstruction of the ulnar collateral ligament. *J Bone Joint Surg Am* 74:67–83, 1992.

The authors report longer-term follow-up of the original Jobe cohort of UCL reconstruction. Seventy patients were reported at an average of 6.3 years post surgery. Seven of fourteen repairs (50%) and 38 of 56 (68%) reconstructions returned to the same level of competition or higher. Twelve of sixteen major league players were able to return to the major leagues after reconstruction. Ulnar neuropathy occurred postoperatively in 15 patients, with nine requiring subsequent surgery for the neuropathy. Patients with previous surgery on the elbow had a significantly lower chance of return to the same level of competition. (Level IV evidence)

Jobe FW, Stark H, Lombardo SJ: Reconstruction of the ulnar collateral ligament in athletes. *J Bone Joint Surg Am* 68:1158–1163, 1986.

The is the landmark article reported by Jobe on reconstruction of the ulnar collateral ligament using a free tendon graft on 16 athletes in sports that involved throwing (mostly professional baseball). Jobe describes his surgical technique and rehabilitation program. Ten of the sixteen patients returned to their previous level of participation in sports, one returned to a lower level of participation, and five retired from professional athletics. There was a high incidence of complications related to the ulnar nerve. Two patients had postoperative ulnar neuropathy that required a secondary operation, but they eventually recovered completely, and three others reported some transient postoperative hypoesthesia that resolved after a few weeks or months. (Level IV evidence)

Petty DH, Andrews JR, Fleisig GS, et al: Ulnar collateral ligament reconstruction in high school baseball players: Clinical results and injury risk factors. *Am J Sports Med* 32:1158–1164, 2004.

The authors report the outcome of ulnar collateral ligament reconstruction and evaluated potential risk factors for injury at the high school level. Follow-up physical examination and questionnaire data were collected at an average of 35 months after ulnar collateral ligament reconstruction from 27 former high school baseball players. Six potential risk factors were evaluated: year-round throwing, seasonal overuse, event overuse, throwing velocity more than 80 mph, throwing breaking pitches before age 14, and inadequate warm-ups. Overall, 74% returned to baseball at the same or higher level. Patients averaged three potential risk factors, and 85% demonstrated at least one overuse category. Of the pitchers, the average self-reported fastball velocity was 83 mph, and 67% threw breaking pitches before age 14. The success rate of ulnar collateral ligament reconstruction in high school baseball players is nearly equal to that in more mature groups of throwers. Overuse of the throwing arm and throwing breaking pitches at an early age may be related to their injuries. Special attention should be paid to elite-level teenage pitchers who throw with high velocity. (Level IV evidence)

Smith GR, Altchek DW, Pagnani MJ, et al: A muscle-splitting approach to the ulnar collateral ligament of the elbow. Neuroanatomy and operative technique. *Am J Sports Med* 24:575–580, 1996.

The authors describe the relevant anatomy of a novel surgical approach to the UCL by a muscle-splitting approach, rather than the traditional muscle detachment (Jobe) or elevation (Andrews).

Thompson WHJF, Yocum LA: Ulnar collateral ligament reconstruction in throwing athletes: Muscle-splitting approach without transposition of the ulnar nerve [abstract]. *J Shoulder Elbow Surg* 7:175, 1998.

The authors report the outcome of UCL reconstruction with a muscle-splitting approach without transposition of the ulnar nerve in 83 athletes with medial elbow instability. Thirty-three were available for minimum 2-year follow-up. Postoperatively, 5% of this group had transient ulnar nerve symptoms, all of which resolved with nonoperative management. There were no reoperations for nerve dysfunction and no permanent nerve problems. Ninety-three percent of the highly competitive athletes who had not had a prior surgical procedure had an excellent result. All athletes, regardless of whether they had a prior procedure, were able to return to their sport. The authors felt these surgical modifications yielded a decreased postoperative complication rate and improved outcomes compared with the results of prior procedures. (Level IV evidence)

Multiple Choice Questions

QUESTION 1. During which phase of the throwing motion do symptoms most commonly occur with UCL injury?

A. Wind-up
B. Acceleration
C. Ball release
D. Follow-through

QUESTION 2. What position in baseball most commonly injures the UCL?

A. Catcher
B. Infield
C. Outfield
D. Pitcher

QUESTION 3. What is the most common physical exam finding with UCL injury?

A. Pain with resisted pronation
B. Positive Tinel's at the cubital tunnel
C. Pain with valgus stress
D. Loss of motion

QUESTION 4. What percentage of athletes is expected to return to the same level or higher competition after UCL reconstruction?

A. Less than 25%
B. 25% to 50%
C. 50% to 75%
D. Greater than 75%

QUESTION 5. What is the gold standard diagnostic test for UCL injury?

A. Plain radiographs
B. CT scan
C. Ultrasound
D. Arthrogram MRI

Answer Key

QUESTION 1. *Correct answer:* **B** (see Clinical Presentation)

QUESTION 2. *Correct answer:* **D** (see Epidemiology)

QUESTION 3. *Correct answer:* **C** (see Clinical Presentation)

QUESTION 4. *Correct answer:* **D** (see Evidence)

QUESTION 5. *Correct answer:* **D** (see Imaging Studies)

NONOPERATIVE REHABILITATION OF ULNAR COLLATERAL LIGAMENT INJURIES

E. Lyle Cain, Jr., MD, Kevin E. Wilk, PT, DPT,
and Todd R. Hooks, PT, OCS, SCS, ATC, MOMT, MTC, CSCS, FAAOMPT

GUIDING PRINCIPLES OF REHABILITATION

- Restrict elbow range of motion and valgus forces during the early phases of treatment to minimize stresses upon healing structures.
- Conduct a proper assessment and institute a proper rehabilitation of the entire kinetic chain to reduce the valgus stresses imparted upon the elbow during overhead athletics.
- Ensure an appropriate functional interval return to play program is implemented to allow for a controlled progression into sporting activities.
- Proper communication between coach, player, physician, and clinician to determine appropriate return to play guidelines based upon sport of the athlete.

Phase I (Immediately following injury through week 2)

Protection

- A hinged elbow brace is used to restrict motion and prevent valgus strain.
- The athlete is allowed to perform personal care ADLs while wearing brace.

Management of Pain and Swelling

- Analgesic and antiinflammatory medications may be used as needed to decrease pain and swelling.
- The athlete is instructed to perform cryotherapy for 20 minutes every hour throughout the acute phase or until swelling subsides.
- Therapeutic modalities (IFC, Hi-Volt, TENS, and low level laser therapy [cold laser]) can be used to decrease pain and inflammation and augment the healing process.
- A compression wrap can be worn to decrease swelling.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- The rehabilitation specialist can perform manual PROM of the elbow within 20° to 90° to neuromodulate pain and aid in collagen alignment of the healing ligamentous tissue.

Soft Tissue Techniques

- The clinician may begin edema massage from distal to proximal to assist in swelling reduction.
- Soft tissue mobilizations to decrease muscle guarding and tone can be performed by the clinician.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Light pain-free stretching activities can be prescribed for the wrist and forearm musculature within the prescribed elbow range of motion limitations.
- Shoulder PROM can be conducted to maintain capsular and shoulder mobility.

Other Therapeutic Exercises

- The athlete can perform stationary biking activities while wearing a hinged elbow brace to maintain cardiovascular fitness.
- Core strengthening exercises that do not task the upper extremity, such as crunches, can be implemented.
- Lower extremity strengthening and stretching exercises may be initiated to retard muscle atrophy and maintain flexibility.

Activation of Primary Muscles Involved

- Week 1: gripping exercises, wrist, elbow, and shoulder isometrics
- Week 2: rotator cuff (ER/IR tubing at 0° abduction, full can, and abduction) and scapular (prone row, prone horizontal abduction) exercises can be performed.

Sensorimotor Exercises (Balance Proprioception, Kinesthesia)

Rhythmic stabilization drills for the scapula (Figure 11-2), shoulder, and elbow joint can be performed as well as passive/active joint repositioning for sensorimotor stimulus (Figure 11-3).

Open and Closed Kinetic Chain Exercises

- Week 1: OKC exercises for the throwing arm are performed to minimize any undue stresses at the elbow.
- Week 2: CKC exercises can be initiated such as wall wipes (Figure 11-4) and table slides.



FIGURE 11-2. Sitting rhythmic stabilization drills performed to develop proximal stability for the upper extremity during throwing.



FIGURE 11-3. Passive/Active reproduction of the elbow can be performed as the clinician will impart a passive motion upon the elbow as the athlete's eyes are closed. The athlete actively reproduces this joint angle to provide proprioceptive input.

Techniques to Increase Muscle Strength, Power, and Endurance

- The patient will perform low resistance, high repetition exercises for the involved upper extremity to improve vascularity, endurance, and diminish atrophy.

Neuromuscular Dynamic Stability Exercises

- The athlete may perform sitting or side-lying scapular PNF (Figure 11-5) and neuromuscular drills.
- The clinician can give tactile and verbal cueing to the patient to assist in proper muscle recruitment and correct movement patterns during the exercises.

Milestones for Progression to the Next Phase

- Minimal joint effusion
- Elbow ROM 20° to 90°
- Pain free special tests and minimum to no increased laxity with valgus stress testing
- No pain to palpation at medial elbow

Phase II (weeks 2 to 10)

Protection

A hinged elbow brace should continue to be used and will be gradually opened 10° per week.

Management of Pain and Swelling

- The patient can continue with NSAID treatment as prescribed by MD.
- The clinician can initiate rehabilitation with moist hot pack to increase local blood flow and prepare tissues for treatment by increasing tissue extensibility.

TIMELINE 11-1: **Nonoperative Rehabilitation Following Ulnar Collateral Ligament Sprains of the Elbow in Throwers**

PHASE I (weeks 0 to 2)	PHASE II (weeks 3 to 10)

• Goals:
  • Increase range of motion
  • Promote healing of ulnar collateral ligament
  • Retard muscular atrophy
  • Decrease pain and inflammation
• Absolute control of valgus forces for __ weeks (physician discussion)
• ROM:
  • Brace (optional) nonpainful ROM [20°-90°]
  • AAROM, PROM elbow, and wrist (nonpainful range)
  • Shoulder ROM, especially internal rotation and horizontal adduction
• Exercises:
  • Isometrics wrist and elbow musculature
  • Shoulder strengthening (Throwers' Ten Program)
  • Initiate rhythmic stabilization of elbow
• Ice and compression
	• Goals:
	  • Increase range of motion
	  • Improve strength/endurance
	  • Decrease pain and inflammation
	  • Promote stability
	• ROM: Gradually increase motion 0° to 135° (increase 10° per week)
	• Exercises:
	  • Continue Throwers' Ten Program
	  • Initiate manual resistance of elbow/wrist flexor/pronator
	  • Emphasize wrist flexor/pronator strengthening
	  • Initiate rhythmic stabilization drills for elbow
	• Ice and compression
	• No throwing motion or valgus stress



FIGURE 11-4. Closed kinetic chain exercises can be initiated with exercises such as wall wipes. The athlete can emphasize the rotator cuff by performing circular movements and target the scapular musculature with horizontal abduction/adduction motions.



FIGURE 11-5. Side-lying scapula PNF. The clinician will give tactile input to the superior, medial, inferior border of the scapula, and at the elbow to provide resistance as the athlete performs scapula elevation, retraction, depression, and protraction.

- Laser treatment can also be performed to assist in soft tissue healing.
- Following the rehabilitation treatment, the clinician can mitigate any exercise induced inflammation and/or soreness with the use of ice, compression, and electrical stimulation treatment.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- The clinician can progress with passive range of motion to the elbow to allow full elbow range of motion by week 4.

Soft Tissue Techniques

- The clinician should assess for any increase muscle guarding, tone, and/or trigger points.
- The clinician can perform soft tissue mobilization techniques to restore normal muscle extensibility and hemodynamics to the forearm musculature.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- The athlete can continue to progress with a flexibility program for the forearm and glenohumeral musculature.
- The clinician should assure full mobility and flexibility of the scapula, trunk, and lower extremity to allow for the transfer and absorption of kinetic chain energy to optimize performance and decrease potential strains incurred during overhead athletics.

TIMELINE 11-1: **Nonoperative Rehabilitation Following Ulnar Collateral Ligament Sprains of the Elbow in Throwers** (Continued)

PHASE III (weeks 10 to 14)

- Criteria to progress:
  - Full range of motion
  - No pain or tenderness
  - No increase in laxity
  - Strength 4/5 of elbow flexor/extensor
- Goals:
  - Increase strength, power, and endurance
  - Improve neuromuscular control
  - Initiate high speed exercise drills
- Exercises:
  - Initiate isotonic strengthening
  - Thrower's Ten Program
  - Biceps/triceps program
  - Supination/pronation wrist
  - Extension/flexion
  - Plyometrics throwing drills
- Two- hand drills at week 10 to 12
- Single arm plyos at week 12 to 14

PHASE IV (weeks 14 to 18)

- Criteria to progress to return to throwing:
  - Full nonpainful ROM
  - No Increase in laxity
  - Isokinetic test fulfills criteria
  - Satisfactory clinical exam
  - No pain on valgus stress test
- Exercises:
  - Initiate interval throwing—monitor signs and symptoms
  - Continue Thrower's Ten Program
  - Continue plyometrics
  - Continue rhythmic stabilization drills

Other Therapeutic Exercises

- Lower extremity exercises can be progressed including elliptical and machine-based LE strengthening exercises.
- The athlete can perform well-armed strengthening exercises such as lateral raises, shoulder rows, and shoulder press to maintain strength and promote the neuromuscular crossover effect for the involved upper extremity.
- Core strengthening and stabilization exercises can be performed including planks, and stabilization exercises on unstable surface (physio ball) (Figure 11-6).

Activation of Primary Muscles Involved

- Wrist strengthening exercises are progressed, with emphasis upon wrist flexion and pronation strengthening.
- Biceps and triceps exercises can be implemented as tolerated.
- Scaption, abduction, side-lying ER, prone row, prone extension, prone horizontal abduction, prone scaption, and prone row into ER are progressed as tolerated.

Sensorimotor Exercises (Balance Proprioception, Kinesthesia)

- Lower extremity proprioception and coordination drills can be performed for hip/core stabilization, including: tilt board squats, single leg activities, and perturbation training drills.

Open and Closed Kinetic Chain Exercises

- CKC exercises can be integrated into rehabilitation program, including stabilization exercises on a ball (Figure 11-7), push-up plus, and upper extremity machine-based weight training. The athlete is instructed to perform these exercises in a pain-free range and perform the exercise with the elbows maintained close to the trunk to minimize strain upon the UCL.



FIGURE 11-6. Trunk and scapula stabilizations performed on a BOSU ball as the clinician incorporates perturbations upon the athlete's trunk and upper extremity.

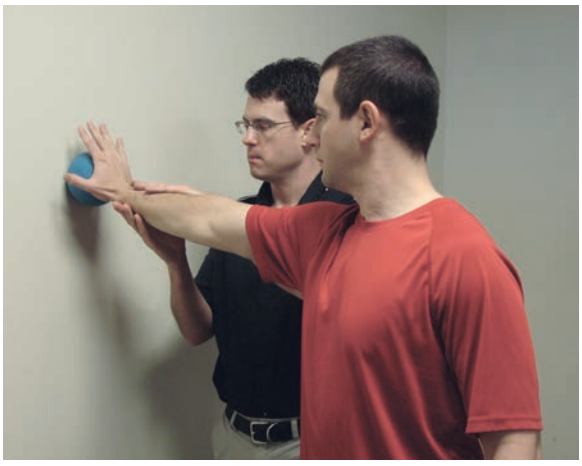


FIGURE 11-7. Ball on wall stabilization drills. The athlete places an open palm onto a ball and maintains a static position while keeping the elbow extended as the clinician performs rhythmic stabilizations. These stabilization can begin proximally upon the upper arm and progress distally upon the wrist.

Techniques to Increase Muscle Strength, Power, and Endurance

- The athlete can be progressed with strengthening exercises by decreasing repetitions and increasing weight to allow for progression training of the forearm, glenohumeral, and scapulothoracic musculature.

Neuromuscular Dynamic Stability Exercises

- Manual PNF resistance exercises for the distal arm can by performed by alternating resistance of the elbow, wrist, and finger flexion and forearm supination followed by elbow, wrist, and finger extension and forearm pronation (Figure 11-8).
- Manual resistance exercises can also be performed for external rotation. Because of the high EMG activity in



FIGURE 11-8. Manual PNF resistance of the elbow/wrist performed as the clinician concomitantly resists elbow, wrist, and finger flexion and supination followed by elbow, wrist, and finger extension and pronation.

the follow-through phase of throwing, eccentric manual resistance exercises can be implemented for the scapula, rotator cuff, and forearm musculature.

Functional Exercises

- The athlete should perform total body strengthening exercises to allow for synchronization of hips/core/shoulder movement patterns. This can also include performing single leg and split stance exercises, as well as PNF patterns involving the trunk and lower extremities.
- Agility exercises for the lower extremity such as cone and agility ladder exercises can be incorporated into the athlete's program.

Sport-Specific Exercises

- Athletes involved in contact sports and those suffering from injury on the nondominant extremity may be released to return to competitive sports following clearance from MD.
- In addition, quarterbacks have been shown to return to competition sooner than baseball pitchers. Dodson et al. (2010) reported a mean return to play following nonoperative management of an acute UCL injury to be 26.4 days; therefore proper communication is needed to determine appropriate return to play expectations.

Milestones for Progression to the Next Phase

- Full, pain-free elbow range of motion
- MMT 5/5 for involved upper extremity
- Satisfactory clinical examination with negative valgus laxity and provocation testing.

Phase III (weeks 10 to 14)

Protection

- The hinged elbow brace can be discharged during this phase.

Management of Pain and Swelling

- Cryotherapy can be used following treatment as needed to avoid post-rehabilitation soreness and inflammation.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Ensure the athlete maintains full elbow and shoulder range of motion throughout treatment and avoiding the potential loss of motion with the addition of plyometric and the integration of sporting activities.

Soft Tissue Techniques

- The clinician should continue to evaluate the entire upper extremity and scapular musculature to assess for pliability of the soft tissue. Soft tissue restrictions, trigger points, and decreased flexibility could cause movement impairments for the athlete.
- The clinician can perform soft tissue mobilization treatments and in addition instruct the athlete in soft mobilization techniques as part of the activity warm-up and cool down program.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- The clinician should continue to monitor the flexibility and pliability of the soft tissue of the entire upper extremity to ensure the athlete does not develop any diminished flexibility as the result of delayed onset muscle soreness (DOMS).

Other Therapeutic Exercises

- Lower extremity strength training should continue to be progressed for quadriceps, hamstrings, and hip musculature. These exercises can be progressed to include functional exercises such as multidirectional lunges, and step up drills.
- Core stabilization and strengthening exercises should be progressed to include stable and unstable surfaces and resistive core training.
- Upper extremity weight training can be progressed with rows, lat pull downs, shoulder presses, and bench press as tolerated.

Activation of Primary Muscles Involved

- The athlete should continue with Thrower's Ten exercise progression (see Figure 11-3).

Sensorimotor Exercises (Balance Proprioception, Kinesthesia)

- The athlete can perform PNF training exercises on unstable surface in both seated and standing position to allow integration of core and lower extremity stabilization.

Open and Closed Kinetic Chain Exercises

- The athlete can progress with upper extremity CKC exercises including front and side planks, push ups, and weight bearing stabilization drills on unstable surfaces as deemed necessary based upon sporting participation.

Techniques to Increase Muscle Strength, Power, and Endurance

- Lower extremity and core strengthening and stabilization exercises can be performed in a kneeling, double and single leg stance to allow for functional training of the athlete.
- Upper extremity strengthening exercises are progressed with machine and free weight training with bench press, rows, latissimus dorsi pull downs, and triceps extension exercises are incorporated.

Neuromuscular Dynamic Stability Exercises

- Dynamic rhythmic stabilization and upper extremity strengthening exercises can be performed with the arm



FIGURE 11-9. Stabilization drills performed at 90/90 position as the athlete performs external plyometric wall dribbles.

in an overhead position to increase strength and stability with the arm in a functional position (Figure 11-9).

Plyometrics

- Two-hand plyometric exercises are initiated at week 10. The athlete will begin with hands close to the trunk with chest and side throws, and progress to side-to-side throws and soccer style throw.
- The athlete will perform two hand plyometric exercises for approximately 2 weeks and upon successful completion will progress to one-hand plyometric drills.

Functional Exercises

- A swimming program can be implemented to include an aquatic shoulder therapeutic program that can be performed as an adjunct to the rehabilitation program.

Sport-Specific Exercises

- Stabilization exercises and manual resistance training drills are performed in an overhead position. The athlete can perform plyometric exercises and drills that incorporate the trunk and lower extremity with weighted medicine balls (Figure 11-10).

Milestones for Progression to the Next Phase

- Full pain-free elbow ROM
- Satisfactory clinical examination, including valgus and provocation testing
- Satisfactory completion of two-hand plyometric drills
- MMT 5/5 strength all muscle groups

Phase IV (weeks 14 to 18)

Protection

- Functional elbow brace if prescribed by MD if athlete is involved in a contact sport

Management of Pain and Swelling

- Cryotherapy as needed to mitigate postexercise-induced soreness.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- PROM to maintain full wrist, elbow, and shoulder ROM

Soft Tissue Techniques

- The clinician can continue with soft tissue mobilization techniques to address facial or musculature restrictions as well and any tone or trigger points that may occur as part of an increase in workload activities.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Flexibility exercises for the wrist, elbow, and shoulder musculature are encouraged throughout the rehabilitation program pre- and posttreatment to minimize postexercise soreness.

Other Therapeutic Exercises

- Lower extremity strengthening exercises are progressed with free and machine-based strengthening exercises.
- The athlete can progress with dynamic movement drills to replicate throwing motion. Core stabilization exercises drills can be performed in quadruped, kneeling, and standing position to progress with core training.

Activation of Primary Muscles Involved

- Advanced Thrower's Ten exercise program is continued and can be performed on stability ball to integrate core stabilization with upper extremity exercises.

Sensorimotor Exercises (Balance Proprioception, Kinesthesia)

- PNF patterns to include the trunk and upper extremity using medicine balls, cables, or kettle bells (Figure 11-11).



FIGURE 11-10. Forward lunge with overhead plyometric toss to incorporate trunk synchronization with upper extremity movement patterns.

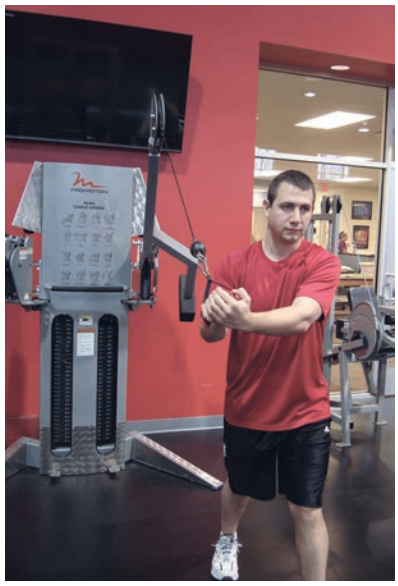


FIGURE 11-11. Cable chops performed in a split stance position.

Open and Closed Kinetic Chain Exercises

- Upper extremity CKC exercises on both stable and unstable support to facilitate proprioception input. These exercises and drills can be performed with and without manual stabilizations.

Techniques to Increase Muscle Strength, Power, and Endurance

- The athlete can perform high-speed coordination and neuromuscular training exercises for the involved upper extremity including the rotator cuff and biceps musculature. Training at high speeds prepares the athlete for sporting activity to eccentrically control and dissipate the forces that are imparted upon the elbow during overhead activities such as throwing.

Neuromuscular Dynamic Stability Exercises

- Dynamic training exercises on unstable surfaces, trunk perturbations, and single leg activities are performed to mimic the throwing motion.

Plyometrics

- One-hand plyometric drills are initiated at week 12. These exercises are begun with internal and external rotation throws at 0° of abduction and wall dribbles. These exercises can be progressed to 90/90 throws and simulated throwing motion.

Functional Exercises

- Lower extremity agility and sport-specific running program to increase overall cardiovascular function and preparation for athletic competition.

Sport-Specific Exercises

- Initiate interval throwing program (Phase I) can be implemented during this phase and progressed to throwing off the mound (Phase II) upon successful completion.

Table 11-1 Isokinetic Testing of Elbow Flexion/Extension

Bilateral Comparison		
Velocity	**Elbow (Flex)**	**Elbow (Ext)**
180°/sec	110% to 120%	105% to 115%
300°/sec	0.5% to 115%	100% to 110%
Unilateral Muscle Ratios		
Velocity	**Elbow (Flex/Ext)**	
180°/sec	70% to 80%	
300°/sec	63% to 69%	

Milestones for Progression to the Next Phase

- Pain that limits athlete at sporting activity
- Inability to complete sport specific program
- Unsatisfactory clinical examination including valgus testing
- Inability to return to competition following 3+ months of conservative management

Milestones for Progression to Advanced Sport-Specific Training and Conditioning

- Full elbow ROM
- Completion of sport-specific training program
- Isokinetic testing of bilateral elbow flexion and extension reveals: elbow flexion 10% to 20% stronger and 5% to 15% stronger in extensors as compared with the noninvolved arm
- Satisfactory isokinetic testing (Table 11-1).

Tips and Guidelines for Transitioning to Performance Enhancement

- The clinician should make certain the athlete maintains full shoulder and elbow ROM throughout the rehabilitation and return to sports program in order to minimize any stresses imparted upon the elbow with throwing activity.
- Total arm including scapular muscle strength should be emphasized during treatment to increase performance and minimize injury potential.
- The clinician should ensure a systematic program is used, including strength training, proprioception drills, flexibility, and proprioception, performed before the initiation of a throwing program.

Performance Enhancement and Beyond Rehab: Training/Trainer, and Optimization of Athletic Performance

- Continued maintenance program for the throwing athlete during the season that is usually performed every other day

- Endurance and cardiovascular fitness to decrease injuries related to fatigue
- Core strengthening and stabilization exercises to allow for efficient transfer and dissipation of energy throughout the kinetic chain.

Specific Criteria for Return to Sports Participation: Tests and Measurements

- Satisfactory clinical examination
- Clearance by MD
- Successful completion of an interval sporting program
- Pain and symptom free with sports participation
- MMT 5/5 strength for all muscle groups
- Satisfactory isokinetic testing (see Table 11-1)

Evidence

Dodson CC, Slenker N, Cohen SB, et al: Ulnar collateral ligament injuries of the elbow in professional football quarterbacks. *J Shoulder Elbow Surg* 19:1276–1280, 2010.

This retrospective study examined the outcome of 10 reported cases of UCL injuries in NFL quarterbacks from 1994 to 2008. Nine cases were treated nonoperatively and were able to return to play at a mean of 26.4 days. (Level III evidence)

Elliott B, Fleisig G, Nicholls R, et al: Technique effects on upper limb loading in the tennis serve. *J Sci Med Sport* 6:76–87, 2003.

This controlled laboratory study analyzed the kinematics and kinetics during a tennis serve of 20 male and female Olympic athletes. The authors noted athletes who demonstrated less knee flexion of the front leg during the backswing of the serve (7.6 degrees vs. 14.7 degrees) had an increased valgus load of 21% at the elbow.

Fleisig GS, Bolt B, Fortenbaugh D, et al: Biomechanical comparison of baseball pitching and long-toss: Implications for training and rehabilitation. *J Orthop Sports Phys Ther* 41:296–303, 2011.

This controlled laboratory study examined the kinematic and kinetic differences between pitching from a mound and a long-toss in 17 healthy college pitchers. Analysis was performed during mound pitching, horizontal throws at 37 and 55 m, and maximum distance throws with no restraint upon arc of trajectory. Results indicate that horizontal, flat throws produce biomechanical patterns similar to pitching, whereas maximum distance throws had increased torques (including an elbow varus torque) as compared to mound pitching.

Rettig AC, Sherrill C, Snead DS, et al: Nonoperative treatment of ulnar collateral ligament injuries in throwing athletes. *Am J Sports Med* 29:15–17, 2001.

This retrospective study examined the outcome of 31 throwing athletes following ulnar collateral ligament injury and determined which factors would predict return to competition nonoperatively. Thirteen (42%) athletes were able to return the previous level of competition at an average of 24.5 weeks. No findings obtained through history or physical examination were noted to predict successful outcome. (Level III evidence)

Multiple Choice Questions

QUESTION 1. Once adequate strength, range of motion, and tissue healing has occurred, when is it safe to begin a plyometric program?

A. Week 2
B. Week 6
C. Week 10
D. Week 16

QUESTION 2. Based upon anatomical approximation to the UCL, these muscle groups are emphasized during rehabilitation to provide dynamic stability to the medial aspect of the elbow with overhead athletics.

A. Wrist extensors and forearm pronators
B. Wrist extensors and forearm supinators
C. Wrist flexors and forearm pronators
D. Wrist flexors and forearm supinators

QUESTION 3. A hinged elbow brace is frequently prescribed during the acute phase to minimize stress upon the UCL and diminish inflammation. What range of motion guidelines are generally used for elbow motion?

A. 0° to 90° for 1 week, full elbow motion by week 2
B. 20° to 90° for 2 weeks, full elbow motion by week 4
C. 40° to 100° for 4 weeks, full elbow motion by week 6
D. Full elbow ROM allowed immediately within brace

QUESTION 4. Which statement is NOT true in regard to Phase II (weeks 3 to 10)?

A. An interval throwing program can be initiated during this phase.
B. Elbow range of motion is gradually restored to full range.
C. Thrower's Ten Program is progressed for elbow, glenohumeral, and scapulothoracic strengthening.
D. Hinged elbow brace may be discharged during this phase.

QUESTION 5. Which of the following criteria would warrant failure of nonoperative treatment and consideration of surgical repair of UCL?

A. Unable to complete sport-specific program
B. Failure to return to competition following 3+ months of conservative management
C. Pain that limits sporting activity
D. All of the above

Answer Key

QUESTION 1. Correct answer: **C** (see Phase III)

QUESTION 2. Correct answer: **C** (see Phase II)

QUESTION 3. Correct answer: **B** (see Phases I and II)

QUESTION 4. Correct answer: **A** (see Phase II)

QUESTION 5. Correct answer: **D** (see Phase IV)

POSTOPERATIVE REHABILITATION AFTER ULNAR COLLATERAL LIGAMENT RECONSTRUCTION

E. Lyle Cain, Jr., MD, Kevin E. Wilk, PT, DPT,
and Todd R. Hooks, PT, OCS, SCS, ATC, MOMT, MTC, CSCS, FAAOMPT

Indications for Surgical Treatment

- Physical examination demonstrating excessive valgus instability
- Imaging studies (i.e., MRI) confirming UCL injury (Figure 11-12)
- Persistent pain with inability to perform at desired level of sports/activities
- Failure of nonoperative rehabilitation program
- Surgery may be recommended without undergoing nonoperative rehabilitation in the overhead athlete depending on history and seasonal timing issues.

Brief Summary of Surgical Treatment

Major Surgical Steps

- Our current surgical approach is a modification of the original technique described by Jobe et al.
- The modifications include elevation of the flexor-pronator muscle mass without detachment and subcutaneous rather than submuscular ulnar nerve transposition.
- An anterolateral arthroscopic portal is established for evaluation of the anterior compartment articular surfaces and synovium and to perform the arthroscopic valgus stress test at 70° of flexion with the arm pronated.
- A medial opening of greater than 1 to 2 mm suggests ulnar collateral ligament insufficiency.
- The open procedure begins with a medial incision centered over the medial epicondyle.
- The medial antebrachial cutaneous nerve is initially identified and protected.
- The ulnar nerve is carefully dissected free from the cubital tunnel and protected with a vessel loop. Ulnar nerve release must continue proximally to the arcade of Struthers and distally into the flexor carpi ulnaris muscle mass.
- A portion of the medial intermuscular septum is removed to prevent tenting of the ulnar nerve after transposition.
- The anterior band of the ulnar collateral ligament is exposed by elevation of the flexor muscles from the ulnar collateral ligament distal attachment at the sublime tubercle of the ulna.
- The ligament is inspected for attenuation or tearing and is incised longitudinally to permit visualization of the deep portion of the ligament if a complete tear is not present.
- If concomitant valgus extension overload with olecranon osteophytes is suspected, a vertical posterior capsulotomy is placed proximal to the fibers of the posterior band of the ulnar collateral ligament to expose the olecranon tip. Posteromedial olecranon osteophytes are removed with a small osteotome and high-speed burr.
- Graft harvest is then performed. Ipsilateral palmaris longus tendon is our current graft choice, followed by contralateral palmaris longus or contralateral gracilis (autografts).
- The median nerve lies deep to the palmaris longus tendon and should be protected during harvest by avoiding deep dissection.
- Tunnels are then placed in the ulna and medial epicondyle with a 3.2-mm drill bit. A single ulnar tunnel is made by placing two ulnar drill holes 3 to 4 mm distal to the articular surface of the coronoid process, separated by approximately 1 cm at the native attachment site of the ulnar collateral ligament.
- Two medial epicondylar tunnels are placed along the proximal portion of the epicondyle and converge at the origin of the native ulnar collateral ligament.
- The graft is then passed in a figure-eight fashion.
- The elbow is placed at 30° of flexion and varus stress is applied while the graft is secured side-to-side with multiple nonabsorbable sutures.

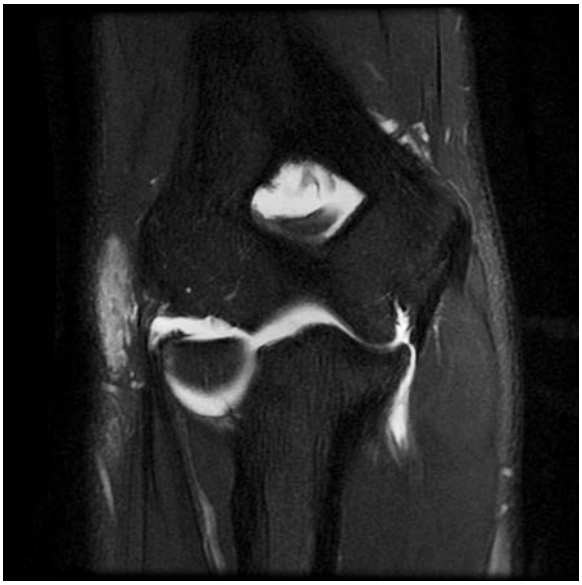


FIGURE 11-12. MRI of a full-thickness UCL tear.

- The ulnar nerve is then transposed subcutaneously and held in place with a single fascial sling from the flexor pronator muscle fascia. The sling is tensioned loosely to prevent any compression of the ulnar nerve.
- The skin is closed with subcuticular suture and the elbow is splinted at 90° of flexion for the first week after surgery to allow soft tissue healing.

Factors That May Affect Rehabilitation

- Graft choice, graft fixation, additional procedures (osteophyte excision, ulnar nerve transposition)

Other Surgical Techniques and Options

- Other techniques use a flexor muscle splitting approach, often without ulnar nerve transposition.
- Graft fixation using interference screws or a "docking technique" may also alter the rehab program.

Before Surgery: Overview of Goals and Guidelines[1]

- Educate patient about postoperative rehabilitation and expectations.
- Normalize elbow range of motion and document preoperative elbow motion.
- Diminish pain and swelling.
- Perform wrist, elbow, glenohumeral, and scapula strengthening exercises.
- Normalize shoulder ROM and scapular posture.

GUIDING PRINCIPLES OF POSTOPERATIVE REHABILITATION

- Understand the surgical technique, including graft selection and whether a concomitant ulnar nerve transposition was performed.
- Appreciate the biomechanical stresses that occur with exercises and activities during the rehabilitation program.
- Utilization of elbow hinged brace for 4 to 6 weeks to minimize stress.
- Respect ROM progression and proper end feel assessment to determine the appropriate manual therapy and exercise techniques to restore motion.
- Proper rehabilitation progression to allow for return to sports for the overhead athlete, including plyometric exercises and completion of an interval throwing program.
- Protection of the repair during postoperative therapy.

[1]*The pre-habilitation outline is included in the nonoperative treatment section of this chapter.*

Phase I (first days 14): Immediate Postoperative Period

- Decrease pain and swelling through cryotherapy, compression, PROM, and electrotherapeutic modalities.
- Minimize the effects of immobilization.
- Protect the reconstructed UCL and associated surgeries.
- Elbow PROM 25° to 100°.

Clinical Pearl

During this phase the clinician should assess for any postoperative complications involving the ulnar nerve. The patient should perform isometric and ROM exercises to diminish the effects of inactivity. The patient should avoid exercises on the involved leg for 1 week if a gracilis graft was used. Initiate wrist and hand ROM, gripping exercises to prevent Complex regional pain syndrome (CRPS).

Protection

- The patient will wear posterior splint with compression dressing locked at 90° flexion for 1 week and then day 8 the patient will be placed into a hinged brace set at 25° to 100°.
- The patient will wear this brace at all times, including during sleep.
- If a gracilis graft is used for reconstruction, the patient may use one crutch the first week as needed.

Management of Pain and Swelling

- Analgesics and antiinflammatory medicines.
- The patient is instructed in cryotherapy for 20 minutes every hour for the first 2 weeks based on pain and swelling.
- A vasopneumatic compression device may be used for simultaneous swelling and pain control.
- Therapeutic modalities for pain and inflammation, including IFC, Hi-Volt, TENS, and therapeutic laser.
- A compression sleeve or wrap may be used to reduce swelling.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- The rehabilitation specialist may begin manual PROM of the elbow to neuromodulate pain and aid in collagen alignment of the healing ligamentous tissue.
- PROM for the first 2 weeks is limited to 20° to 100°.

Soft Tissue Techniques

- Light scar mobilization along distal incision can be performed once sutures have been removed and adequate tissue healing has occurred. Scar mobilization to graft location (wrist or knee).

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Shoulder ROM to maintain capsular mobility and shoulder motion. Stretching exercises for wrist, elbow (calf/knee, if gracilis graft is used) not performed to allow for soft tissue healing and transposed ulnar nerve to embed in fascial sling.

Other Therapeutic Exercises

- Patient can perform stationary biking activities while wearing the elbow brace for low intensity cardiovascular conditioning.
- Patient can perform selected and specific core, hip, and LE exercises.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Gripping activities and active wrist ROM exercises.
- Shoulder isometrics all planes except external rotation (to minimize possible valgus torque at the elbow).
- Biceps and triceps isometrics.

Sensorimotor Exercises

- Passive/active joint reposition exercises and drills.
- Rhythmic stabilization drills for the shoulder and elbow joint.

Open and Closed Kinetic Chain Exercises

- The patient should only perform OKC exercises during the immediate postoperative phase.
- Week 2: The patient is able to perform WB exercises against the wall or onto a table.

Techniques to Increase Muscle Strength, Power, and Endurance

- The patient performs light muscle activation exercises for the intrinsics, wrist, elbow, and shoulder during this phase.

Neuromuscular Dynamic Stability Exercises

- Scapular neuromuscular control drills seated and side-lying position
- Rhythmic stabilization drills for the shoulder, elbow, and wrist

Milestones for Progression to the Next Phase

- Minimal effusion in elbow and distal upper extremity.
- Elbow PROM 30° to 100°
- No marked pain at medial elbow or signs of infection.
- No distal (hand) neurologic symptoms.
- Incision is healed.

Phase II (weeks 2 to 6 postop)

- Protect repaired soft tissues.
- Minimize the effects of immobilization.
- Discharge hinged elbow at 5 weeks postoperative.
- Obtain full elbow PROM at 6 weeks postoperative.
- Progress with scapular strengthening and Thrower's Ten Program (Figure 11-13).

Clinical Pearl

The rehabilitation specialist will gradually progress the patient to full elbow ROM during the first 6 weeks following surgery while ensuring no deleterious stresses are imparted upon the healing structures. Because of the adaptive changes that frequently occur in the overhead athlete, the clinician should understand the patient's preinjury elbow ROM in order to establish appropriate ROM expectations following surgery. Be sure to correct or normalize shoulder ROM (esp. IR) and normalize scapular position. Base elbow ROM on end feel assessment, especially when improving elbow extension.

Protection

- Elbow hinged brace will be unlocked at week 2 and set at varying degrees to allow for gradual restoration of motion:
  - Week 2: 20° to 100°
  - Week 3: 10° to 110°
  - Week 4: 0° to 120°
  - Week 5: 0° to 130°
  - Week 6: Discontinue use of elbow brace

Management of Pain and Swelling

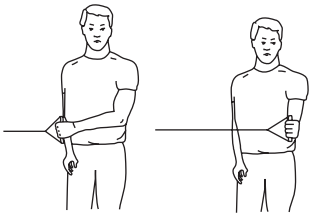
- The patient has discontinued the use of oral pain medications and is taking a nonsteroidal antiinflammatory medication (NSAID).
- The rehabilitation specialist can use moist heat, laser, cryotherapy, vasopneumatic devices, and electrical stimulation (ESTIM) for pain and for preparatory rehabilitation.
- The patient can be prescribed NSAIDs as needed for swelling. The clinician can use vasopneutic devices, and ESTIM, and apply compressionette tubing for swelling reduction.

CSM CHAMPION SPORTS MEDICINE

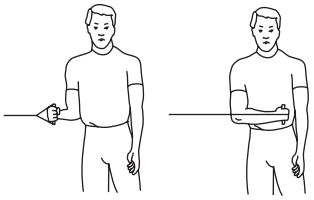
"Throwers Ten + 2" Exercise Program

The Thrower's Ten Program is designed to exercise the major muscles necessary for throwing. The Program's goal is to be an organized and concise exercise program. In addition, all exercises included are specific to the thrower and are designed to improve strength, power and endurance of the shoulder complex musculature.

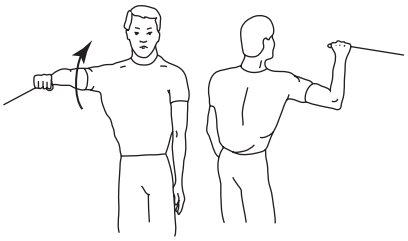
1A. **External Rotation at 0° Abduction:** Stand with involved elbow fixed at side, elbow at 90° and involved arm across front of body. Grip tubing handle while the other end of tubing is fixed. Pull out arm, keeping elbow at side. Return tubing slowly and controlled. Perform _____ sets of _____ repetitions _____ times daily.



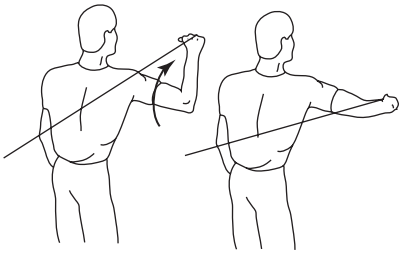
2A. **Internal Rotation at 0° Abduction:** Standing with elbow at side fixed at 90° and shoulder rotated out. Grip tubing handle while other end of tubing is fixed. Pull arm across body keeping elbow at side. Return tubing slowly and controlled. Perform _____ sets of _____repetitions _____ times daily.



1B. (Optional) **External Rotation at 90° Abduction:** Stand with shoulder abducted 90°. Grip tubing handle while the other end is fixed straight ahead, slightly lower than the shoulder. Keeping shoulder abducted, rotate shoulder back keeping elbow at 90°. Return tubing and hand to start position.
I. Slow Speed Sets: (Slow and Controlled) Perform _____ sets of _____ repetitions _____ times daily.
II. Fast Speed Sets: Perform _____ sets of _____ repetitions _____ times daily.



2B. (Optional) **Internal Rotation at 90° Abduction:** Stand with shoulder abducted to 90°, externally rotated 90° and elbow bent to 90°. Keeping shoulder abducted, rotate shoulder forward, keeping elbow bent at 90°. Return tubing and hand to start position.
I. Slow Speed Sets: (Slow and Controlled) Perform _____ sets of _____ repetitions _____ times daily.
II. Fast Speed Sets: Perform _____ sets of _____ repetitions _____ times daily.



4. **Scaption, ER "Full Can":** Stand with elbow straight and thumb up. Raise arm to shoulder level at 30° angle in front of body. Do not go above shoulder height. Hold 2 seconds and lower slowly. Perform _____ sets of _____ repetitions _____ times daily.

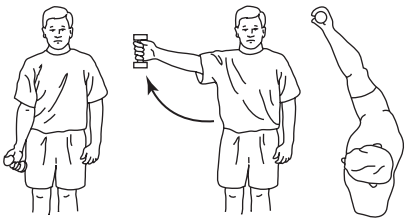
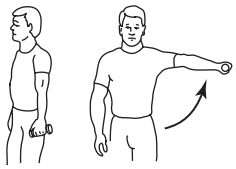
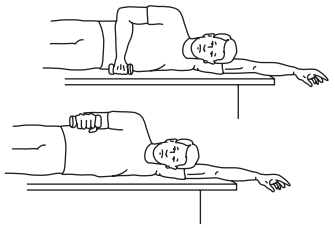


FIGURE 11-13. Thrower's Ten Exercise Program.

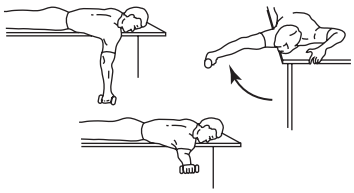
3. **Shoulder Abduction to 90°:** Stand with arm at side, elbow straight, and palm against side. Raise arm to the side, palm down, until arm reaches 90° (shoulder level). Perform _____ sets of _____ repetitions _____ times daily.



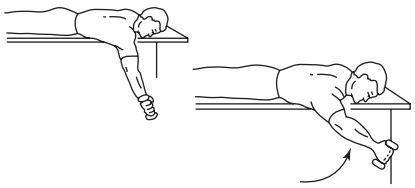
5. **Sidelying External Rotation:** Lie on uninvolved side, with involved arm at side of body and elbow bent to 90°. Keeping the elbow of involved arm fixed to side, raise arm. Hold seconds and lower slowly. Perform _____ sets of _____ repetitions _____ times daily.



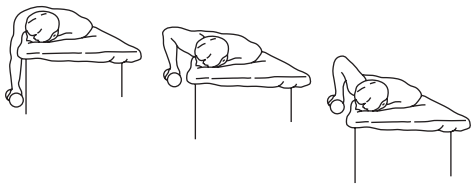
6A. **Prone Horizontal Abduction (Neutral):** Lie on table, face down, with involved arm hanging straight to the floor, and palm facing down. Raise arm out to the side, parallel to the floor. Hold 2 seconds and lower slowly. Perform _____ sets of _____ repetitions _____ times daily.



6B. **Prone Horizontal Abduction (Full ER, 100° ABD):** Lie on table face down, with involved arm hanging straight to the floor, and thumb rotated up (hitchhiker). Raise arm out to the side with arm slightly in front of shoulder, parallel to the floor. Hold 2 seconds and lower slowly. Perform _____ sets of _____ repetitions _____ times daily.



6C. **Prone Rowing:** Lying on your stomach with your involved arm hanging over the side of the table, dumbbell in hand and elbow straight. Slowly raise arm, bending elbow, and bring dumbbell as high as possible. Hold at the top for 2 seconds, then slowly lower. Perform _____ sets of _____ repetitions _____ times daily.



6D. **Prone Rowing into External Rotation:** Lying on your stomach with your involved arm hanging over the side of the table, dumbbell in hand and elbow straight. Slowly raise arm, bending elbow, up to the level of the table. Pause one second. Then rotate shoulder upward until dumbbell is even with the table, keeping elbow at 90°. Hold at the top for 2 seconds, then slowly lower taking 2 – 3 seconds. Perform _____ sets of _____ repetitions _____ times daily.

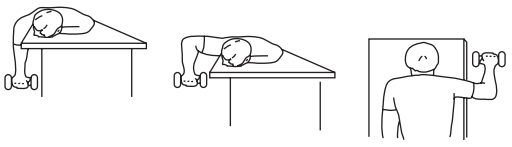
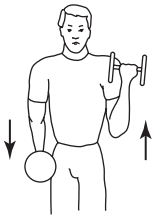


FIGURE 11-13, cont'd

8. **Rows into ER at 90° Abduction, seated on stability ball:** Seated on Stability Ball, with both arms straight ahead, grasping tubing. Keeping arms at shoulder height bend elbows and pull tubing towards the body until elbows are at shoulder level and directly out to both sides (90° Abduction). Hold for a second then rotate shoulder upward until arm is at 90° of ER and Abduction. Hold at top for 2 seconds then return slowly to starting position. Perform _____ sets of _____ repetitions _____ times daily.

8B. **Lower trap, Seated on stability ball:** Seated on Stability Ball, with both arms fixed at side and elbows bent to 90°, thumbs facing upwards. Grasp tubing with both hands and rotate both shoulders outward (External Rotation), rotating thumbs until parallel with floor. Hold for 2 seconds then return to starting position.
Perform ____ sets of ____ repetitions ____ times daily.

9A. **Elbow Flexion:** Standing with arm against side and palm facing inward, bend elbow upward turning palm up as you progress. Hold 2 seconds and lower slowly. Perform _____ sets of _____ repetitions _____ times daily.



9B. **Elbow Extension, Tricep Pushdowns (Optional):** Standing with arms against side, elbows bent to 90°, facing cable column machine. Grasp handles of short bar and "pull down" until elbows straighten. Hold at bottom for 2 seconds then slowly return to starting position. Perform _____ sets of _____ repetitions _____ times daily.

10A. **Wrist Extension:** Supporting the forearm and with palm facing downward, raise weight in hand as far as possible. Hold 2 seconds and lower slowly. Perform _____ sets of _____ repetitions _____ times daily.



FIGURE 11-13, cont'd

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Manual passive range of motion to restore full elbow motion by week 5.

Soft Tissue Techniques

- Soft tissue mobilization to decrease muscle guarding and tone, and to reduce edema. Scar mobilization to prevent adhesions along surgical incisions

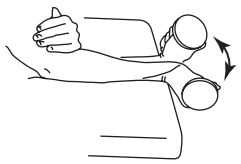
Stretching and Flexibility Techniques for the Musculotendinous Unit

- Initiation of light stretching activity at week 3 for wrist (palmaris graft) and hamstring (gracilis graft)

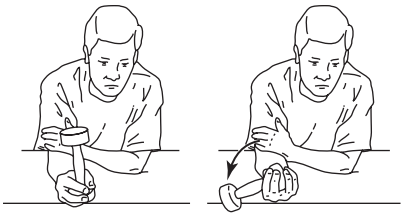
Other Therapeutic Exercises

- Elbow isometrics are initiated at week 3 and progressive resistance exercises are performed, including

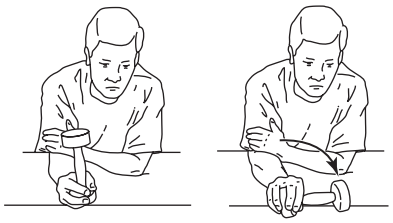
10B. **Wrist Flexion:** Supproting the forearm and with palm facing upward, lower a weight in hand as far as possible and then curl it up as high as possible. Hold for 2 seconds and lower slowly.



10C. **Supination:** Forearm supported on table with wrist in neutral position. Using a weight or hammer, roll wrist taking palm up. Hold for a 2 count and return to starting position. Perform _____ sets of _____ repetitions _____ times daily.



10D. **Pronation:** Forearm should be supported on a table with wrist in neutral position. Using a weight or hammer, roll wrist taking palm down. Hold for a 2 count and return to starting position. Perform _____ sets of _____ repetitions _____ times daily.



11. **Sleeper Stretch:** Lay on the involved or injured side, with involved arm directly out in front (forward flexed to 90°), elbow bent to 90°. With opposite arm apply force to the top of involved arm's wrist forcing the arm to internally rotate towards the table. Hold for 20 seconds and repeat 3 times.

12. **Supine Horizontal Adduction stretch into IR:** Lay supine (on back) with involved arm across chest and elbow bent to 90°. With opposite arm grasp involved arms elbow and pull involved arm across chest until stretch is felt. With uninvolved arms forearm apply a force towards feet onto the involved arm's wrist forcing involved arm into internal rotation. Hold for 20 seconds and repeat 3 times.

FIGURE 11-13, cont'd

shoulder scaption and abduction, ER/IR tubing, scapula retraction, and horizontal abduction.
- Lower extremity exercises can be performed including stationary bike, and machine-based LE strength training equipment (palmaris graft).
- Patients undergoing UCL reconstruction using a gracilis graft can initiate isometric hamstring and gastrocnemius isometrics at week 4 and isotonic exercises at week 6.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Well-arm exercises are performed to promote neuromuscular crossover effect.
- Elbow extension isometrics are performed at week 2 postoperatively.
- Shoulder (scaption, abduction, and ER/IR) and scapular (rows) active movements can begin at week 3.

- Wrist progressive resistive exercises are initiated during week 4 for wrist (flexion, extension, pronation, and supination) and elbow (flexion and extension).

Open and Closed Kinetic Chain Exercises

- The patient should only perform OKC exercises during the immediate postoperative phase for the shoulder girdle.
  - Scaption
  - Abduction
  - Side-lying ER
  - ER/IR tubing
  - Elbow flexion/extension
  - Prone row
  - Prone horizontal abduction
  - Scapular manual resistance exercises

Techniques to Increase Muscle Strength, Power, and Endurance

- Lower extremity strengthening exercises such as lunges, wall sits, knee extensions, and biking to maintain cardiovascular fitness.

TIMELINE 11-2: **Postoperative Rehabilitation Following Ulnar Collateral Ligament Reconstruction Using Autogenous Gracilis Graft (Accelerated ROM)**

PHASE I (weeks 0 to 3)

- Goals:
  - Protect healing tissue
  - Decrease pain/inflammation
  - Retard muscular atrophy
  - Protect graft site—allow healing

Postoperative Week 1

- Brace: Posterior splint at 90 degrees elbow flexion
- ROM:
  - Wrist AROM ext/flexion immediately postoperative
  - Knee active ROM flexion/extension day 1
- Elbow postoperative compression dressing (5 to 7 days)
- Calf (graft site) compression dressing 7 to 10 days
- Exercises:
  - Gripping exercises
  - Wrist ROM
  - Shoulder isometrics (no shoulder ER)
  - Biceps isometrics
  - No involved leg exercises first week
- Cryotherapy: To elbow joint and to graft site below knee
- Crutch: Use one crutch as needed for 3 to 5 days

Postoperative Week 2

- Brace: Elbow ROM 15° to 105° (gradually increase ROM: 5° Ext/10° of Flex per week)
- Exercises:
  - Continue all exercises listed above
  - Elbow range of motion in brace (30° to 105°)
  - Initiate elbow extension isometrics
  - Continue knee ROM exercises
  - Initiate light scar mobilization over distal incision (graft)
- Cryotherapy: Continue ice to elbow and graft site

Postoperative Week 3

- Brace: Elbow ROM 5/10° to 115/120°
- Exercises:
  - Continue all exercises listed above
  - Elbow ROM in brace
  - Initiate active ROM wrist and elbow (no resistance)
  - Initiate light hamstring stretching
  - Initiate active ROM shoulder
- Full can
- Lateral raises
- ER/IR tubing
- Elbow flex/extension
  - Initiate light scapular strengthening exercises
  - Initiate bicycle for lower extremity ROM and strength
  - May initiate light hamstring isometrics

PHASE II (weeks 4 to 7)

- Goals:
  - Gradual increase to full ROM
  - Promote healing of repaired tissue
  - Regain and improve muscular strength
  - Restore full function of graft site

Postoperative Week 4

- Brace: Elbow ROM 0° to 135°
- Exercises:
  - Begin light resistance exercises for arm (1 lb)
  - Wrist curls, extensions, pronation, supination
  - Elbow extension/flexion
  - Progress shoulder program emphasize rotator cuff and scapular strengthening
  - Initiate shoulder strengthening with light dumbbells
  - Isometrics for hamstrings and calf muscles

Postoperative Week 5

- ROM: Elbow ROM 0° to 135°
- Discontinue brace
- Continue all exercises: progress all shoulder and UE exercises (progress weight 1 lb.)

Postoperative Week 6

- AROM: 0° to 145° without brace or full ROM
- Exercises:
  - Initiate Thrower's Ten Program
  - Progress elbow strengthening exercises
  - Initiate shoulder external rotation strengthening
  - Progress shoulder program
  - Initiate isotonic strengthening for graft site hamstrings/calf

Postoperative Week 7

- Progress Thrower's Ten Program (progress weights)

Initiate PNF diagonal patterns (light)

A timeline for rehabilitation after UCL reconstruction using autogenous palmaris longus graft (accelerated ROM) is given in the following section of this chapter.

Neuromuscular Dynamic Stability Exercises

- Joint repositioning drills for elbow and shoulder joint
- LE balance activities such as single leg balance, BOSU squats, star excursion
- Core stabilization exercises such as well arm side-lying planks, rhythmic stabilization drills of trunk.
- Well-arm rhythmic stabilization drills to facilitate neuromuscular crossover effect
- Functional exercises: trunk active mobility, including PNF patterns to maintain mobility in thoracic and lumbar spine and provide neuromuscular coordination training

Milestones for Progression to the Next Phase

- Full pain-free elbow range of motion
- Symptom-free wrist, elbow, shoulder, and scapular active movements
- Good scar mobility along surgical incisions
- Minimal to no joint/distal upper extremity edema
- No medial elbow pain

Phase III (weeks 7 to 10 postop)

- Maintain full elbow ROM.
- Promote healing of repaired soft tissues.

TIMELINE 11-2: **Postoperative Rehabilitation Following Ulnar Collateral Ligament Reconstruction Using Autogenous Gracilis Graft (Accelerated ROM)** (Continued)

PHASE III (weeks 8 to 14)

- Goals:
  - Increase strength, power, endurance
  - Maintain full elbow ROM
  - Gradually initiate sporting activities

Postoperative Week 8

- Exercises:
  - Initiate eccentric elbow flexion/extension
  - Continue isotonic program: forearm and wrist
  - Continue shoulder program—Thrower's Ten Program
  - Manual resistance diagonal patterns
  - Initiate plyometric exercise program
  - (Two-hand plyos close to body only)
  - Chest pass
  - Side throw close to body
  - Continue stretching calf and hamstrings

Postoperative Week 10

- Exercises: Continue all exercises listed above
- Progress plyometrics to two-hand drills away from body
  - Side to side throws
  - Soccer throws
  - Side throws

Postoperative Weeks 12 to 14

- Continue all exercises
- Initiate isotonic machines strengthening exercises (if desired)
  - Bench press (seated)
  - Lat pull down
- Initiate golf, swimming
- Initiate interval hitting program

PHASE IV (weeks 14 to 32)

- Goals:
  - Continue to increase strength, power, and endurance of upper extremity musculature
  - Gradual return to sport activities

Postoperative Week 14

- Exercises:
  - Continue strengthening program
  - Emphasis on elbow and wrist strengthening and flexibility exercises
  - Maintain full elbow ROM
  - Initiate one hand plyometric throwing (stationary throws)
  - Initiate one hand wall dribble
  - Initiate one hand baseball throws into wall

Postoperative Week 16

- Exercises:
  - Initiate interval throwing program (Phase I) [long toss program]
  - Continue Thrower's Ten Program and plyos
  - Continue to stretch before and after throwing

Postoperative Weeks 22 to 24

- Exercises: Progress to Phase II throwing (once successfully completed Phase I)

Postoperative Weeks 30 to 32

- Exercises: Gradually progress to competitive throwing/sports

- Regain and improve muscular strength.
- Restore function at graft donor site.

Clinical Pearl

The patient will maintain full elbow PROM without complaints of pain during this stage while progressing with a strengthening program for the entire upper extremity. The rehabilitation specialist should ensure restoration of full elbow range of motion by using manual techniques including: PROM, manual flexibility exercises, soft tissue mobilizations to the forearm and arm muscular and soft tissues, joint mobilizations (grades II to III) to the humero-ulnar joint. In addition, low-load long-duration (LLLD) stretches can be used to aid in regaining full elbow motion. A rehabilitation program for the overhead athlete should also include strengthening and neuromuscular control drills for the trunk and lower extremity because of the generation and dissipation of forces that occur with the throwing motion. These activities will help minimize the forces imparted at the elbow during the throwing motion.

Protection

- The patient can discontinue the use of a hinged elbow brace.

Management of Pain and Swelling

- The patient may take NSAIDs as needed to control any mild pain or inflammation that may persist.
- A compressionette tubing can be used as well as ESTIM and cryotherapy posttherapy to mitigate inflammation and soreness.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Oscillatory mobilizations (grades I and II) can be performed to neuromodulate pain. If joint restrictions are noted, the rehabilitation specialist can perform joint mobilization techniques (grades II and III) at end range to regain full motion (Figure 11-14).

Soft Tissue Techniques

- Scar mobilization techniques can be performed along incisions to obtain full tissue mobility.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- The rehabilitation specialist should ensure that the patient has good flexibility of the wrist flexors and extensors, as well as maintaining full shoulder mobility in the overhead athlete. The rehabilitation specialist can augment the ROM stretching with LLLD stretch for extension (Figure 11-15), flexion, or active assistive stretches such as wall slides (Figure 11-16).



FIGURE 11-14. Grade III mobilization of the radio-ulnar joint to regain supination.

Other Therapeutic Exercises

- Thrower's Ten Program performed on a stability ball.
- Cardiovascular: The patient can progress with cardiovascular fitness with increased cadence and resistance including treadmill, stationary bike, and upper body ergometer (UBE).
- Well-arm lifting exercises can be progressed to include lifting on upper extremity machines with bench press, rows, lateral shoulder raises, bicep curls, and triceps extension.
- Lower body strengthening and conditioning is progressed to include closed kinetic chain (CKC) (i.e., leg press, lunges, wall sits) and open kinetic chain exercises. (If a gracilis graft is used, patients can initiate light isotonic strengthening for hamstrings and gastrocnemius at 6 weeks and gradually progress with strengthening exercises.)



FIGURE 11-15. Low-load, long duration stretch into elbow extension.

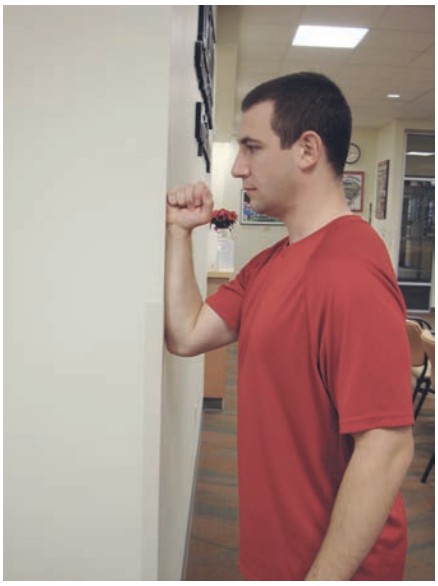


FIGURE 11-16. Wall-slide stretch. The patient is instructed to maintain forearm contact onto the wall while sliding the elbow toward the floor. The patient can also perform contract-relax techniques of the triceps and overpressure by leaning forward with the trunk.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Rotator cuff strengthening exercises will be progressed with the patient performing scaption, abduction, ER/IR tubing, and side-lying ER.
- Scapulothoracic musculature will be progressed during this phase to increase strength.
- The patient will perform prone row into external rotation and prone scaption.
- Biceps and triceps strengthening exercises are progressed as tolerated to include eccentrics at week 8.
- The patient will continue to progress with wrist strengthening exercises (flexion, extension, pronation, supination, and radial and ulnar deviation).

Sensorimotor Exercises

- Rhythmic stabilization drills can be progressed by having the patient perform these in a seated or standing position to facilitate recruitment of the core musculature.
- Lower extremity proprioception and coordination drills can be performed using foam and cones can be beneficial in preparation for the overhead athlete to regain hip and trunk coordinative movement patterns.

Open and Closed Kinetic Chain Exercises

- OKC Thrower's Ten program can begin at week 6.
- For athletes involved in upper extremity weight bearing sports (wrestling, gymnastics, football) CKC exercises should be considered. These activities could be initiated with simple weight shifting with hands on table. CKC exercises could be progressed to ball on wall stabilizations (Figure 11-17) can be performed initially with perturbations applied on proximal arm to minimize stress on the medial elbow and progressed to distal hand.

Techniques to Increase Muscle Strength, Power, and Endurance

- Lower extremity strengthening exercises are progressed with both machine weights and body weight activities.
- The patient can perform aquatic strength training activities for the lower extremity and upper extremity as an adjunct to the current rehabilitation program.
- Endurance training can also be incorporated into the current program by instructing the patient to decrease the rest time between exercises or by performing super sets.

Neuromuscular Dynamic Stability Exercises

- The rehabilitation specialist can begin performing light manual resistance drills for shoulder and scapular musculature.
- PNF patterns can be initiated during this phase using either elastic tubing or manual resistance for the forearm, scapulohumeral, and scapulothoracic musculature.

Plyometrics

- Plyometric exercises can be initiated at week 8.
- The patient will begin two-hand drills performed close to the body (chest pass and side throws) and perform these drills for 2 weeks as part of a progression to two-hand plyometric tosses with arms extending from body.
- The athlete should be instructed to use lower extremity, hip, and trunk movements in synchronization with shoulder movement as a precursor for throwing activity and transfer of forces throughout the kinetic chain.
- The patient can perform ball flips and reverse ball flips at week 8 for forearm musculature (Figure 11-18*A*,*B*).



FIGURE 11-17. Ball on the wall stabilization exercise with the clinician providing perturbations.

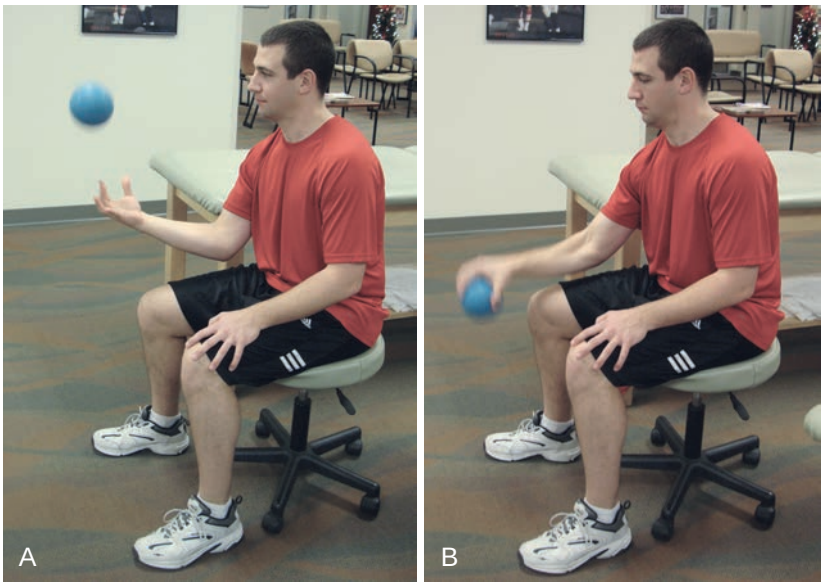


FIGURE 11-18. A,B, Plyometric wrist snaps (wrist flexors) and flips (wrist extensors).

Functional Exercises

- The patient can perform total body strengthening exercises to engage trunk and core musculature to include resistive trunk rotation and total body PNF pattern for synchronization of movement patterns (Figure 11-19).

Milestones for Progression to the Next Phase

- Full pain-free elbow range of motion
- No tenderness or pain with palpation medial elbow
- Adequate strength with manual muscle testing (MMT) greater than 4/5 throughout involved upper extremity
- Satisfactory clinical examination
- Successful completion of two-hand plyometric drills



FIGURE 11-19. Full body PNF D2 pattern.

Phase IV (weeks 11 to 14 postop)

- Normalize and improve upper extremity strength.
- Maintain full elbow range of motion.
- Enhance power and endurance.
- Initiate sports-specific drills.

Clinical Pearl

The clinician should ensure continued treatment of the entire kinetic chain throughout the remainder of the rehabilitation process to prepare a patient for return to sporting activities. Progress the patient to a higher level of physical condition in this phase. For the throwing athlete we emphasize endurance, stabilization, and improving strength. The patient should continue to progress with total body functional training with strength training and establishing coordinative movement patterns during sport-specific drills. Isokinetic testing can be performed before the initiation of an interval throwing program to determine if the athlete is ready to progress with throwing activities.

Protection

- Protection is no longer needed.

Management of Pain and Swelling

- NSAIDs as needed
- The clinician can use cryotherapy posttreatment to mitigate exercise-induced inflammation.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- PROM to maintain full wrist, elbow, and shoulder ROM. The clinician can perform grade III and IV mobilizations to ensure full elbow ROM.

Soft Tissue Techniques

- The rehabilitation specialist should continue performing scar massage and soft tissue mobilization techniques to forearm and elbow musculature as deemed necessary.
- Assessment of the glenohumeral and scapular musculature is also warranted for possible trigger points or other fascial restrictions that can develop as the patient is progressing with a functional training program that could impede the throwing motion.
- The clinician can perform manual techniques, or the patient can be instructed in self–soft tissue mobilization techniques with the aid of foam rollers or similar device (Figure 11-20).

Stretching and Flexibility Techniques for the Musculotendinous Unit

- The rehabilitation specialist should continue to maintain full flexibility of the forearm, elbow, and shoulder girdle with both manual and self-stretches.
- The clinician should also assess for any lack of flexibility throughout the entire kinetic chain (trunk, hip girdle, lower extremity).
- The clinician should make certain that adequate flexibility and mobility are present to allow for the proper generation and dissipation of energy for the throwing athlete.
- Ensure shoulder joint ROM is appropriate.

Other Therapeutic Exercises

- Initiate Advanced Thrower's Ten Exercise Program on stability ball.
- Lower extremity lifting is progressed with exercises such as back squat and lunges. The clinician can progress isotonic isolation strengthening exercises for the hamstring and calf musculature for patients that have a gracilis graft.
- The athlete can progress with core stabilization and dynamic movement patterns (Figure 11-21).



FIGURE 11-20. Soft tissue mobilization utilizing a foam roll.

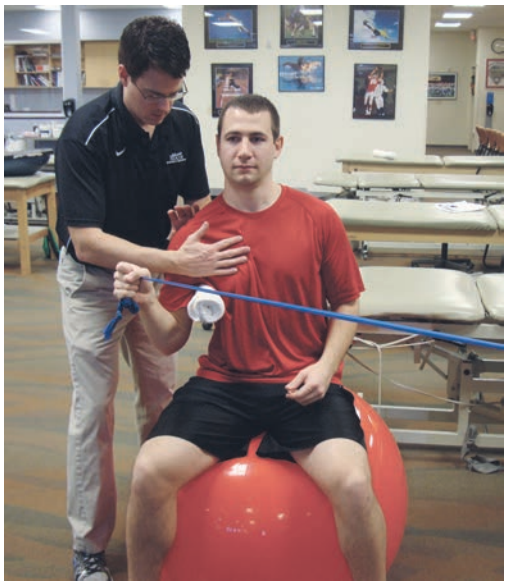


FIGURE 11-21. External rotation tubing while performing core stabilization on a swiss ball.

- Upper extremity lifting exercises are initiated and progressed as tolerated to include seated bench press, lat pull down, and shoulder presses.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- The patient will continue with Thrower's Ten strengthening exercises and progress with resistance as tolerated.

Sensorimotor Exercises

- PNF D2 manual resistance exercises can be performed in supine, seated, or standing position (Figure 11-22).

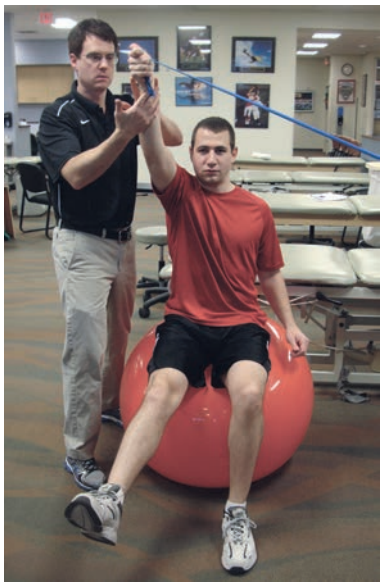


FIGURE 11-22. Manual resistance PNF D2 pattern performed while patient is seated on swiss ball.

Open and Closed Kinetic Chain Exercises

- CKC exercises for upper extremity weight-bearing athletes can be perform to include:
  - Push-ups progression: wall, table, floor
  - Planks: front, side
- Perform plank exercises for the shoulder and UE

Techniques to Increase Muscle Strength, Power, and Endurance

- Manual PNF training can be performed for the distal upper extremity of the forearm and upper arm
- Cardiovascular fitness will be progressed utilizing bike, elliptical, UBE, and jogging program.

Neuromuscular Dynamic Stability Exercises

- Rhythmic stabilization and manual resistance exercises are progressed to include exercises on unsupported surface to engage trunk musculature

Plyometrics

- Two-hand plyometric drills are progressed by performing drills with arms away from body: including side to side, soccer, and side throws (Figure 11-23)

Functional Exercises

- Begin golf activities at week 12.

Sport-Specific Exercises

- Interval training programs (golf, hitting) can be initiated at week 12 (Table 11-2 and Box 11-1).

Milestones for Progression to the Next Phase

- Full pain-free elbow range of motion
- No tenderness or pain with palpation medial elbow—no neurological symptoms
- Adequate strength with manual muscle testing (MMT) 5/5 throughout involved upper extremity
- Satisfactory clinical examination
- Successful completion of two-hand plyometric drills
- Satisfactory isokinetic testing (Table 11-3) or objective MMT



FIGURE 11-23. Two-handed plyometric side-to-side throws. The patient is instructed to incorporate lower extremity/trunk movement with throws.

Table 11-2 Interval Golf Rehab Program

	Monday	Wednesday	Friday
Week 1	20 putts 15 chips 5′ rest 15 chips	25 putts 15 chips 5′ rest 25 chipping	20 putts 20 chips 5′ rest 20 putts 20 chips 10 irons off tee 5′ rest 10 chips 5 irons off tee
Week 2	20 chips 10 short irons 5′ rest 10 short irons 15 med. Irons (5 iron off tee)	20 chips 15 short irons 10′ rest 15 short irons 15 chips Putting 15 med. irons	15 short irons 10 medium irons 10′ rest 20 short irons 15 chips
Week 3	15 short irons 20 medium irons 10′ rest 5 long irons 15 short irons 15 medium irons 10′ rest 20 chips	15 short irons 10 medium irons 10 long irons 10′ rest 10 short irons 10 medium irons 5 long irons 5 wood	15 short irons 15 medium irons 10 long irons 10′ rest 10 short irons 10 medium irons 10 long irons 10 wood
Week 4	15 short irons 10 medium irons 10 long irons 10 drives 15′ rest Repeat	Play 9 holes	Play 9 holes
Week 5	9 holes	9 holes	18 holes

The same principles should be followed with the interval golf program as with the interval baseball program. Proper warm-up, stretching, and strengthening should still be implemented throughout the entire interval golf rehabilitation program. As you start your program, remember that mechanics play an important role in your recovery. If there are any further questions, please contact your physician or rehabilitation specialist.

Do flexibility exercises before hitting. Use ice after hitting. ′, Abbreviation for minute; *chips*, pitching wedge; *short irons*, wedge, 9, 8 irons; *medium irons*, 7, 6, 5 irons; *long irons*, 4, 3, 2 irons; *wood*, 3, 5 woods; *drives*, driver.

BOX 11-1 Interval Hitting Program

Off a Tee Stand

Step 1: 50% effort (15 to 20 swings)
Step 2: 50% effort (two sets of 15 swings)
Step 3: 65% to 70% effort (two sets of 15 swings)
Step 4: 70% to 75% effort (two sets of 20 to 25 swings)
Step 5: 80% to 90% effort (two sets of 25 swings)

Soft Toss Swings

Warm-Up Using a Tee Stand
Step 6: 50% to 60% effort (15 to 20 swings)
Step 7: 65% to 70% effort (two sets of 20 to 25 swings)
Step 8: 80% to 90% effort (two sets of 25 swings)

Batting Practice Swings

Warm-Up with Soft Toss Swings
Step 9: 50% to 65% effort (two sets of 25 swings)
Step 10: 70% to 75% effort (two sets of 30 swings)
Step 11: 80% to 90% effort (two sets of 30 to 35 swings)

Hit three times per week with a day off in between. Perform each step for 2 days before progressing to next step.

Clinical Pearl

A well-constructed and implemented interval sports program is crucial in preparing an athlete for return to competition. The rehabilitation specialist should implement this program into the athlete's current rehabilitation program. A methodical approach, such as having the athlete properly warm-up, stretch, and perform a set of exercises before throwing as part of a preparatory activity, including plyometric activities and followed up with a proper cool down and stretching activity, can augment the athlete safely return to competition. During this phase the plyometrics are used to perform the athlete to throw, then the interval throwing program is used to general improve arm strength, endurance, and so on. Proper throwing mechanics are critical during the ITP.

Phase V (weeks 15 to 26 postop)

- Full pain-free ROM
- MMT 5/5 strength for wrist, elbow, shoulder, and scapular muscles
- Satisfactory clinical examination
- Successful progression of interval sports training program

Management of Pain and Swelling

- NSAIDs as needed for exercise-induced muscle soreness.
- Laser therapy is beneficial to control postexercise soreness.
- The rehabilitation specialist should monitor the athlete's symptoms throughout the interval sports program to ensure the athlete is progressed based on his or her symptoms and tolerance of activity.
- The athlete should be encouraged to ice following an interval sports program to mitigate exercise muscle soreness or exercise induced inflammation.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Full ROM should be monitored throughout the rehabilitation program as the patient should maintain full motion.
- The clinician can perform stretching, joint mobilizations (grades III and IV) as indicated during this phase.

Table 11-3 Satisfactory Isokinetic Values for Overhead Athletes

Bilateral Comparisons						
Velocity	*Elbow (Fl)*	*Elbow (Ext)*	*Shoulder (ER)*	*Shoulder (IR)*	*Shoulder (Abd)*	*Shoulder (Add)*
180°/sec	110% to 120%	105% to 115%	98% to 105%	110% to 120%	98% to 105%	110% to 128%
300°/sec	105% to 115%	100% to 110%	85% to 95%	105% to 115%	96% to 102%	111% to 129%

Unilateral Muscle Ratios				
Velocity	*Elbow (Fl/Ext)*	*Shoulder (ER/IR)*	*Shoulder (Abd/Add)*	*Shoulder (ER/Abd)*
180°/sec	70% to 80%	66% to 76%	78% to 84%	67% to 75%
300°/sec	63% to 69%	61% to 71%	88% to 94%	67% to 75%

Peak Torque-to-Body Weight Ratios				
Velocity	*Shoulder (ER)*	*Shoulder (IR)*	*Shoulder (Abd)*	*Shoulder (Add)*
180°/sec	18% to 23%	28% to 33%	26% to 33%	32% to 38%
300°/sec	12% to 20%	25% to 30%	20% to 25%	28% to 34%

Abd, Abduction; *Add*, adduction; *Ext*, extension; *ER*, external rotation; *Fl*, flexion; *IR*, internal rotation.

Soft Tissue Techniques

- The clinician should assess for any soft tissue restrictions, such as myofascial trigger points that can arise from an increase in activity level.
- The clinician can use instrument assisted techniques to aid in the treatment of any restriction.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- The rehabilitation specialist should perform pre- and postexercise stretching for the wrist, elbow, shoulder, and scapular musculature to allow for proper warm-up and cool-down as the athlete progresses with an interval sporting program.

Other Therapeutic Exercises

- Advanced Thrower's Ten exercises are progressed as indicated.
- Trunk and core exercises can be progressed to include total body movement patterns and drills.
- Lower extremity lifting should be progressed to incorporate strength, power, and endurance training.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- The patient will continue with wrist, elbow, and shoulder girdle strengthening activities.
- When rehabilitating an athlete undergoing an interval sports program, the clinician can opt to instruct the athlete to perform one set of exercises before throwing as part of a general warm-up and tissue preparation and complete two sets of exercises following the interval program.

Sensorimotor Exercises

- Rhythmic stabilization drills, core stabilizations with concomitant shoulder girdle strengthening exercises can be performed.

Open and Closed Kinetic Chain Exercises

OKC Exercises

- Rows
- Lat pull down
- Lateral raises
- Shoulder presses

CKC Exercises

- Planks
- Bench press
- Push-ups on unstable surface (Figure 11-24)
- CKC slide board
- Quadruped or push-up position

Techniques to Increase Muscle Strength, Power, and Endurance

- Advance strength training by decreasing sets to six to eight repetitions per set.



FIGURE 11-24. Push-ups performed on a BOSU ball.

- Incorporate endurance training by decreasing recover time with exercises.
- Progress running, cardiovascular training.

Neuromuscular Dynamic Stability Exercises

- The athlete can perform rotator cuff and scapula strengthening exercises in sport-specific position to allow for increase dynamic control and functional training
- PNF exercises will be progressed utilizing both speed and resistance to prepare for athletic activity.

Plyometrics

- Two-hand plyometric drills will be progressed throughout this phase.
  - Chest throws
  - Side-to-Side throws
  - Side throws
  - Soccer throws
- One-hand plyometrics can be initiated at week 14.
  - One-hand plyometric throwing
  - One-hand wall dribble
  - One-hand baseball throws

Functional Exercises

- A swimming program can be continued to be used to perform shoulder therapeutic exercises as well as part of a general conditioning program.

Sport-Specific Exercises

- Flat ground interval throwing program can be initiated at week 16 (Box 11-2).

Milestones for Progression to the Next Phase

- See the following.

Phase VI (weeks 27 to 52 postop)

- Satisfactory clinical examination
- MMT 5/5 strength for all muscles groups

BOX 11-2 Interval Throwing Program: Phase I

Flat Ground Throwing

The Interval Throwing Program (ITP) is designed to gradually return motion, strength, and confidence in the throwing arm after injury or surgery by slowly progressing through graduated throwing distances. The ITP is initiated upon clearance by the athlete's physician to resume throwing, and performed under the supervision of the rehabilitation team (physician, physical therapist, and athletic trainer).

The program is set up to minimize the chance of reinjury and emphasize pre-throwing warm-up and stretching. In development of the interval throwing program, the following factors are considered most important.

1. The act of throwing the baseball involves the transfer of energy from the feet through the legs, pelvis, trunk, and out the shoulder through the elbow and hand. Therefore any return to throwing after injury must include attention to the entire body.
2. The chance for reinjury is lessened by a graduated progression of interval throwing.
3. Proper warm-up is essential.
4. Most injuries occur as the result of fatigue.
5. Proper throwing mechanics lessen the incidence of reinjury.
6. Baseline requirements for throwing include:
   - Pain-free range of motion
   - Adequate muscle power
   - Adequate muscle resistance to fatigue

Because there is individual variability in all throwing athletes, there is no set timetable for completion of the program. Most athletes, by nature, are highly competitive individuals and wish to return to competition at the earliest possible moment. Although this is a necessary quality in all athletes, the proper channeling of the athlete's energies into a rigidly controlled throwing program is essential to lessen the chance of reinjury during the rehabilitation process. The athlete may have the tendency to want to increase the intensity of the throwing program. This will increase the incidence of reinjury and may greatly retard the rehabilitation process. It is recommended to follow the program rigidly because this will be the safest route to return to competition.

During the recovery process the athlete will probably experience soreness and a dull, diffuse aching sensation in the muscles and tendons. If the athlete experiences sharp pain, particularly in the joint, stop all throwing activity until this pain ceases. If pain continues, contact your physician.

WEIGHT TRAINING

The athlete should supplement the ITP with a high-repetition, low-weight exercise program. Strengthening should address a good balance between anterior and posterior musculature so that the shoulder will not be predisposed to injury. Special emphasis must be given to posterior rotator cuff musculature for any strengthening program. Weight training will not increase throwing velocity, but will increase the resistance of the arm to fatigue and injury. Weight training should be done the same day as you throw; however, it should be after your throwing is completed, using the day in between for flexibility exercises and a recovery period. A weight training pattern or routine should be stressed at this point as a "maintenance program." This pattern can and should accompany the athlete into and throughout the season as a deterrent to further injury. It must be stressed that weight training is of no benefit unless accompanied by a sound flexibility program.

INDIVIDUAL VARIABILITY

The ITP is designed so that each level is achieved without pain or complications before the next level is initiated. This sets up a progression in which a goal is achieved before advancement rather than advancing to a specific timeframe. Because of this design, the ITP may be used for different levels of skills and abilities from those in high school to professional levels. Progression will vary from person to person throughout the ITP. Example: One athlete may wish to use alternate days throwing with or without using weights in between; another athlete may have to throw every third or fourth day because of pain or swelling. "Listen to your body. It will tell you when to slow down." Again, completion of the steps of the ITP will vary from person to person. There is no set timetable in terms of days to completion.

WARM-UP

We recommend one set of 10 repetitions of RTC be performed before ITP. Jogging may also assist in warm-up. Jogging increases blood flow to the muscles and joints. Thus increasing their flexibility and decreasing the chance of reinjury. Because the amount of warm-up will vary from person to person, the athlete should jog until developing a light sweat, and then progress to the stretching phase.

STRETCHING

Because throwing involves all muscles in the body, all muscle groups should be stretched before throwing. This should be done in a systematic fashion beginning with the legs and including the trunk, back, neck, and arms. Continue with capsular stretches and L-bar range of motion exercises.

THROWING MECHANICS

A critical aspect of the ITP is maintenance of proper throwing mechanics throughout the advancement. The use of the Crow-Hop method simulates the throwing act, allowing emphasis of the proper body mechanics. This throwing method should be adopted from the set of the ITP. Throwing flat footed encourages improper body mechanics, placing increased stress on the

Continued on following page

BOX 11-2 Interval Throwing Program: Phase I *(Continued)*

throwing arm, and therefore predisposing the arm to reinjury. The pitching coach and sports biomechanic (if available) may be valuable allies to the rehabilitation team with their knowledge of throwing mechanics.

Components of the Crow-Hop method are first a hop, then a skip, followed by the throw. The velocity of the throw is determined by the distance, whereas the ball should have only enough momentum to travel each designed distance. Again, emphasis should be placed upon proper throwing mechanics when the athlete begins Phase II, "Throwing off the Mound" or from the athlete's respective position, to decrease the chance of reinjury.

THROWING

Using the Crow-Hop method, the athlete should begin warm-up throws at a comfortable distance (approximately 30 to 45 ft), and then progress to the distance indicated for that phase (refer to the box that follows). The program consists of throwing at each step two to three times without pain or symptoms before progressing to the next step. The object of each phase is for the athlete to be able to throw the ball without pain the specified number of feet (45 ft, 60 ft, 90 ft, 120 ft, 150 ft, 180 ft), 75 times at each distance. After the athlete can throw at the prescribed distance without pain, he or she will be ready for throwing from flat ground 60 ft, 6 in. in the normal pitching mechanics or return to his or her respective position (step 14). At this point, full strength and confidence should be restored in the athlete's arm. It is important to stress the Crow-Hop method and proper mechanics with each throw. Just as the advancement to this point has been gradual and progressive, the return to unrestricted throwing must follow the same principles. A pitcher should first throw only fast balls at 50%, progressing to 75% and 100%. At this time, he may start more stressful pitches such as breaking balls. The position player should simulate a game situation, again progressing to 50%, 75% and 100%. Once again, if an athlete has increased pain, particularly at the joint, the throwing program should be backed off and re-advanced as tolerated, under the direction of the rehabilitation team.

BATTING

Depending on the type of injury that the athlete has, the time of return to batting should be determined by the physician. It should be noted that stress placed upon the arm and shoulder in the batting motion are very different from the throwing motion. Return to unrestricted use of the bat should also follow the same progression guidelines as seen in the training program. Begin with dry swings progressing to hitting off the tee, then soft toss, and finally live pitching.

SUMMARY

In using the Interval Throwing Program (ITP) in conjunction with a structured rehabilitation program, the athlete should be able to return to full competition status, minimizing any chance of reinjury. The program and its progression should be modified to meet the specific needs of each individual athlete. A comprehensive program consisting of maintenance strength and flexibility program, appropriate warm-up and cool down procedures, proper pitching mechanics, and progressive throwing and batting will assist the baseball player in returning safely to competition.

Phase I for Pitchers

45′ PHASE

Step 1: A) Warm-up Throwing
B) 45′ (25 Throws)
C) Rest 3 to 5 min.
D) Warm-up Throwing
E) 45′ (25 Throws)

Step 2: A) Warm-up Throwing
B) 45′ (25 Throws)
C) Rest 3 to 5 min.
D) Warm-up Throwing
E) 45′ (25 Throws)
F) Rest 3 to 5 min.
G) Warm-up Throwing
H) 45′ (25 Throws)

60′ PHASE

Step 3: A) Warm-up Throwing
B) 60′ (25 Throws)
C) Rest 3 to 5 min.
D) Warm-up Throwing
E) 60′ (25 Throws)

Step 4: A) Warm-up Throwing
B) 60′ (25 Throws)
C) Rest 3 to 5 min.
D) Warm-up Throwing
E) 60′ (25 Throws)
F) Rest 3 to 5 min.
G) Warm-up Throwing
H) 60′ (25 Throws)

90′ PHASE

Step 5: A) 60′ (10 throws)
B) 90′ (20 throws)
C) Rest 3-5 min.
D) 60′ (10 throws)
E) 90′ (20 Throws)

Step 6: A) 60′ (7 throws)
B) 90′ (18 Throws)
C) Rest 3 to 5 min.
D) 60′ (7 throws)
E) 90′ (18 Throws)
F) Rest 3-5 min.
G) 60′ (7 throws)
H) 90′ (18 Throws)

120′ PHASE

Step 7: A) 60′ (5 to 7 throws)
B) 90′ (5 to 7 throws)
C) 120′ (15 Throws)
D) Rest 3 to 5 min.
E) 60′ (5 to 7 throws)
F) 90′ (5 to 7 throws)
G) 120′ (15 Throws)

Step 8: A) 60′ (5 throws)
B) 90′ (10 throws)
C) 120′ (15 Throws)
D) Rest 3 to 5 min.
E) 60′ (5 throws)
F) 90′ (10 throws)
G) 120′ (15 Throws)
H) Rest 3 to 5 min.
I) 60′ (5 throws)
J) 90′ (10 throws)
K) 120′ (15 Throws)

Flat Throwing

A) Throw 60 ft. (10 to 15 throws)
B) Throw 90 ft. (10 throws)
C) Throw 120 ft. (10 throws)
D) Throw 60 ft. (flat ground) using pitching mechanics (20 to 30 throws)

A) Throw 60 ft. (10 to 15 throws)
B) Throw 90 ft. (10 throws)
C) Throw 120 ft. (10 throws)
D) Throw 60 ft. (flat ground) using pitching mechanics (20 to 30 throws)
E) Rest 3 to 5 min.
F) Throw 60 to 90 ft. (10 to 15 throws)
G) Throw 60 ft. (flat ground) using pitching mechanics (20 throws)

Throwing program should be performed every other day, with one day of rest between steps, unless otherwise specified by your physician
Perform each step two times before progressing to the next step.

- Full pain-free ROM
- Successful completion of interval sport program
- Return to prior level of function/sports

Clinical Pearl

In preparation for return to sporting activity, the rehabilitation specialist should perform a complete musculoskeletal screen to assess for any deficits in strength, mobility, stability, or a lack in coordinative movement pattern that may impede in the athlete's progression. In addition, the rehabilitation specialist should evaluate the athlete's throwing mechanics during his or her sporting activity and seek additional consultation if needed for movement analysis. Often a motion analysis is beneficial once the athlete is throwing at the level of 80% of normal performance.

Management of Pain and Swelling

- Ice and/or laser following exercise/activity
- Ice following exercise/activity

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Manual techniques can be continued as needed to maintain full ROM using grade III and IV mobilizations.

Soft Tissue Techniques

- Manual soft tissue mobilizations performed as indicated, as well as educating the patient on self–soft tissue mobilization

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Pre-exercise and sport training flexibility as well as posttraining flexibility exercises are encouraged to prepare the athlete for activities as well as reduce soreness following activities. Stretching exercises for shoulder and entire UE.

Other Therapeutic Exercises

- Multijoint/total body movement exercises are performed in conjunction with isolation exercises to increase total body strength and coordinative movement patterns.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Thrower's Ten exercises are continued.

Sensorimotor Exercises

- Lower extremity proprioceptive exercises are performed on unstable surfaces.
- PNF patterns are continued using manual techniques, cables, or medicine balls.
- Upper extremity strengthening can be performed as the athlete stands on unstable surface.

Open and Closed Kinetic Chain Exercises

- The athlete can advance all previous exercises.
- Overhead strength training and Olympic lifting can be implemented if needed.

Techniques to Increase Muscle Strength, Power, and Endurance

- Rehabilitation focus is to restore preinjury level of strength and muscular endurance.

Neuromuscular Dynamic Stability Exercises

- Resistance and dynamic training exercises will be progressed using unstable surface, single leg stance, perturbations, and CKC activities that mimic the athlete's sport.

Plyometrics

- One- and two-handed plyometric drills are continued throughout this phase and can be used as a precursor to the throwing program.
- CKC plyometric push-ups can be progressed for athletes involved in weight-bearing activities.

Functional Exercises

- Sport-specific training drills (running and agility) should be performed to prepare the athlete for return to completion.
- Functional training for weight-bearing athletes with increased impact loading and training drills.

Sport-Specific Exercises

- Following successful completion of Phase I, interval throwing program (Phase II) can begin at week 24 (Box 11-3).

Milestones for Progression to Return to Sport

- See Criteria for Return to Sport.

Criteria for Return to Sport

General Criteria

- Full ROM
- Satisfactory clinical examination

BOX 11-3 Interval Throwing Program: Phase II

Throwing Off the Mound

After the completion of Phase I of the Interval Throwing Program (ITP) and the athlete can throw to the prescribed distance without pain, the athlete will be ready for throwing off the mound or return to his or her respective position. At this point, full strength and confidence should be restored in the athlete's arm. Just as the advancement to this point has been gradual and progressive, the return to unrestricted throwing must follow the same principles. A pitcher should first throw only fast balls at 50%, progressing to 75% and then 100%. At this time, the athlete may start more stressful pitches, such as breaking balls. The position player should simulate a game situation, again progressing at 50%, 75%, and then 100%. Once again, if an athlete has increased pain, particularly at the joint, the throwing program should be backed off and readvanced as tolerated, under the direction of the rehabilitation team.

SUMMARY

In using the Interval Throwing Program (ITP) in conjunction with a structured rehabilitation program, the athlete should be able to return to full competition status, minimizing any chance of reinjury. The program and its progression should be modified to meet the specific needs of each individual athlete. A comprehensive program consisting of a maintenance strength and flexibility program, appropriate warm-up and cool-down procedures, proper pitching mechanics, and progressive throwing and batting will assist the baseball player in returning safely to competition.

Stage I: Fastballs Only

Step 1: Interval throwing
15 throws off mound 50%
Step 2: Interval throwing
30 throws off mound 50%
Step 3: Interval throwing
45 throws off mound 50%
Step 4: Interval throwing
60 throws off mound 50%
Step 5: Interval throwing
70 throws off mound 50%
Step 6: 45 throws off mound 50%
30 throws off mound 75%
Step 7: 30 throws off mound 50%
45 throws off mound 75%
Step 8: 65 throws off mound 75%
10 throws off mound 50%

Stage II: Fastballs Only

Step 9: 60 throws off mound 75%
15 throws in batting practice
Step 10: 50 to 60 throws off mound 75%
30 throws in batting practice
Step 11: 45 to 50 throws off mound 75%
45 throws in batting practice

Stage III

Step 12: 30 throws off mound 75% (warm-up)
15 throws off mound 50% breaking balls
45 to 60 throws in batting practice (fastball only)
Step 13: 30 throws off mound 75% (warm-up)
30 breaking balls 75%
30 throws in batting practice
Step 14: 30 throws off mound 75% (warm-up)
60 to 90 throws in batting practice (Gradually increase breaking balls)
Step 15: Simulated game: Progressing by 15 throws per workout (pitch count)

Use interval throwing 120' phase as warm-up except for step 12, 13, 14. All throwing off the mound should be done in the presence of your pitching coach to stress. (Use speed gun to aid in effort control.) Copyright © 2004 by the Advanced Continuing Education Institute, LLC. All Rights Reserved. Any redistribution or reproduction of any materials herein is strictly prohibited.

- Completion of sport-specific program
- Satisfactory isokinetic testing
- Clearance by MD

Sport-Specific Criteria

- The clinician should assess for any asymmetries or deficits that could potentially impede an athlete's return to competition (shoulder GIRD and shoulder TROM).
  - Bilateral comparison of shoulder range of motion
  - Scapular muscular strength
  - Mobility and stability of the trunk
  - Biomechanical faults with throwing

After Return to Sport

Continuing Fitness or Rehabilitation Exercises

- Continued maintenance program for throwing athlete during the season (usually every other day)
- Total body endurance training to minimize fatigue related injuries

Exercises and Other Techniques for Prevention of Recurrent Injury

- The rehabilitation specialist should implement both an in-season and off-season program of which the goals and aims will differ.
  - The in-season program should emphasize maintaining strength, flexibility, range of motion, and neuromuscular control in order to aid the athlete in the recovery and preparation of athletic competition.
  - The off-season program should focus on athletic preparation and enhancement through the combination of strength, agility, power, endurance, and sport-specific training.
- Maintain proper shoulder ROM (especially, prevent GIRD and normalize TROM).
- Maintain scapular position and posture.

Evidence

Bernas GA, Ruberte Thiele RA, Kinnaman KA, et al: Defining safe rehabilitation for ulnar collateral ligament reconstruction of the elbow: A biomechanical study. *Am J Sports Med* 37:2392–2400, 2009.

This controlled laboratory study evaluated the strain on the ulnar collateral ligament in eight cadaveric elbows following ulnar collateral ligament reconstruction using a gracilis tendon graft. Differential variable reluctance transducers were used to measure strain on the anterior and posterior bands during elbow passive range of motion, 22.2 N isometric flexion and extension contractions, and 3.34 N x m varus and valgus torques at 90° flexion. The authors reported at 0 to 50 degrees flexion produced 3% or less strain, strain at 90° flexion of 7%, no significant strain with forearm rotation, and an significant increase in strain with valgus torques. (Level of evidence NA)

Cain EL, Jr, Andrews JR, Dugas JR, et al: Outcome of ulnar collateral ligament reconstruction of the elbow in 1281 athletes: Results in 743 athletes with minimum 2-year follow-up. *Am J Sports Med* 38:2426–2434, 2010.

This retrospective outcome study reported on the outcomes of athletes and return to play following UCL reconstruction minimum 2-year follow-up (average 38.4 months, range 24 to 130 months). Eighty-three percent were able to return to their previous level of competition or higher. The average time for the initiation of throwing was 4.4 months and return to full competition was 11.6 months. The protocol described in this chapter was used in this study with 83% of the patients returning to preinjury level. (Level IV evidence)

Davidson PA, Pink M, Perry J, et al: Functional anatomy of the flexor pronator muscle group in relation to the medial collateral ligament of the elbow. *Am J Sports Med* 23:245–250, 1995.

This controlled laboratory study evaluated the anatomical relationship of the pronator teres, flexor carpi radialis, flexor digitorum superficialis, and flexor carpi ulnaris muscles to the ulnar collateral ligament at 30, 90, and 120 degrees of elbow flexion in 11 cadaveric elbows. The flexor carpi ulnaris is functionally important because it is the predominant musculotendinous unit overlying the UCL, whereas the flexor digitorum superficialis muscle has a large bulk and a near proximity, making these specific muscle groups important to provide stability to the medial aspect of the elbow in the throwing athlete. (Level of evidence NA)

Fleisig GS, Bolt B, Fortenbaugh D, et al: Biomechanical comparison of baseball pitching and long-toss: Implications for training and rehabilitation. *J Orthop Sports Phys Ther* 41:296–303, 2011.

The authors performed a biomechanical analysis of 17 healthy college baseball pitchers throwing from a mound, 37 m, 55 m, and maximum distance long toss. They reported horizontal trajectory flat-ground throwing produced similar biomechanical patterns to pitching; whereas maximum-distance throws had increased torques and changes in kinematics. These torques are especially true at the medial elbow and onto the UCL. The authors advised caution of maximum distance throwing during rehabilitation and training. (Level of evidence NA)

Werner SL, Fleisig GS, Dillman CJ, et al: Biomechanics of the elbow during baseball pitching. *J Orthop Sports Phys Ther* 17:274–278, 1993.

This controlled laboratory study evaluated the biomechanics of seven healthy pitchers. During pitching a medial shear force of 300 N and a compressive force of 900 N are imparted upon the elbow. A valgus stress of 64 N x m occurs at the elbow during the acceleration phase of throwing. This study demonstrates the stresses that occur during throwing and the importance of optimal strength and endurance of the upper extremity kinetic chain. (Level of evidence NA)

Multiple Choice Questions

QUESTION 1. The hinged brace is used to accomplish what goal(s)?

A. Protect the reconstructed ligament.
B. Gradually increase PROM.
C. Restrict activities at the elbow joint.
D. All of the above

QUESTION 2. Criteria for implementing an interval throwing program includes all of the following except

A. full, pain-free elbow ROM.
B. shoulder isokinetic test ER/IR ratio of 45%.
C. negative valgus instability.
D. successful completion of one- and two-hand plyometric program.

QUESTION 3. When is it safe to initiate isotonic strengthening exercises for hamstring/calf following UCL reconstruction utilizing gracilis graft?

A. Week 2
B. Week 4
C. Week 6
D. Week 8

QUESTION 4. Plyometrics (two-hand drills) can be safely initiated at what time frame postoperatively?

A. Week 4
B. Week 8
C. Week 12
D. None of the above

QUESTION 5. UCL reconstruction surgery in the throwing athlete results in what percentage returning back to preinjury sport level?

A. 50%
B. 74%
C. 84%
D. 100%

Answer Key

QUESTION 1. Correct answer: **D** (see Box A, Phase II)

QUESTION 2. Correct answer: **B** (see Phase IV)

QUESTION 3. Correct answer: **C** (see Phase III)

QUESTION 4. Correct answer: **B** (see Phase III)

QUESTION 5. Correct answer: **C** (see Evidence, Cain et al., 2010)

BEYOND BASIC REHABILITATION: RETURN TO PITCHING AFTER ULNAR COLLATERAL LIGAMENT RECONSTRUCTION

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ASPECTS OF PITCHING THAT REQUIRE SPECIAL ATTENTION IN REHABILITATION

- Pitching is a repetitive activity that produces extremely high stresses upon the elbow, including a valgus force of 64 Nm, which exceeds the tensile strength of the UCL.
- Increased valgus forces have been shown to occur with improper pitching mechanics, including late trunk rotation, reduced shoulder external rotation, and increased elbow flexion.
- Youth baseball pitchers who pitch more than 100 innings in a year, pitch when fatigued, and also play catcher have been shown to have an increased risk of elbow injury; therefore proper education is critical for these athletes.

Introduction

Injury to the ulnar collateral ligament (UCL) is common among baseball pitchers and is increasingly being reported in youth baseball players and high school players. Because of the inherent valgus stresses placed upon the elbow that exceed the ultimate tensile strength of the UCL with pitching, a comprehensive rehabilitation program is crucial to enable the athlete to return to play. Current surgical reconstruction and rehabilitation techniques have provided good results with return-to-play criteria.

Literature

In the first report of UCL reconstruction, Jobe et al.[1] reported a 62.5% success rate, with complications mainly related to the ulnar nerve. Since that initial report, several authors have documented improved success and fewer complications through use of a muscle-splitting technique, and modifications of the original surgical reconstructive fixation.

Rohrbough et al.[2] reported on the docking technique, with 33 of 36 (92%) patients able to return to their prior level of competition.

Recently Cain et al.[3] reported on the outcomes of 643 patients following UCL reconstruction, with an 83% return to the same or higher level of competition rate.

Phase I: Advanced Strength and Conditioning Programs

Periodization

- Athletes seen postoperatively, whether in a clinic or training room, following UCL reconstruction typically will follow a linear periodization program because of the precautions that are inherent upon the reconstructed ligament during the acute phases of rehabilitation.
- Therefore during the early phases of treatment while the ligamentization process is occurring, the athlete will focus on the initial phases of the linear periodization model of hypertrophy and strength gains. The athlete will perform forearm, glenohumeral, and scapulothoracic strengthening exercises for increased vascularity and hypertrophy and to allow tissue preparation for the advanced strengthening exercises, which are typically begun at 8 weeks postoperatively.
- Plyometric activities can be initiated at 8 weeks postoperatively and mark a transition into power training, functional movement patterns, and conditioning as the athlete is able to progress to machine-based isotonic strengthening exercises to allow further gains for the phasic major muscle groups of the upper extremity.
- The athlete will continue with this training as an interval throwing program is begun at approximately 16 weeks postoperatively.
- The clinician will implement various mesocycle and microcycle training programs throughout the rehabilitation program, including the implementation of a hitting program (which may be begin around week 12 to 14) and introduction of an isotonic machine-based strength-based strengthening program.
- The clinician should be aware of the natural healing process of the reconstructed ligament and ensure that the rehabilitation and return-to-play program abides by these healing parameters.

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- Training continuum
  - A program that incorporates core training and hip and lower extremity training. This program can be initiated early during the rehabilitation program (usually at about 4 to 6 weeks postoperatively). Often stability ball exercises are used to incorporate trunk, core, and lower extremity into the program.
- Flexibility and mobility for joint stability
  - The clinician should ensure that the athlete maintains full range of motion and flexibility of the entire upper extremity throughout the advanced phases of rehabilitation.



FIGURE 11-25. Grade III mobilization to regain elbow extension. The clinician applies a dorsal translation to the proximal ulna while stabilizing the humerus to regain extension range of motion.

- As physical demands are increased upon the arm during the rehabilitation program, an athlete may have difficulty maintaining full elbow range of motion. The athlete will perform pre- and post-workout flexibility exercises for the forearm flexors and extensors, biceps, and triceps musculature.
- In addition, the clinician should continually monitor the glenohumeral and scapulothoracic soft tissue throughout the rehabilitation program.
- The clinician can also ensure full elbow range of motion is maintained during the advanced strengthening phase by performing grade III and IV mobilizations. Mobilizations at end range can be performed at this later stage in the rehabilitation because of adequate ligament healing. Mobilizations can be performed for flexion and/or extension as deemed appropriate by the clinician. Humeroulnar and humeroradial mobilizations can be performed for extension with a force applied dorsally on the proximal radial or ulna (Figure 11-25). A scooping technique can be used to regain full elbow flexion (Figure 11-26). Soft tissue mobilization and stretching programs should be implemented daily into the rehabilitation program.



FIGURE 11-26. The clinician grasps the proximal ulna and applies a distraction/proximal scooping motion to assist in regaining lost elbow flexion.

- Training with optimum posture
  - Postural position training can be performed by having the athlete perform upper extremity strengthening exercises while in a functional position. The athlete can perform exercises with a split stance or single leg stance and perform prone stability ball exercises.
  - The primary emphasis when rehabilitating a throwing athlete will be on the posterior rotator cuff and scapular musculature with exercise training.
  - The athlete should strive to improve shoulder girdle strength, endurance, and power to ensure proper mechanics and to reduce the risk of shoulder injury following elbow surgery.
- Sensorimotor and balance training
  - Lower extremity proprioception exercises can be either integrated into upper extremity strength training or performed in isolation depending upon the aims and the phase of treatment.
  - Upper extremity proprioception and neuromuscular controls drills can be performed, including rhythmic stabilizations drills at 90/90 and PNF patterns performed while seated on a stability ball.
  - To enhance body proprioception and train the sensorimotor system the exercises may be performed on a stability ball to challenge the patient's entire body. The program we use is referred to as the advanced Thrower's Ten program.[4]
- Core training
  - Core training involves both mobility and stability training. The clinician should ensure the athlete has proper mobility in the thoracic and lumbar spine. The athlete may be instructed to perform mobility exercises, including thoracic rotation, and

TIMELINE 11-3: **Return To Pitching Following Ulnar Collateral Ligament Reconstruction Using Autogenous Palmaris Longus Graft (Accelerated ROM)**

PHASE I (weeks 0 to 3)

- Goals:
  - Protect healing tissue
  - Decrease pain/inflammation
  - Retard muscular atrophy
  - Protect graft site—allow healing

Postoperative Week 1

- Brace: Posterior splint at 90° elbow flexion
- ROM:
  - Wrist AROM ext/flexion immediately postoperative
- Elbow postoperative compression dressing (5 to 7 days)
- Wrist (graft site) compression dressing 7 to 10 days as needed
- Exercises:
  - Gripping exercises
  - Wrist ROM
  - Shoulder isometrics (no shoulder ER)
  - Biceps isometrics
- Cryotherapy: to elbow joint and to graft site at wrist

Postoperative Week 2

- Brace: Elbow ROM 25° to 100° (gradually increase ROM: 5° Ext/10° of Flex per week)
- Exercises:
  - Continue all exercises listed above
  - Elbow ROM in brace (30° to 105°)
  - Initiate elbow extension isometrics
  - Continue wrist ROM exercises
  - Initiate light scar mobilization over distal incision (graft)
- Cryotherapy: Continue ice to elbow and graft site

Postoperative Week 3

- Brace: Elbow ROM 10° to 120°
- Exercises:
  - Continue all exercises listed above
  - Elbow ROM in brace
  - Initiate active ROM wrist and elbow (no resistance)
  - Initiate light wrist flexion stretching
  - Initiate active ROM shoulder:
  - Full can
  - Lateral raises
  - ER/IR tubing
  - Elbow flex/extension
  - Initiate light scapular strengthening exercises
  - May incorporate bicycle for lower extremity strength and endurance

PHASE II (weeks 4 to 7)

- Goals:
  - Gradual increase to full ROM
  - Promote healing of repaired tissue
  - Regain and improve muscular strength
  - Restore full function of graft site

Postoperative Week 4

- Brace: Elbow ROM 0° to 125°
- Exercises:
  - Begin light resistance exercises for arm (1 lb)
  - Wrist curls, extensions, pronation, supination
  - Elbow extension/flexion
  - Progress shoulder program emphasizing rotator cuff and scapular strengthening
  - Initiate shoulder strengthening with light dumbbells

Postoperative Week 5

- ROM: Elbow ROM 0° to 135°
- Discontinue brace
- Maintain full ROM
- Continue all exercises: Progress all shoulder and UE exercises (progress weight 1 lb)

Postoperative Week 6

- AROM: 0° to 145° without brace or full ROM
- Exercises:
  - Initiate Thrower's Ten program
  - Progress elbow strengthening exercises
  - Initiate shoulder external rotation strengthening
  - Progress shoulder program

Postoperative Week 7

- Progress Thrower's Ten Program (progress weights)
- Initiate PNF diagonal patterns (light)

A timeline for rehabilitation after UCL reconstruction using autogenous gracilis graft (accelerated ROM) is given in the previous section of this chapter.

quadruped exercises, to help promote mobility and allow for dissociation of adjacent body segments.
  - Core stability exercises that are performed in prone, side-lying, quadruped, and supine position can be continued as deemed appropriate by the rehabilitation specialist. These exercises can be progressed to include rotational and diagonal pattern exercises for the upper extremity while having the athlete sit on a stability ball or in a standing position.
  - Additional side-lying ER can be performed on a stability ball using a HALO trainer (Figure 11-27).
- Cardiorespiratory training
  - Endurance training should be progressed to include aerobic and anaerobic training that can be performed for both the upper and lower extremity. Cardiorespiratory training should be initiated early in the rehab program (usually at 2 to 3 weeks postoperatively).
- Multiplanar training activities
  - D2 PNF pattern exercises are performed to increase functional strength of the upper extremity and allow integration of movement patterns. These exercises can be performed using Thera tubing or manual resistance.
- Training for optimum muscle balance
  - Although a balanced program for the rotator cuff and scapular musculature is employed during the postoperative program, posterior cuff training is emphasized because of the inherent weakness of the posterior cuff. This can be accomplished during the

TIMELINE 11-3: **Return To Pitching Following Ulnar Collateral Ligament Reconstruction Using Autogenous Palmaris Longus Graft (Accelerated ROM)** (Continued)

PHASE III (weeks 8 to 14)

- Goals:
  - Increase strength, power, endurance
  - Maintain full elbow ROM
  - Gradually initiate sporting activities

Postoperative Week 8

- Exercises:
  - Initiate eccentric elbow flexion/extension
  - Continue isotonic program: forearm and wrist
  - Continue shoulder program—Thrower's Ten program
  - Manual resistance diagonal patterns
  - Initiate plyometric exercise program
  - (Two-hand plyos close to body only)
  - Chest pass
  - Side throw close to body
  - Continue stretching calf and hamstrings

Postoperative Week 10

- Exercises: Continue all exercises listed above
- Program plyometrics to two-hand drills away from body
  - Side to side throws
  - Soccer throws
  - Side throws

Postoperative Weeks 12 to 14

- Continue all exercises
- Initiate isotonic machines strengthening exercises (if desired)
  - Bench press (seated)
  - Lat pull down
- Initiate golf, swimming
- Initiate interval hitting program

PHASE IV (weeks 14 to 32)

- Goals:
  - Continue to increase strength, power, and endurance of upper extremity musculature
  - Gradual return to sport activities

Postoperative Week 14

- Exercises:
  - Continue strengthening program
  - Emphasis on elbow and wrist strengthening and flexibility exercises
  - Maintain full elbow ROM
  - Initiate one hand plyometric throwing (stationary throws)
  - Initiate one-hand wall dribble
  - Initiate one-hand baseball throws into wall

Postoperative Week 16

- Exercises:
  - Initiate interval throwing program (Phase I) (long toss program)
  - Continue Thrower's Ten Program and plyos
  - Continue to stretch before and after throwing

Postoperative Weeks 22 to 24

- Exercises: Progress to Phase II throwing (once Phase I successfully completed)

Postoperative Weeks 30 to 32

- Exercises: Gradually progress to competitive throwing/sports



FIGURE 11-27. Sidelying external rotation performed on a stability ball with modified support.

training program by a multitude of variations in the rehabilitation program, including performing additional sets or number of exercises that emphasize the posterior rotator cuff.
    - Unilateral muscular ratios of thrower's shoulder are imperative. We routinely examine and focus on ER/IR ratios, ER/Abd ratios, scapular retraction/protraction ratios, and scapular elevation/depression. These values can be found in articles by Wilk et al.[5,6]
- Training for optimum muscle functional strength:
    - Isotonic strength training exercises are performed to improve total arm strength and emphasize the phasic musculature. The athlete can perform seated chest press, lat pull down, and seated rows. The primary emphasis of this strength training will be on the scapular musculature.
    - In addition, the core of the body and LE is critical to train.
- Training for optimum muscle functional power:
    - Power training exercises are performed to train for explosive movement. Power training should involve both lower and upper body training. Power training exercises are performed with maximum intensity for a few repetitions.
    - The athlete can perform these exercises with a medicine ball with the behind the back throw (Figure 11-28), ball slams (Figure 11-29), and lunge throws (Figure 11-30).
- Neuromuscular dynamic stability exercises:
    - Rhythmic stabilization exercises are performed with the shoulder in the 90/90 position. The athlete is instructed to maintain a static position while the clinician provides perturbations to the athlete with the eyes open or closed (Figure 11-31).
- Training for speed, agility, and quickness:
    - The athlete can perform high-speed neuromuscular exercises for the involved upper extremity. This can be performed using manual resistance or Thera tubing as the clinician maintains constant tension throughout the range of motion (Figure 11-32).
    - Training at high speeds prepares the athlete for sporting activity by increasing eccentric control and learning to dissipate the forces that are imparted upon the elbow during overhead activities such as throwing.
- Plyometric training
    - Two-hand plyometric drills can be performed for strength and conditioning training either against a wall or plyoback, depending upon availability. The athlete is encouraged to integrate lower extremity and trunk movements during the exercise.
    - These exercises are performed 8 to 10 repetitions to provide advanced strength training. These exercises are initiated with arms close to body and are progressed to arms away from body. The athlete can



FIGURE 11-28. Behind the back toss is performed by having the athlete grasp a medicine ball in a squatting position and explosively stand with extending arms overhead to throw the ball behind the back.



FIGURE 11-29. Ball slams are performed by having the athlete raise a medicine ball overhead followed by throwing the ball toward the ground as hard as possible.



FIGURE 11-31. 90/90 Rhythmic stabilization drills performed during ER tubing exercise.

perform chest pass, side throws, and overhead throws.
  - The two-hand drills are initiated at 12 weeks postoperatively, whereas one-hand drills are usually initiated at 14 weeks postoperatively. The actual timeframes are based on objective criteria such as ROM, elbow stability, functional progression, and rehab progression.
- Functional training
  - The athlete can perform high speed strengthening exercises for throwing shoulder using a Thera-Band or surgical tubing while the clinician provides constant elastic tension throughout the range of motion. This exercise is designed to provide high speed strength training and incorporate eccentric deceleration training.
  - Functional training is usually initiated at 12 to 14 weeks postoperatively but is based on fulfilling specific criteria.
- Sport-specific training:
  - The athlete can perform medicine ball overhead and side throws using a step lunge with training focus on generating power with the lower extremity through leg drive.
  - The most common athlete undergoing UCL reconstruction is the throwing athlete; therefore sport-specific training begins with one-hand baseball-style throws with a lightweight Plyoball (1 lb) at 14 to 16 weeks postoperatively.

Olympic Lifts Used in the Training Program

- Snatch: not safe for UCL rehabilitation
- Clean and jerk: not safe for overhead athletes
- Power clean: not safe for overhead athletes

Training Principles Used in the Design of the Program

- The strength and conditioning program follows the principle of variation. The initial phases of rehabilitation focus on regaining full elbow range of motion and strength training.
- As the athlete progresses into a throwing program, the intensity and frequency of the program is adjusted to account for the increased workout.
- The athlete will typically perform strengthening exercises on the same day as throwing and perform core



FIGURE 11-30. Forward lunges are performed by having the athlete lunge forward while simultaneously throwing the ball forward.



FIGURE 11-32. High speed Thera tubing manual resistance exercise. The clinician maintains a constant tension throughout the motion as the athlete performs the high speed exercise.

stability, lower extremity exercises, and cardiovascular training on alternating days.
- The program will be individualized based on the overhead athlete's sport, age, position, and time of injury. It is important to make changes based on the patient's age.

Application of Acute Training Variables

- Repetitions: 10 to 15
- Sets: three
- Rest interval: recovery times can vary depending upon the exercise format performed, and can be incorporated into the treatment such as with active recovery when the athlete is performing superset exercises. The athlete can also use a return to resting respiratory rate during high-intensity strength training.
- Intensity: moderate to high intensity in later stages of rehabilitation program
- Repetition tempo:
  - Repetition tempos can be varied throughout the rehabilitation program. Typically a set of exercise performed during the strengthening phase of treatment will last 30 to 50 seconds.
  - A 3-0-1-2 tempo can be used during the later stages of treatment, where the athlete will lower the weight over 3 seconds, no rest at the bottom of the movement, and concentrically raise the arm in 1 second, and perform a 2-second isometric hold at the top of the exercise movement.
- Training frequency: Upper extremity strengthening exercises are typically performed 3 times per week (and can be performed during the interval throwing program if applicable) and the athlete can perform core training, lower extremity, and conditioning training on alternate days.
- Training duration: Training durations of 2 to 3 hours are typical when including warm-up, flexibility, and manual techniques. Training volume: A high volume of exercises will be performed during the rehabilitation program, with repetitions varying depending upon the muscle group. Typically for posterior rotator cuff and scapular musculature the athlete may perform three to five exercises with each exercise performed at three sets of 10 to 20 repetitions depending upon the treatment goal, lending upon a high volume of exercises.
- Specific exercises used in the training
  - Thrower's Ten exercise
  - Prone bilateral horizontal abduction, extension, scaption, and row into ER on stability ball
  - Latissimus pull-down
  - Seated rows
  - Seated bench press

Phase II: Performance Enhancement Training Techniques

Periodization

- The performance enhancement training can be implemented using a mesocycle periodization method.
- A pre-throwing mesocycle program consists of a series of microcycle exercises to prepare the athlete for throwing by ensuring the athlete has full range of motion, flexibility, strength, and proprioceptive sense.
- The next mesocycle, the throwing program phase, is further broken down into microcyles that focus on generating, controlling, and dissipating the forces that occur during throwing.
- The athlete will also perform microcycles that focus on plyometric activities, power training, endurance exercises, and body movement coordination exercises.

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- Flexibility/joint mobility for joint stability
  - Pre- and postexercise flexibility activities are encouraged to prevent any DOMS related tightness and decreased muscle flexibility. The clinician can also perform soft tissue mobilization exercise with joint motion to increase mobility of the soft tissue.
  - The clinician should assess the mobility of the elbow to determine if the restriction is joint or soft tissue related. The clinician can perform joint mobilization activities if a restriction is noted. The clinician can perform grade III and IV mobilizations. If a joint restriction is noted into flexion, the athlete can also perform wall slides to increase range of motion into elbow flexion.
- Training with optimum posture
  - Postural and position awareness are important for the overhead athlete to optimize athletic performance and decrease risk of injury. The athlete can perform scapular retraction exercises on a stability ball, lawnmower diagonal chops in a split stance.
- Sensorimotor and balance training
  - Neuromuscular control and proprioception training can be performed for the lower and upper extremity. The clinician can incorporate shoulder diagonal pattern exercises while in a single leg stance.
  - Lower extremity proprioception training can be performed with upper or lower extremity movement drills to shift the center of gravity for increased proprioception training.
- Core training
  - The athlete can progress concomitantly performing isometric core exercises with upper extremity isotonic exercises to integrating the core with upper and/or lower extremity therapeutic exercises.
  - The athlete can perform diagonal pattern flexion/extension activities to provide isotonic strengthening and neuromuscular education to the trunk musculature.
- Cardiorespiratory training
  - Although cardiovascular fitness is important for the athlete, local muscular endurance exercises can also be integrated into the rehabilitation program.
  - The athlete can perform time bouts of exercises to provide endurance training for the rotator cuff musculature. Plyometric prone ball drops and rainbow

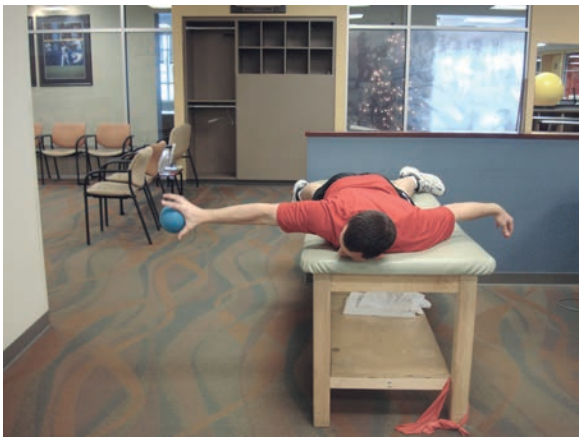

FIGURE 11-33. Prone ball flips. This exercise is used to increase local endurance.

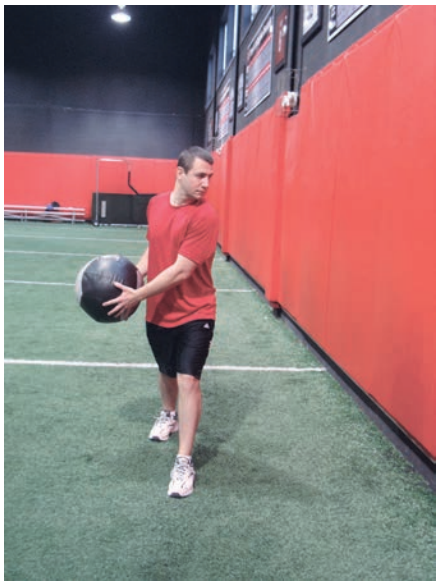

FIGURE 11-34. Rotational side throws. The athlete lunges forward while rotating the trunk and throwing a medicine ball across the body.

wall dribbles can be implemented with sets beginning at 30 seconds and can be progressed to 1 minute as tolerated (Figure 11-33).

- Multiplanar training activities
  - PNF D2 flexion and extension can be performed unilaterally and bilaterally. The athlete can also perform diagonal movement exercises for the trunk and entire body to allow for coordination training and facilitation of neurophysiological motor learning.
- Training for optimum muscle balance
  - Posterior cuff and scapular musculature are emphasized throughout rehabilitation. Manual resistance exercises can be performed including side-lying ER, prone row, and prone horizontal abduction.
- Training for optimum muscle functional strength
- Lower extremity strengthening exercises are performed to optimize the generation of forces for forces with throwing. The athlete can perform leg press, multiangle hip, and lunge exercises.
- Training for optimum muscle functional power
  - The athlete can perform lower extremity specific power exercises such as box hops, scissor jumps, and sled pushes; upper extremity drills such as medicine ball underhand throws, rotational side throws (Figure 11-34), and step throws can be performed to engage lower extremity and trunk in power generation.
- Neuromuscular dynamic stability exercises
  - Rhythmic stabilization drills can be performed with the athlete in a single leg stance with the arm in a 90/90 position. The athlete can perform diagonal movement pattern exercises incorporating the trunk and lower extremity with manual perturbations and stabilizations applied to the core and upper extremity.
- Training for speed, agility, quickness
  - High speed exercises using Thera-Band and/or speed pulleys can be used to prepare the athlete for throwing activities.
  - The athlete should also participate in lower extremity agility exercises such as ladder and cone drills, and high/low hurdles for hip activation (Figure 11-35).
- Plyometric training
  - Lower extremity plyometric drills are performed to isolate and train the athlete in explosive movements in preparation of throwing. Skipping, hop skips (Figure 11-36), and drop jumps (Figure 11-37) can be performed to improve explosive power of the lower extremity.
- Functional training
  - Exercises that incorporate hip and core activities with upper extremity movements can be performed to allow for the integration and coordination of activities. The athlete can perform lunges with rotational underhand medicine ball chop throws onto a wall.



FIGURE 11-35. High/low hurdles. The athlete performs step overs and squats under the high and low hurdles, respectively, for hip mobility and control.



FIGURE 11-36. Hop skips. The athlete performs a skip with a bounding hop on alternate landings.

- Sport-specific training
  - The athlete can perform strengthening exercises to simulate baseball specific activities such as throwing and batting by performing resistance training in a simulated stance and movement.

Training Principles Used in the Design of the Program

- The rehabilitation program to return an overhead athlete following UCL reconstruction to return to throwing will use the specific adaptation to imposed demands (SAID) principle.
- The initial or acute phases of treatment will focus on the restoration of normal range of motion, flexibility, and baseline strength. In this phase the athlete is placed on the advanced Thrower's Ten program.
- As the athlete is progressed throughout the rehabilitation, functional movement patterns are incorporated into the athlete's rehabilitation program to prepare the athlete for sport-specific training exercises.
- An interval throwing program is introduced into the treatment program to gradually introduce the stresses that incur with throwing.
- It is important that the clinician ensures baseline strength, flexibility, stability, and correct movement patterns are achieved before the institution of the highly specific act of throwing is introduced into the athlete's program.



FIGURE 11-37. Drop jumps. The athlete steps off a box landing on both feet and immediately jumps as high as possible.

Application of Acute Training Variables

- Repetitions: 8 to 10
- Sets: three
- Rest interval: 20 seconds to 1 minute depending upon the intensity of exercises performed.
- Intensity: high
- Repetition tempo: Performance enhancement exercises are performed at functional speeds to mimic sporting activity.
- Training frequency: The athlete can perform high demand activities such as plyometric drills 2 to 3 times per week, and perform functional sport specific drills on alternate days to allow for active recovery and avoid overtraining injuries.
- Training duration: 45 to 60 minutes of training to allow for optimal performance of training effect
- Training volume: The volume of the athlete's rehabilitation program will progressively increase; as such, the clinician should make certain to avoid overtraining by allowing for sufficient rest breaks, by alternating the muscle groups trained during a rehabilitation session, and by alternating the intensity of the exercises.
- Specific exercises used in the training
  - Plyometric external and internal rotation at 90° abduction with Thera tubing
  - Forward and lateral lunges
  - Box step ups with shoulder press

Phase III: Sport-Specific Training

Periodization

- The rehabilitation program of an athlete following UCL reconstruction consists of two mesocycle periodization programs termed the "interval throwing program."
- This program is further broken down into two components, Phase I and Phase II. These mesocycle programs are designed to systemically progress an athlete with a return to sporting activity and minimizing the chance of reinjury by gradually introducing the stresses that occur with throwing on the reconstructed elbow.
- The athlete begins with Phase I (level ground throwing) that is initiated at 45 feet and is gradually progressed to 120 or 180 feet (player and position dependent) and upon successful completion is allowed to begin Phase II (throwing off the mound).
- Phase II is progressed similarly to Phase I through systematically increasing the intensity, pitch count, and the types of pitches. The pitcher will generally begin at an intensity of 50% progressing to 75%, 90%, and 100% over a 4- to 6-week period. These mesocycle periodizations of treatment allow a gradual introduction of forces and strains upon the throwing arm, thus providing the athlete a regiment to increase strength, proper body mechanics, and confidence of throwing throughout this progression.

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- Flexibility/joint mobility for joint stability
  - The athlete should perform flexibility and range of motion activities pre- and post-workout for the throwing arm, trunk, and lower extremities.
- Training with optimum posture
  - In addition to the Thrower's Ten program, the athlete will perform exercises with the shoulder and elbow in a functional position. The athlete can perform ER/IR exercises with the shoulder at 90° abduction and lawnmower rows for scapula musculature.
- Sensorimotor and balance training
  - Lower extremity mobility exercises, such as high and low hurdles, can be performed to integrate hip functional mobility. The athlete can perform rotator cuff strengthening exercises in a single limb stance to integrate lower extremity balance training with upper extremity exercises.
- Core training
  - Abdominal strengthening exercises are performed, including planks and crunches; in addition the athlete should perform trunk extension exercise for the erector spinae musculature. Diagonal pattern core strengthening exercises can be performed to replicate the throwing motion.
- Cardiorespiratory training
  - The athlete should continue with both aerobic and anaerobic conditioning. The athlete is encouraged to alternate the type of conditioning program to avoid overtraining injuries. The athlete can perform aquatic conditioning activities, running hills, or exercising on cardio equipment.
- Multiplanar training activities
  - Multiplanar total body strengthening and coordination exercises are implemented to allow functional training for baseball specific activities. The athlete can perform these exercises using a speed cable column, kettle bells, or medicine balls. The athlete is encouraged to synchronize the lower extremity and trunk throughout the movement.
- Training for optimum muscle balance
  - The athlete will perform a comprehensive shoulder strengthening program with emphasis upon the posterior cuff and scapular musculature because of the high demands incurred during throwing. The athlete can perform additional sets and/or number of exercises for these muscle groups during training.
- Training for optimum muscle functional strength
  - Athlete will progress into a maintenance program as the throwing program is progressed and throughout the baseball season. The athlete can perform a set of the Thrower's Ten exercises before throwing as a warm-up activity, and following a throwing session can perform an additional set or two of exercises as part of a maintenance program.
- Training for optimum muscle functional power
  - Plyometric drills are performed with and without the use of a plyoback. The athlete will increase the weight of the ball and perform sets of six to eight repetitions. The athlete can perform chest, side-to-side, and overhead throws onto a plyoback, as well as lunge throws and cradle underhand tosses using a medicine ball.
- Neuromuscular dynamic stability exercises
  - The athlete can perform joint reproduction/reaction drills during the rotator cuff strengthening exercises. These exercises can incorporate proprioceptive and kinesthetic awareness into the strengthening program.
- Training for speed, agility, and quickness
  - The athlete can perform supine manual band resistance exercises for the rotator cuff and scapulothoracic joint: external rotation, horizontal abduction, shoulder extension, shoulder flexion, D2 flexion, and extension (Figure 11-38). These exercises will be performed at high speeds as the clinician maintains constant tension upon the Thera tubing.
- Plyometric training
  - Two-hand plyometric exercises are continued.
    - Chest, side to side, side throws, overhead throws
  - Single arm plyometrics are performed to replicate the throwing motion and gradually introduce stresses upon the elbow in preparation for throwing.
- Sport-specific training
  - As the interval-throwing program is progressed, the clinician should ensure the athlete is throwing with proper body mechanics including a crow-hop. The use of a crow-hop method encourages proper throwing mechanics by incorporating the lower extremity and trunk.



FIGURE 11-38. Manual Thera tubing resistance. The clinician maintains constant tension upon the Thera tubing as the athlete performs the exercise at a high speed.

Training Principles Used in the Design of the Program

- The rehabilitation specialist should ensure that every athlete is progressed through the interval throwing program using the principle of individualization.
- Most athletes are eager to return to competition as early as possible; therefore some may feel that they can expedite the throwing program. This program is

designed to re-educate the athlete in the proper mechanics of throwing by energy transfer and absorption throughout the throwing motion.
- The interval-throwing program is designed to allow each athlete to progress through each step of the program without pain or complications from throwing before the next step in the program. This program is designed to allow individual variability of each athlete based upon skill level, athletic ability, clinical presentation, and tolerance of activities, while minimizing the chance of re-injury and setbacks.

Application of Acute Training Variables

- A pre-warm up regimen is important throughout the implementation of the throwing program. A prethrowing program consists of a total body warm up and stretching program, followed by one set of the interval throwing program and plyometric exercises. These exercises and activities are designed to provide proper tissue preparation for throwing activities. The prethrowing set of exercises can be performed with a low to moderate weight, and high repetitions.
- The athlete may also choose to perform these exercises with an increased cadence and decreased rest time between exercises with the aim of increasing local blood flow to the glenohumeral and scapulothoracic musculature.
- The athlete will complete the remaining two sets of Thrower's Ten and plyometric drills after the throwing program. The clinician may choose to instruct the athlete to increase weight, repetitions, and cadence for the remaining two sets of strengthening and plyometric drills.
- Plyometric exercises can consist of two- and one-handed drills both below and above shoulder height. The athlete can also perform neuromuscular control drills while the shoulder is maintained at a 90/90 position. Wrist ball flips can also be performed for plyometric drills targeting the forearm musculature.
- Repetitions: six to ten
- Sets: three
- Rest interval: Rest intervals will increase as the intensity of exercise increases. As a result, the athlete may rest up to 5 minutes between sets during a throwing program.
- Intensity: high
- Repetition tempo: The athlete can perform therapeutic exercises with a faster tempo without a pause at the eccentric-isometric phase of the exercise in order to induce a stretch reflex for explosive strength and power training.
- Training frequency: three times per week of sport specific training with core, lower extremity and cardiovascular endurance performed on alternating days
- Training duration: A thorough rehabilitation program to allow sufficient time for warm-up, flexibility, strengthening exercises, plyometrics, and manual techniques may require approximately 2 hours to complete.
- Training volume: The volume of the athlete's rehabilitation program will progressively increase; as such the clinician may adjust the athlete's program by alternating days exercises are performed to minimize the volume of exercises as well as provide rest.
- Specific exercises used in the training
  - Thrower's Ten exercises
  - Advanced Thrower's Ten program
  - Plyometric drills
    - Two-hand: chest, overhead, side throws, step throws, rotational underhand
    - One-hand: 90/90, light toss
  - Machine-based strengthening exercises: lat pull down, rows, shoulder press
  - Core stabilization exercises: planks, side planks, cable chops

Sports Performance Testing

General Information

- General history
  - The clinician should determine the athlete's goals for returning back to play, which can assist the clinician in establishing a comprehensive rehabilitation program.
  - The clinician should determine if the athlete has had any change in throwing mechanics, velocity, or pitching frequency.
  - Determine if the athlete has had prior history of shoulder injury or time missed because of shoulder pain.
  - The athlete's history of prior rehabilitation for any preceding injuries should be determined and outcome following rehab, including the use of a return to sports throwing program.
- Subjective questionnaires
  - The SF 36 form can be used to determine general health status.
  - The Kerlan-Jobe Orthopaedic Clinic Shoulder and Elbow Score and the American Shoulder and Elbow Surgeons scoring system are commonly used to assess the functional status of an athlete.
- Sports injury history
  - The clinician should determine if the injury to the UCL occurred acutely during a pitch or is chronic in nature with no known injury to the athlete.
  - The clinician should also determine if the athlete has any prior injuries/surgeries to the shoulder or current ailments that could hinder outcome.
  - Surgical history: The clinician should gain knowledge of the athlete's current operative procedure, either via operative note or communication with MD.
  - The clinician should also obtain history of any prior elbow or shoulder surgical procedure and outcome following surgery.
- Chronic conditions/medication
  - The clinician should note if the athlete is taking any antiinflammatory medication that could possibly mask the athlete's symptoms. Current or prior history of extended corticosteroid use (either oral or local injection) should be determined.

Specific Criteria for Progression to the Next Stage: Determining Readiness for Pitching

- Static/dynamic postural assessments
  - The clinician should perform a thorough static and dynamic testing of the athlete to determine baseline functional level and periodically throughout the rehabilitation program to assess progress and response to treatment.
  - The clinician can evaluate static posture in both the frontal and sagittal plane to note for any postural deficits in the lower extremity, trunk, and upper extremity that could potentially lead to injury.
  - The athlete can also perform dynamic movement drills such as deep squat and lunges.
  - Upper extremity dynamic assessments of the scapulohumeral rhythm should also be performed to evaluate for asymmetrical movements of the scapula with arm elevation.
- Dynamic muscle performance testing
  - We routinely perform isokinetic testing on the throwers shoulder and elbow joints. In addition, static objective manual muscle testing using a hand-held dynamometer can be beneficial to document scapular muscle strength values.
  - Although static postural assessment is commonly performed and can aid the clinician assessing the athlete, the clinician will also assess the scapulothoracic rhythm during arm elevation. The clinician will make note of asymmetrical movement patterns during both the concentric and eccentric movements of arm elevation.
- Sport-specific testing
  - A motion analysis of the throwing athlete can be beneficial as the athlete is progressing through the throwing program. This evaluation can help correct improper or inefficient movement patterns of the athlete that could potentially cause injury and decrease performance.

Specific Criteria for Release to Unsupervised Complete Participation in Pitching

- The athlete must meet specific objective criteria:
  - ROM: Range of motion measurements for elbow flexion, extension, pronation, and supination should be measured. Although full elbow range of motion in all movements is sought during the rehabilitation program, it is common for these athletes to lack full motion. Therefore preoperative range of motion measurements is ideal to allow the clinician to understand each athlete's normal motion.
  - Strength: Strength assessment can be performed using manual muscle testing; however, the clinician may use a hand-held dynamometer or isokinetics to allow for a more objective test.
  - Joint stability: Valgus testing of the elbow can be performed to assess the stability of the ligament.
  - Patient's rehab progression: A proper and systematic rehabilitation progression should preclude the patient returning to sporting activity, including upper extremity strengthening and core strengthening exercises, plyometrics, and an interval throwing program.

Table 11-4 Peak Torque-to-Body Weight Ratios

Velocity	Shoulder (ER)	Shoulder (IR)	Shoulder (Abd)	Shoulder (Add)
180°/sec	18% to 23%	28% to 33%	26% to 33%	32% to 38%
300°/sec	12% to 20%	25% to 30%	20% to 25%	28% to 34%

Abd, Abduction; *Add,* adduction; *ER,* external rotation; *IR,* internal rotation.

  - Clinical examination: A thorough examination will also include the assessment of the ulnar nerve, pain free palpation, and shoulder range of motion.
- The athlete must be able to perform sporting activities and functional exercises without pain.
- The athlete must have a satisfactory clinical examination and MMT 5/5 all planes. Satisfactory isokinetic testing (Table 11-4).
- Successful completion of interval throwing program.

Recommended Ongoing Exercises

- Thrower's Ten strengthening program.
- Shoulder flexibility program with emphasis upon internal rotation range of motion.

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Evidence

Bernas G, Ruberte Thiele RA, et al: Defining safe rehabilitation for ulnar collateral ligament reconstruction of the elbow: A biomechanical study. *Am J Sports Med* 37:2392–2400, 2009.

This controlled laboratory study reported on the strain in the anterior and posterior bands of the anterior bundle of the reconstructed elbow in eight cadaveric elbows during passive range of motion, 22.2 N isometric flexion and extension contractions, and 3.34 N x m varus and valgus torques. They reported from maximum extension to 50° of flexion 3% or less strain in both bands, no significant strain was noted with pronation and supination or during isometric contractions. Strain was noted approaching 7% in the posterior band at 90°, and increased strain occurred with valgus torque at the elbow. (Level of evidence NA)

Laudner KG, Stanek JM, Meister K: Differences in scapular upward rotation between baseball pitchers and position players. *Am J Sports Med* 35:2091–2095, 2007.

This controlled laboratory study measured the scapular upward rotation with the arm at rest, 60°, 90°, and 120° of elevation in 15 professional baseball pitchers and 15 position players with no recent history of upper extremity injury. They reported less scapula upward rotation (specifically at 60° and 90° elevation) in pitchers as compared with position players. This decrease in scapular upward rotation may place the pitchers at an increased risk of injury to the throwing arm. (Level of evidence NA)

Reinold MM, Wilk KE, Macrina LC, et al: Changes in shoulder and elbow passive range of motion after pitching in professional baseball players. *Am J Sports Med* 36:523–527, 2008.

This controlled laboratory study measured shoulder internal and external rotation and elbow flexion and extension range of motion on the first day of spring training before, immediately after, and 24 hours after pitching in 67 asymptomatic professional baseball pitchers. They reported a significant decrease in shoulder internal rotation (–9.5°), total motion (–10.7°), and elbow extension (–3.2°) were noted immediately after pitching and were present 24 hours after pitching. (Level of evidence NA)

Stanley E, Rauh MJ, Michener LA, et al: Shoulder range of motion measures as risk factors for shoulder and elbow injuries in high school softball and baseball players. *Am J Sports Med* 39:1997–2006, 2011.

This cohort study measured the shoulder range of motion during preseason for high school softball and baseball players and observed them during the season for injury rates. They reported players with a decrease greater than or equal to 25° of IR in the dominant shoulder were at four times greater risk of upper extremity injury as compared with players with a less than or equal to 25° decrease. (Level II evidence)

Vitale MA, Ahmad CS: The outcome of elbow collateral ligament reconstruction in overhead athletes: a systematic review. *Am J Sports Med* 36:1193–1205, 2008.

This systematic review reported on all published reports of UCL reconstruction in overhead athletes to determine what techniques were associated with better outcomes with a minimum of 1-year follow-up resulting in eight studies meeting the criteria. Overall 83% of patients had an excellent result with a complication rate of 10%. The figure-eight technique resulted in a 76% excellent result and an 8% rate of ulnar neuropathy; whereas the docking technique had a 90% excellent result with a 3% rate of postoperative ulnar neuropathy. (Level IIIa evidence)

Multiple Choice Questions

QUESTION 1. To minimize the risk of shoulder and/or elbow injury in a youth pitcher, which of the following would NOT be proper instruction for the athlete?

A. Minimize innings to no more than 100 in competition in a calender year.
B. The pitcher should play catcher when not pitching because of the short throw to the mound.
C. Curveballs should be limited or not thrown at a young age because of inherent stress.
D. Further limitations may need to be imposed upon a skeletally immature athlete.

QUESTION 2. Prone ball drops and wall dribbles are examples of exercises that can be implemented into a rehabilitation program for what training purpose?

A. To build grip strength
B. As a precursor to an interval throwing program
C. To increase local muscle endurance
D. To initiate above the shoulder strengthening exercises.

QUESTION 3. Which of the following activities is commonly used before throwing as part of a rehabilitation program?

A. Shoulder ROM/flexibility exercises
B. A jogging/biking activity for complete body warm-up
C. Two- and one-hand plyometric drills
D. All of the above

QUESTION 4. Altered throwing kinematics can contribute to increased valgus load upon the elbow during throwing. Which of the following kinematic errors could generate increased valgus forces upon the elbow?

A. Late trunk rotation
B. Reduced shoulder external rotation
C. Increased elbow flexion
D. All of the above

QUESTION 5. Which of the following statements is true concerning the relationship of shoulder range of motion and upper extremity injuries?

A. Players with a decrease greater than or equal to 25° of IR in the dominant shoulder were at four times greater risk of upper extremity injury as compared with players with a less than or equal to 25° decrease.
B. Players with a decrease of less than 20° of IR were five times less likely to be injured as compared with players with an increase of 30°.
C. Players with an increase greater than or equal to 25° of IR in the dominant shoulder were at twice the risk of upper extremity injury as compared with players with a less than or equal to 25° increase.
D. Players with an increase of greater than or equal to 5° of IR in the dominant shoulder were at 14 times greater risk of upper extremity injury as compared with players with less than or equal to 5° increase.

Answer Key

QUESTION 1. Correct answer: **B** (see Introduction)

QUESTION 2. Correct answer: **C** (see Phase II)

QUESTION 3. Correct answer: **D** (see Phase III)

QUESTION 4. Correct answer: **D** (see Introduction)

QUESTION 5. Correct answer: **A** (see study by Vitale & Ahmad, 2008)

Chapter 12



Elbow Stiffness

INTRODUCTION

Michael Levinson PT, CSCS, and David Altchek MD

Anatomy

- The elbow is a typical hinge type of joint, and has a normal motion of 0° (extension) to 145° (flexion), although the amount of motion that is required for activities of daily living is approximately 30° to 130°.
- Patients may also have hyperextension beyond 0° of extension in hyperlaxity or other soft tissue disorders.
- The pronation and supination are approximately 80° to 85°. Loss of extension is tolerated less than loss of flexion as patients like to have near full extension (or at least 30° for ADLs).
- Elbow stiffness can affect all aspects of elbow motion, including flexion, extension, supination and pronation.
- There are multiple causes of loss of motion of the elbow and are noted as both intrinsic and extrinsic factors in the following section. These typically cause stiffness of the elbow capsule and loss of volume of the elbow joint, and there are areas of bony overgrowth and osteophytes that may be due to overload or be posttraumatic in nature.
- The capsule and ligaments may also be abnormal, contracted, and thickened.
- The anatomy of the elbow is depicted in Figures 12-1 to 12-3.

Pathophysiology

Intrinsic Factors

- Articular deformities
- Articular surface malalignment
- Fibrosis of the flexor-pronator group
- Contracture of the thin anterior capsule
- Adhesions
- Hemarthrosis resulting from injury to the triceps or brachialis
- Impinging osteophytes
- Loose bodies
- Ulnar nerve entrapment
- Articular degeneration
- Highly congruent elbow joint
- Traversed elbow joint (by muscle rather than tendons)

Traumatic Factors

- Elbow dislocation: hyperextension, axial compression, valgus stress
- Concomitant fractures of the radial head, capitellum or coronoid
- Associated tears of the ulnar or lateral collateral ligaments
- Ischemia and soft tissue swelling
- Extension limited by contracture of the biceps tendon
- Repetitive extension activities (such as throwing or playing tennis) that lead to scarring of the anterior capsule or fibrosis of the flexor-pronator group

Classic Pathological Findings

- Thickened anterior and posterior capsule
- Osteophytes and/or loose bodies
- Loss of range of motion (ROM)
- Loss of upper extremity function
- Gradual increase of elbow pain
- Parasthesia

Clinical Presentation

History

- Significant trauma to the elbow (e.g., dislocation, fractures)

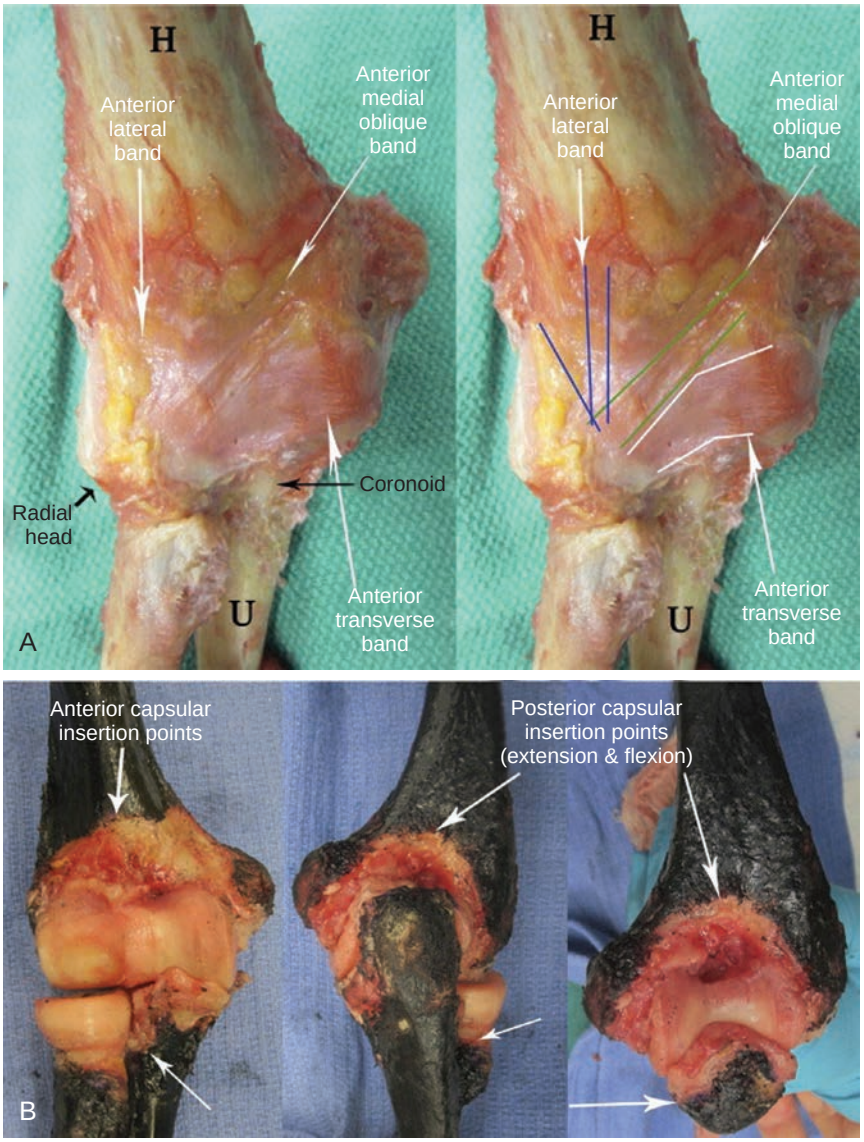

FIGURE 12-1. A, Anterior lateral, anterior medial oblique, and anterior transverse bands of the anterior capsule. **B,** Anterior and posterior view of a painted specimen with the capsule excised, demonstrating the area covered by the capsule. *(From Reichel LM, Morales OA: Gross anatomy of the elbow capsule: A cadaveric study. J Hand Surg. 2013;38:110–116.)*

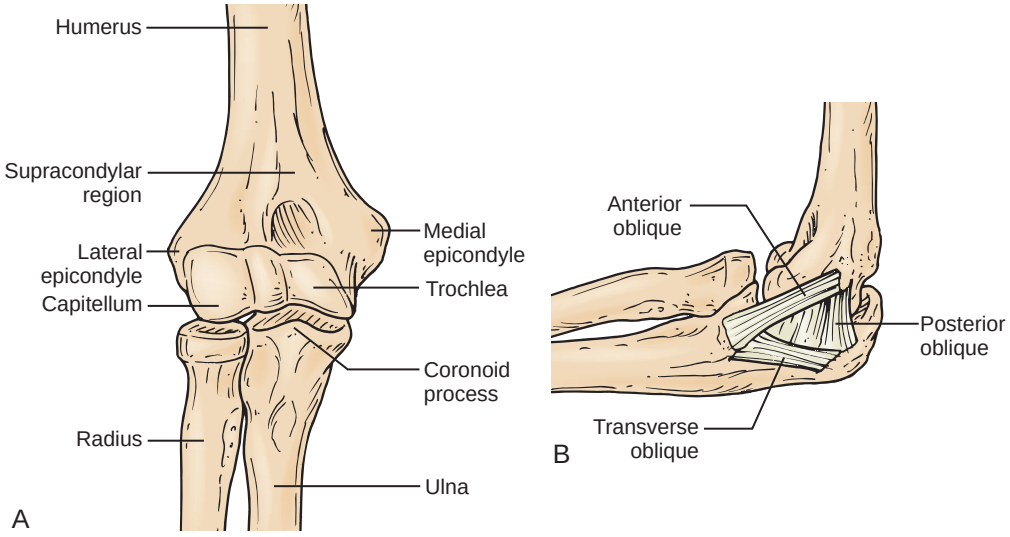

FIGURE 12-2. Anterior view of the elbow. *(Redrawn from Rogachefsky RA, Frey ME, Salcedo V, Santiago FH: The elbow: anatomy, pathology and diagnosis. In O'Young BJ, Young MA, Stiens SA, editors. Physical medicine and rehabilitation secrets, ed 3, 2008, Mosby, pp 352–357.)*

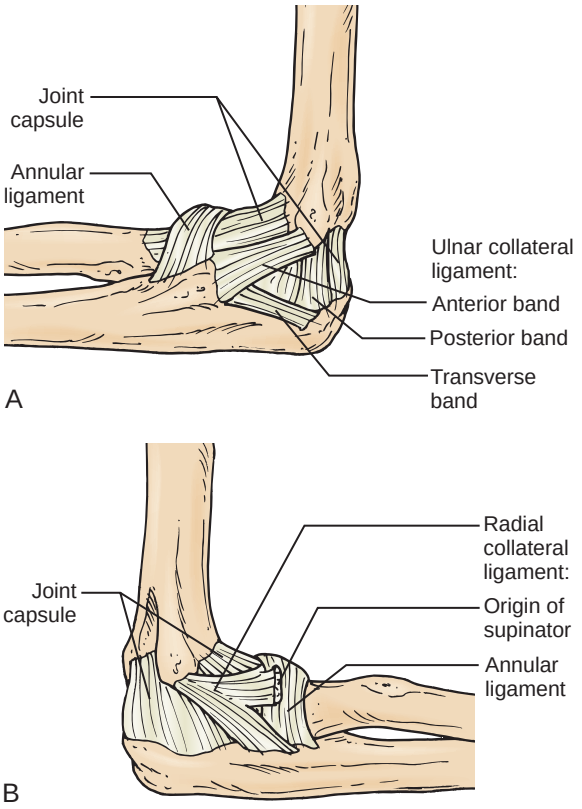

FIGURE 12-3. (**A**) Medial and (**B**) lateral views of the ligaments about the elbow. *(From Miller MD: Core knowledge in orthopaedics: sports medicine, Philadelphia, 2006, Mosby, pp 350–362.)*

- Repetitive extension in sports (e.g., throwing, tennis)
- Gradual loss of ROM with increased pain

Physical Examination

Abnormal Findings

- Progressive loss of range of motion: extension more often than flexion (often ulnohumeral pathology)
- Possible loss of pronation and supination: often radiocapitellar or proximal radial ulnar joint pathology
- Increased pain with progressive ROM loss
- Swelling
- Bony end-feel
- Crepitus
- Muscular spasm
- Mild to moderate pain

Pertinent Normal Findings

- Flexion is limited by the mass of the biceps, tension in the triceps, and articulation of the radius and coronoid.
- Extension is limited by tension of the biceps, anterior band of the UCL, and the olecranon into the olecranon fossa.
- Anterior capsule becomes taut in extension and the posterior capsule becomes taut in flexion.
- Elbow ROM: Extension-Flexion: 0° to 146°; Pronation: 71°; Supination: 84° (AAOS).

Imaging

- Radiographs: reactive osteophytes on the olecranon and olecranon fossa, osteophytes that may fracture and form loose bodies, heterotrophic ossification, degenerative joint disease, heterotrophic ossification, fractures
- MRI: thickened anterior or posterior capsule

Differential Diagnosis

- Ulnar neuritis: parasthesia and/or weakness in fourth and fifth fingers
- Septic arthritis
- Hemophilia
- Spastic neuropathy
- Complex regional pain syndrome

Treatment

Nonoperative Management

- Active and active assistive range of motion
- Low intensity, long duration stretch for extension
- Joint mobilization techniques
- NSAIDS
- Dynamic splinting at night
- Continuous passive motion (CPM)
- Custom molded orthoses
- Activity modification
- Modalities as needed

Guidelines for Choosing among Nonoperative Treatments

- Poor patient motivation
- Patient will not withstand postoperative rehabilitation
- Medical complications
- Symptoms do not interfere with athletic activities or activities of daily living

Surgical Indications

- Failure of nonoperative treatment to return an athlete to a pre-injury competitive level
- Loss of functional ROM
- Significant pain

Factors That Affect Choice of Treatment

- Functional demands of the patient
- Elbow ROM limiting sport- or work-related activities
- Chronic contracture for up to 1 year
- Loss of functional ROM: 30° to 130°

Aspects of Clinical Decision-Making When Surgery Is Indicated

- Radiographic findings
- Failure of conservative treatment

- Postoperative stiffness
- Posttraumatic stiffness

Evidence

Araghi A, Celli A, Adams R, et al: The outcome of examination (manipulation) under anesthesia on the stiff elbow after surgical contracture release. *J Shoulder Elbow Surg* 19:202–208, 2010.

Two hundred patients underwent surgery for release of stiff elbows. Fifty-one patients underwent examination under anesthesia a mean of 40 days after surgery. Forty-four patients with a minimum of 1-year follow up improved by a mean of 40°.

Hildebrand KA, Patterson SD, King JG: Acute elbow dislocations: simple and complex. *Orthop Clin North Am* 30:63–79, 1999.

The authors evaluated the treatment of simple and complex elbow dislocations. They demonstrated that loss of elbow extension is linked to the length of immobilization.

Morrey BF: Post-traumatic contracture of the elbow: operative treatment, including distraction arthroplasty. *J Bone Joint Surg* 72A:601–618, 1990.

Twenty-six patients who had posttraumatic contracture of the elbow were treated by operative release or by release and distraction arthroplasty. Ninety-six percent of the patients were satisfied with the results. In addition, it was found that almost all stiff elbows have thickened anterior and posterior capsules.

Myden C, Hildebrand KA: Elbow joint contracture after traumatic injury. *J Shoulder Elbow Surg* 20:39–44, 2011.

Twenty-five subjects with traumatic elbow injuries were prospectively followed up to 52 weeks after injury. Using a rehabilitation protocol for each injury type, 22 of 25 subjects achieved full flexion-extension ROM and 24 of 25 reached full pronation-supination ROM. Reoperation was performed in 5 of 25 subjects; in 3 of which, this was because of elbow joint contracture.

Ulrich SD, Bonutti PM, Seyler TM, et al: Restoring range of motion via stress relaxation and static progressive stretch in posttraumatic elbow contractures. *J Shoulder Elbow Surg* 19:196–201, 2010.

In this clinical, retrospective review of patients with posttraumatic loss of elbow range of motion, an orthosis that uses static progressive stretch resulted in increased range of motion in 35 of 37 subjects. Mean satisfaction score was 8.5 of 10 points possible.

Multiple-Choice Questions

QUESTION 1: All of these are considered effective clinical options for restoring range of motion in the contracted elbow except:

A. Joint mobilization
B. Aggressive passive stretching
C. Low-intensity, long-duration stretch
D. Custom-molded orthoses

QUESTION 2: Which of the following would not be confused as differential diagnosis with the stiff elbow?

A. Septic arthritis
B. Spastic neuropathy
C. Lateral epicondylitis
D. Hemophilia

QUESTION 3: Which of these may be radiographic findings associated with the stiff elbow?

A. Osteophytes in the olecranon fossa
B. Heterotrophic ossification
C. Degenerative joint disease
D. All of the above

QUESTION 4: All of these are traumatic conditions that may result in elbow contractures except:

A. Elbow dislocation
B. Medial epicondylitis
C. Ulnar or lateral collateral ligament tears
D. Radial head or coronoid fracture

Answer Key

QUESTION 1. Correct answer: **B** (see Treatment)

QUESTION 2. Correct answer: **C** (see Differential Diagnosis)

QUESTION 3. Correct answer: **D** (see Pathophysiology)

QUESTION 4. Correct answer: **B** (see Traumatic Factors)

POSTOPERATIVE REHABILITATION AFTER ELBOW CAPSULAR RELEASE

Michael Levinson PT, CSCS, and David Altchek MD

Indications for Surgical Treatment

- Nonoperative treatment fails to return an athlete to a preinjury competitive level
- Loss of functional range of motion (*functional* being approximately 30° to 130°)
- Significant pain that interferes with activities of daily living
- Radiographic evidence of osteophytes or loose bodies

Brief Summary of Surgical Treatment

Major Surgical Steps

- Regional anesthesia
- Patient is supine with upper extremity elevated in arm holder, elbow flexed
- Anterior, posterior and posterior lateral capsular release (Figure 12-4)
- Any osteophytes or loose bodies are removed
- All contracted tissue must be addressed
- Care is taken to avoid the ulnar nerve and the posterior interosseous nerve
- Postoperative cortisone injection
- Immediate range of motion

Factors That May Affect Rehabilitation

Anesthetic

- Should not affect rehabilitation

Surgical

- The arthroscopic procedure should allow early rehabilitation intervention.

Other Surgical Techniques and Options

- Open contracture release (Figure 12-5).
- An open procedure may result in further soft tissue trauma. This may delay physical therapy secondary to pain and swelling.

GUIDING PRINCIPLES OF POSTOPERATIVE REHABILITATION

- Understand exactly what was performed during the surgical procedure
- Understand the healing rates of the tissues involved
- Avoid excessive passive stretching and painful ROM
- ROM exercises must emphasize positions which improve congruency of the healing joint
- Understand the criteria for returning to functional and athletic activities

Phase I: Immediate Postoperative Period (days 0 to 14)[1]

Clinical Pearls

- Immediate ROM is critical following this procedure. Aggressive passive ROM should be avoided as it can result in increased swelling and stimulate fibrosis. To restore extension, a low-intensity, long-duration stretch has been proven effective.[1]
- Regional anesthesia may be effective to help start immediate postoperative elbow ROM and gentle continuous passive ROM (if utilized).

Goals

- Educate the patient.
- Modify activity to minimize pain.
- Minimize swelling, pain, and inflammation.
- Begin to restore elbow ROM.

Management of Pain and Swelling

- For pain:
  - Oral pain medications and NSAIDs are prescribed.
  - Activity modification to minimize painful activities is critical.
  - Cryotherapy
- Swelling is controlled with cryotherapy and activity modification.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Grade I and II mobilization techniques

[1]*Prehabilitation, if appropriate, is described in the Nonoperative Rehabilitation section of this chapter.*

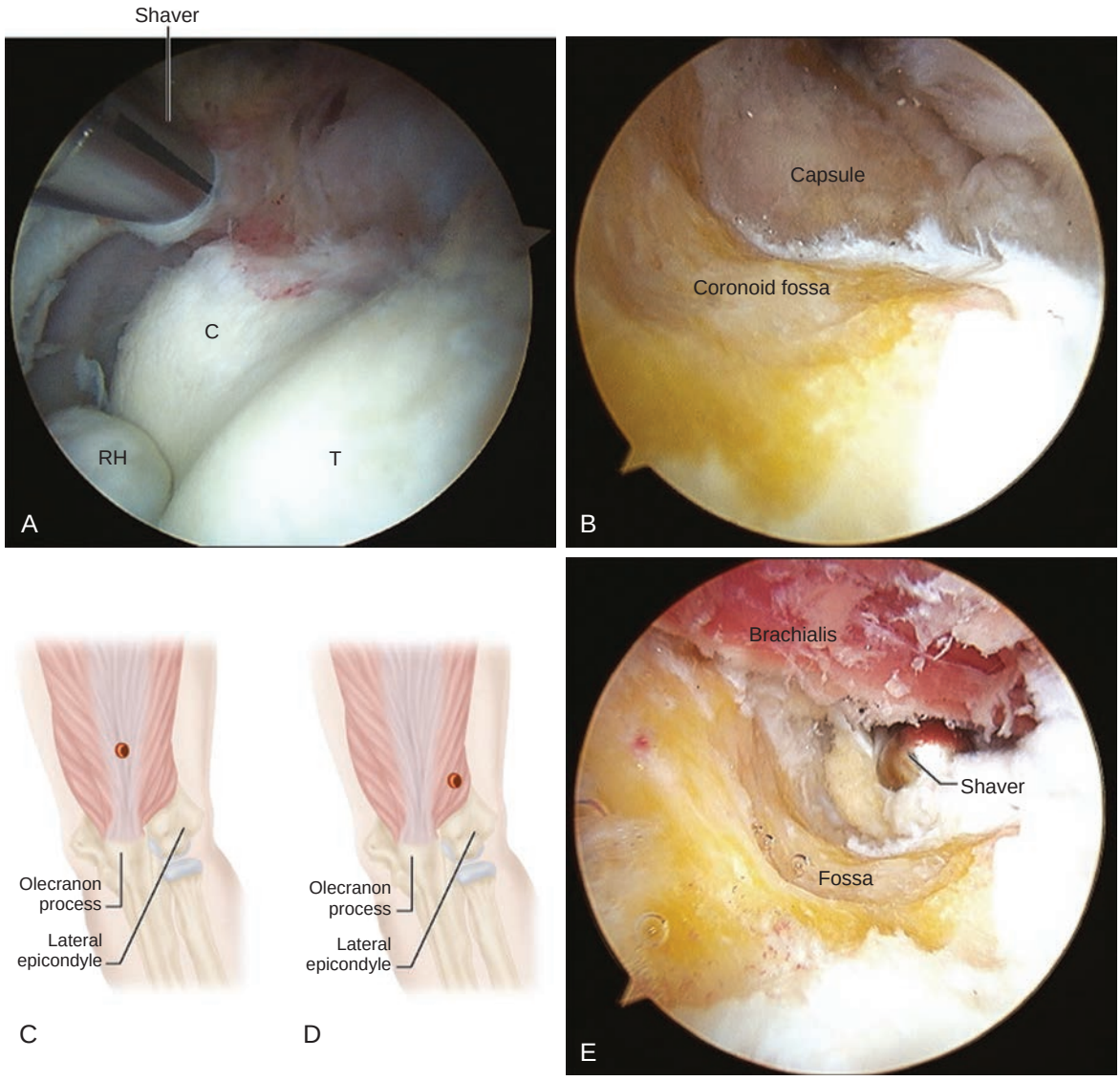

FIGURE 12-4. A, B, Anterior capsular release. Arthroscopic view of a right elbow joint after first obtaining scope entry into the proximal-medial portal, looking laterally. Debridement of synovitis is being performed with the shaver. There is a lack of concavity in the trochlea (T) and capitellum (C) area. (RH, radial head). **B,** Partially completed release. **C–E,** Posterior capsular release. Establish a posterior-central portal for the arthroscope (4 cm proximal to olecranon tip through triceps) **C,** and a posterolateral working portal **D,** (approximately 2 cm proximal to the midpoint between the tip of the olecranon laterally and the lateral epicondyle). Open these widely with a knife down into the olecranon fossa with the elbow extended (protecting the articular surface). The shaver is utilized to debride and open the space, and to remove loose bodies and osteophytes. Elevate the capsule from the distal humerus proximally with a shaver or elevator. Once a view and working space are created, perform all bone recontouring, removing any osteophytes from the olecranon and appropriately deepening the olecranon fossa if indicated. The posterior capsule is released with a basket cutter or arthroscopic elevator on the medial and lateral sides. The release is stopped before the medial aspect of the olecranon fossa (to avoid injury to the ulnar nerve). **E,** An arthroscopic view of the elbow joint after capsulectomy and deepening of the coronoid and radial fossa. The dissection is carried down to the fibers of the brachialis muscle. The posteromedial capsule should be resected in the setting of significant flexion loss (posterior band of the medial collateral ligament). However, this is extremely dangerous and places the ulnar nerve at greatest risk. Alternatively, this capsule can be released after the ulnar nerve has been dissected out through a limited open approach. The posteromedial capsule forms the floor of the cubital tunnel. Perform a final inspection from both portals to ensure adequate release. *(From Ghodadra N, et al: Arthroscopic treatment of elbow stiffness. In Reider B, Terry MA, Provencher MT (eds): Operative techniques: sports medicine surgery. Philadelphia, 2010, Elsevier (Saunders).)*

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Codman exercises are used to increase blood flow to the upper extremity.
- Elbow AROM and AAROM exercises (elbow flexion and extension; forearm pronation and supination) are initiated.
- Low-intensity, long-duration stretch is used to restore extension; aggressive PROM should be avoided (Figure 12-6).
- AROM exercises for the glenohumeral joint are initiated.
- AROM exercises for the wrist (wrist flexion/extension) are performed to prevent stiffness.

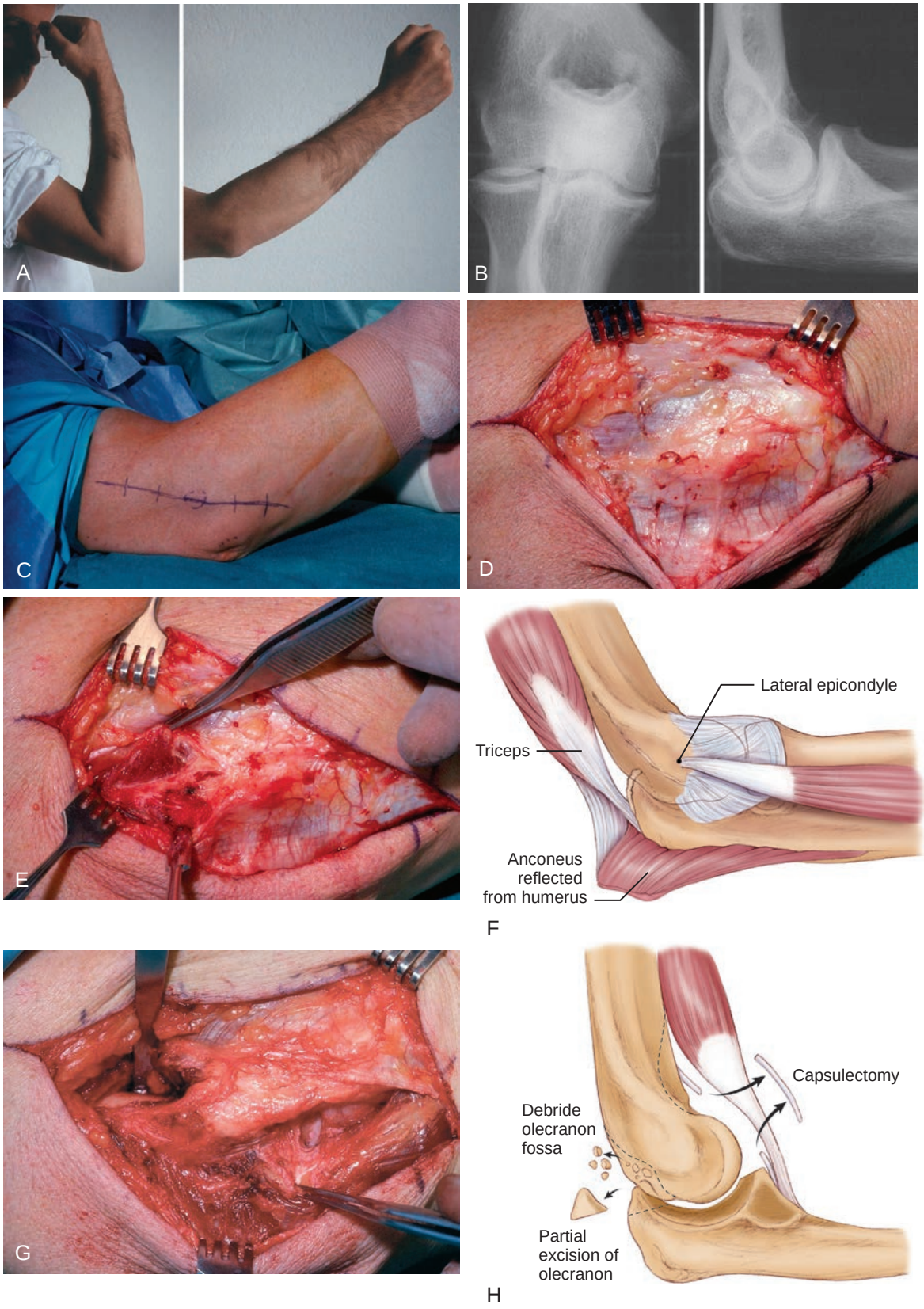

FIGURE 12-5. **A,** A man with a substantial flexion contracture and no ulnar neuropathy after trauma. **B,** Radiographs show mild osteoarthritis. **C,** A lateral skin incision is made. **D,** Full-thickness skin flaps are elevated. **E,** The supracondylar ridge is identified, and the origins of the radial wrist extensors are incised and elevated from the anterior humerus. **F,** The anconeus and the triceps are elevated from the posterior aspect of the humerus and elbow articulation. **G,** The posterolateral capsule (forceps) is excised. **H,** Osteophytes are removed from the tip of the olecranon, and the olecranon fossa is cleared.

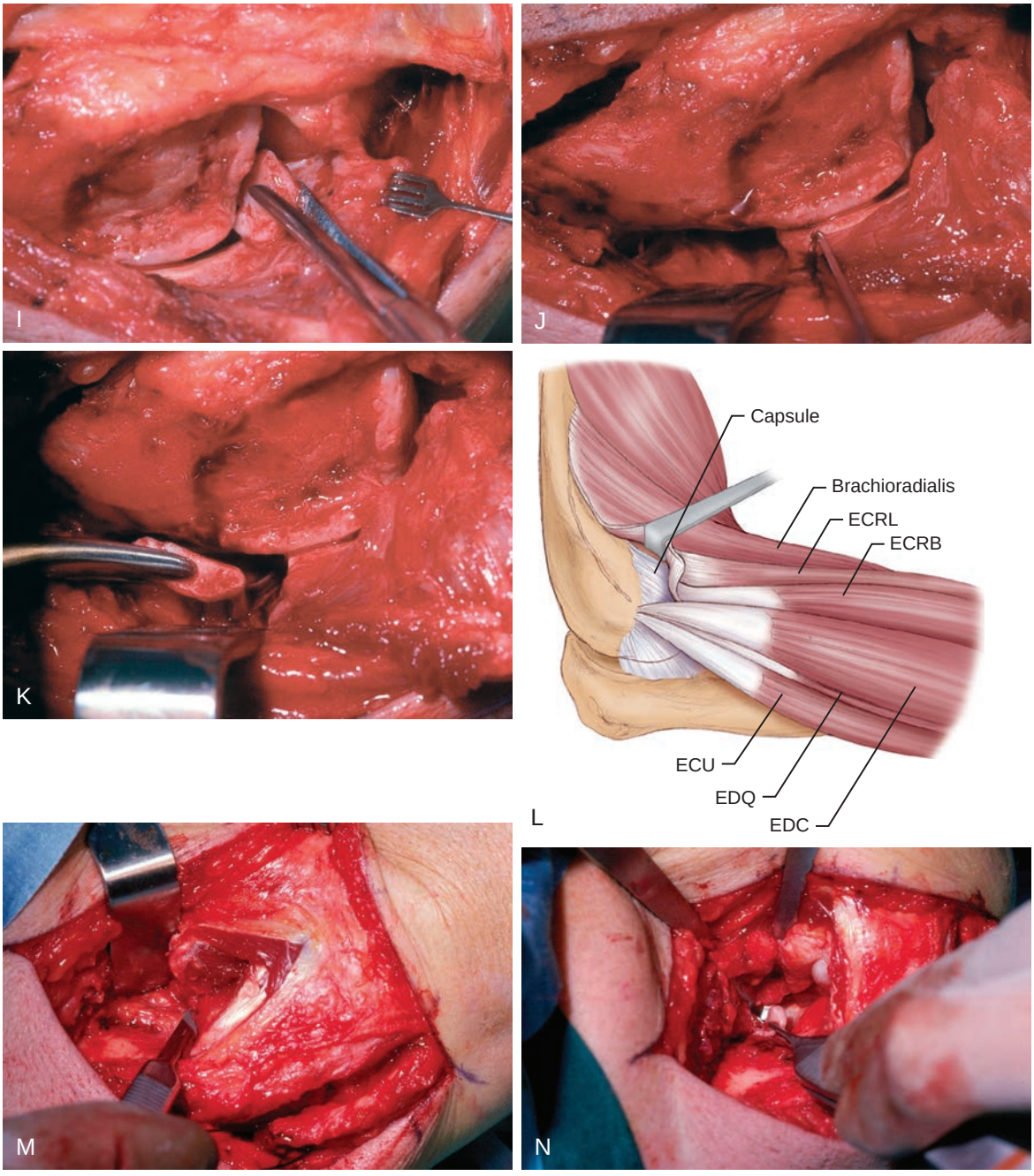

FIGURE 12-5, cont'd I, Loose bodies (forceps) are often found in the posterolateral gutter. **J,** An osteotome is poised to cut the olecranon tip. **K,** Removal of the olecranon tip. **L,** Anteriorly, the interval between the extensor carpi radialis brevis (ECRB) and the extensor digitorum communis (EDC) is developed to better expose the anterior elbow capsule. **M,** The anterior elbow capsule is excised. ECRL, Extensor carpi radialis longus; ECU, extensor carpi ulnaris; EDQ, extensor digiti quinti. **N,** A loose body (forceps) was also found in the anterior part of the joint.

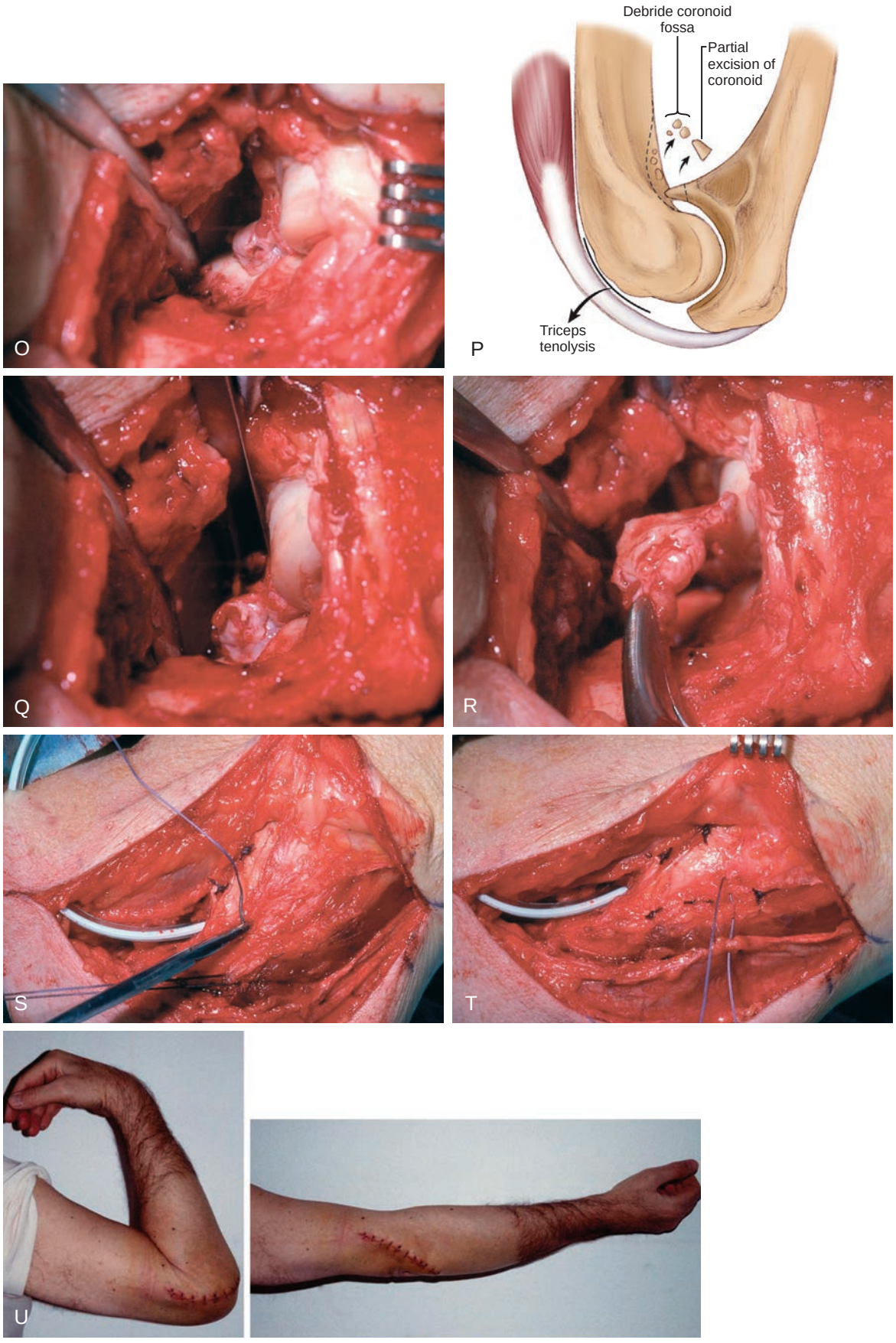

FIGURE 12-5, cont'd O, The elbow after excision of the anterior capsule. **P,** At this point, the coronoid tip is excised and the coronoid fossa is cleared out. **Q,** An osteotome is poised to cut the coronoid tip. **R,** Removal of the olecranon tip (forceps). **S,** The anterior interval is closed, in this case over a suction drain. **T,** Closure of the posterior interval. **U,** Final motion was excellent. *(From Ring D, Fernandez D: Open elbow contracture release. Ch 48. In: Cole, BJ, Sekiya JK (eds): Surgical techniques of the shoulder, elbow, and knee in sports medicine, ed 2. Philadelphia, 2013, Elsevier pp 509–518.)*

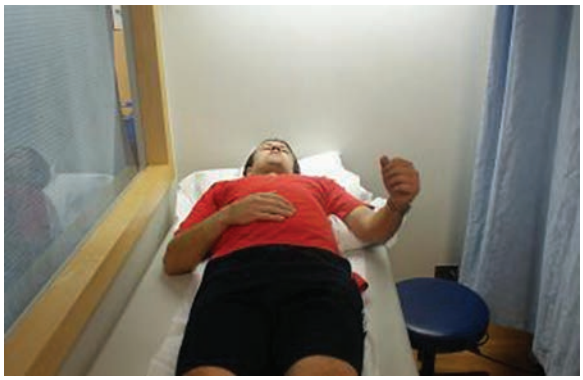

FIGURE 12-6. Low intensity, long duration stretch for elbow extension. Lying supine. Towel roll under the humerus.

Other Therapeutic Exercises

- Once the sutures are removed, the patient may begin to use a stationary bicycle, but avoid leaning heavily on the surgical upper extremity.

Milestones for Progression to the Next Phase

- Minimal pain and swelling

Phase II: Weeks 2 to 6 Postoperatively

Clinical Pearl

When continuing to restore elbow range of motion, certain joint mobilization techniques may be helpful. For example, ulnohumeral distraction or radiohumeral distraction can be effective techniques.

Goals

- Continue to restore functional elbow ROM.
- Continue to reduce pain, swelling and inflammation.
- Continue to modify activity.
- Begin to restore scapula and shoulder strength.

Management of Pain and Swelling

- Continue cryotherapy and NSAIDS as needed.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Continue joint mobilization as needed (Figure 12-7).

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Continue AROM and AAROM for the elbow.
- Continue low intensity, long duration stretch for elbow extension.



FIGURE 12-7. Joint mobilization. Posterior gliding of the proximal ulna on the distal humerus to improve elbow extension.

TIMELINE 12-1: **Postoperative Rehabilitation after Elbow Capsular Release**

PHASE I (weeks 1 to 2)	PHASE II (weeks 3 to 6)	PHASE III (weeks 6 to 10)
• PT modalities • ROM: elbow, wrist, shoulder • Codman exercises • Low-intensity, long-duration stretch for elbow extension • Joint mobilization • Stationary bicycle after sutures are removed	• PT modalities • Elbow AROM/ AAROM • Shoulder and wrist AROM • Low-intensity, long-duration stretch • Joint mobilization as needed • Manual scapula and shoulder strengthening with proximal resistance	• PT modalities as needed • Elbow AROM and AAROM • Joint mobilization as needed • TBS/TAS/TLS activities as recommended and tolerated • TAS: Scapular exercises—PREs • Glenohumeral exercises—PREs • Rotator cuff exercises—PREs • Rhythmic stabilization exercises proximal to the elbow

- Continue AROM for the wrist.
- Continue AROM for the glenohumeral joint

Other Therapeutic Exercises

- Initiate scapula and shoulder strengthening with manual resistance proximal to the elbow joint (e.g., sidelying scapula stabilization).
- Continue the stationary bicycle while avoiding leaning heavily on the surgical upper extremity.

Milestones for Progression to the Next Phase

- Minimal pain and swelling
- Elbow ROM sufficient to progress to isotonic upper-extremity strengthening

Phase III: Weeks 6 to 10 Postoperatively

Clinical Pearl

- If the patient is having difficulty restoring elbow extension, a light resistance band or light weight may be applied distally. The resistance should be light enough that it is tolerable for an extended period of time (Figure 12-8).

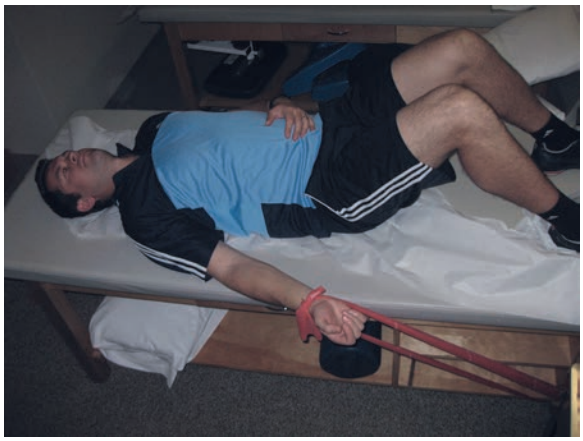

FIGURE 12-8. Low intensity, long duration stretch with elastic resistance.

Goals

- Continue to restore functional elbow ROM.
- Continue to restore scapula and shoulder strength.
- Continue to reduce pain, swelling and inflammation.

Management of Pain and Swelling

- For pain:
  - Cryotherapy
  - TENS may be utilized if significant pain persists
- For swelling:
  - Cryotherapy
  - Behavior modification

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Continue joint mobilization.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Continue AROM and AAROM for the elbow.
- Continue low-intensity, long-duration stretch for elbow extension (add light resistance if needed).
- Continue AROM for the wrist.

TIMELINE 12-1: **Postoperative Rehabilitation after Elbow Capsular Release** (Continued)

PHASE IV (weeks 10 to 14)	PHASE V (weeks 14 to 24)	PHASE VI (weeks 24 to 52)
• PT modalities as needed • Elbow AROM: full Joint mobilization as needed • Forearm stretching • Shoulder flexibility TBS/TAS/TLS activities as recommended and tolerated • Scapular exercises—PREs • TAS: biceps/triceps PREs Glenohumeral exercises—PREs • Rotator cuff exercises—PREs • IR/ER at 90°- 90° • Rhythmic stabilization with long lever arm and in overhead position • PNF exercises	• Elbow AROM: maintain full motion Mobilizations as needed • Full upper-extremity flexibility program • Hip and trunk flexibility program • TBS/TAS/TLS activities as recommended and tolerated • Scapular exercises—PREs TAS: biceps/triceps PREs Glenohumeral exercises—PREs • Rotator cuff exercises—PREs • Light forearm PREs • PNF exercises • Hip and trunk PREs Rhythmic stabilization exercises • BodyBlade when available • Plyometrics: two-arm progressing to one-arm • Overhead strengthening exercises • Sport-specific interval program begins	• Elbow ROM: maintain full motion • Full upper extremity, lower extremity and trunk flexibility program • TBS/TAS/TLS activities as recommended and tolerated • Scapular exercises—PREs • TAS: biceps/triceps PREs • Glenohumeral exercises—PREs • Rotator cuff exercises—PREs • IR/ER exercises at 90° • Forearm PREs • PNF exercises • Rhythmic stabilization exercises • Core and lower extremity PREs • Return to play

Other Therapeutic Exercises

- If symptoms and ROM allow, isotonic strengthening for the shoulder and scapula may be initiated using elastic resistance or light weights. This may include the rhomboids, serratus, upper, middle and lower trapezius, latissimus, deltoid, and rotator cuff.

Neuromuscular Dynamic Stability Exercises

- Rhythmic stabilization exercises for the shoulder may be initiated. Resistance should be initiated proximal to the elbow.

Milestones for Progression to the Next Phase

- Good proximal strength base
- Pain free with exercises and activities of daily living

Phase IV: Weeks 10 to 14 Postoperatively

Clinical Pearl

For the athletic population, aside from the elbow contracture, there are often selective losses of shoulder flexibility. These should be addressed during this phase, before advancing the athlete functionally.

Goals

- Restore normal shoulder and scapula strength.
- Begin to restore shoulder flexibility where needed.
- Begin to restore elbow strength.
- Begin to restore forearm flexibility.
- Begin to restore upper extremity endurance.

Management of Pain and Swelling

- Cryotherapy

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Continue joint mobilization if required.

Soft Tissue Techniques

- Gently massage soft tissue if required.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Continue AROM and AAROM for the elbow.
- Continue low-intensity, long-duration stretch for elbow extension if required.
- Initiate pain-free forearm stretching.
- Address any shoulder flexibility deficits: use standard goniometry and standard shoulder stretches based on findings.



FIGURE 12-9. Elbow flexion with elastic resistance.

Other Therapeutic Exercises

- Progress gradually with scapula and shoulder strengthening as tolerated.
- If rotator cuff strength is good and scapulothoracic function appears normal, strengthening of the rotator cuff in the overhead position may begin (e.g., IR/ER strengthening at 90°).

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- If range of motion allows, elbow extension and flexion strengthening are initiated using light weights or elastic resistance (Figures 12-9 and 12-10).



FIGURE 12-10. Elbow extension with elastic resistance.

Sensorimotor Exercises

- Initiate PNF patterns based on the demands of the patient: D1 flexion/ extension, D2 flexion/ extension.

Techniques to Increase Muscle Strength, Power, and Endurance

- As range of motion allows, initiate upper-body ergometry.

Neuromuscular Dynamic Stability Exercises

- Progress rhythmic stabilization to long lever arm. Progress to overhead positions as tolerated. Begin with proximal resistance and progress to more distal resistance. Begin with shoulder in a neutral position and progress to greater elevations to challenge the upper extremity more.

Milestones for Progression to the Next Phase

- Good upper extremity flexibility
- Good shoulder and scapula strength base

Phase V: Weeks 14 to 24 Postoperatively

Clinical Pearl

Sport-specific or work-specific activities should only be initiated after the patient demonstrates functional elbow ROM. The patient should be pain free and have normal upper body strength and flexibility. In the case of an athlete, normal neuromuscular function should be established through drills such as plyometrics before beginning a sport-specific program.

Goals

- Restore forearm strength.
- Restore normal neuromuscular function.
- Begin sport specific or activity specific activities without pain.
- Restore full body strength, flexibility, and endurance.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Joint mobilization techniques if needed

Soft Tissue Techniques

- Soft tissue massage if needed

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Stretching should be continued for the entire upper extremity. In addition, for the athlete any lower body and trunk flexibility deficits should be addressed.

Other Therapeutic Exercises

- For the athletic patient (e.g., a tennis player), a full core and lower extremity program should be incorporated (for the tennis player, a strong emphasis is placed on hip and trunk strength).

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Elbow flexion and extension strengthening should be progressed. For the overhead athlete, emphasis should be placed on eccentric activity and building endurance in these muscles (that is, biceps curls and triceps extensions emphasizing the eccentric component).
- Forearm strengthening can be initiated; however, resistance should be relatively light with an emphasis on building endurance and not over working the flexor/ pronator.

Techniques to Increase Muscle Strength, Power, and Endurance

- Continue upper body ergometry to build endurance. Isokinetics can also be used for the upper extremity to build power and endurance.

Neuromuscular Dynamic Stability Exercises

- Rhythmic stabilization should be progressed to all functional positions. When available, the BodyBlade can be used, progressing to all positions of the functional range of motion. Begin in a neutral rotation and abduction position and progress to more functional positions that reproduce the demands of the activity.

Plyometrics

- May begin if the patient is asymptomatic, and has a normal strength base and function range of motion and flexibility.
- Plyometrics should be functionally specific. For the tennis player, the progression can be the following: chest pass, side-to-side wood chops, overhead soccer pass, one hand external rotation in neutral, 90° to 90° position (90° of abduction and 90° of external rotation) (Figures 12-11 to 12-15).

Functional Exercises

- Deceleration exercises should be performed with a Plyoball.



FIGURE 12-11. Plyometric chest pass.



FIGURE 12-12. Plyometric side to side wood chops.



FIGURE 12-14. Plyometric one hand external rotation.

- Tossing a Plyoball over the shoulder and catching it and decelerating the arm. This may be progressed from a kneeling position to a standing position as the athlete uses the larger body parts to absorb stress from the upper extremity.

Sport-Specific Exercises

- Upon completing a plyometric program without symptoms, a sport-specific interval program may be initiated.
- The program should be progressed individually. The program should be progressed by the number of repetitions and level of plyometric activity.

Milestones for Progression to the Next Phase

- Normal upper extremity flexibility
- Normal upper extremity strength, power endurance as measured by manual muscle testing, isokinetics, and functional testing such as tolerating plyometrics
- Normal lower extremity and trunk strength and flexibility. Normal lower extremity goniometry and special tests such as a Thomas Test and hamstring flexibility are used
- Completion of a sport-specific interval program

Phase VI: Weeks 24 to 52 Postoperatively

Clinical Pearl

When returning to sport, the athlete may develop certain selective strength and flexibility deficits that may slow progress and lead to reinjury. These deficits should be monitored closely and addressed with a full body strength and flexibility program. In addition, elbow range of motion should be carefully monitored to avoid recurrence of contracture.

Goals

- Avoid reinjury.
- Maintain elbow range of motion.
- Maintain strength and flexibility.
- Return to play.

Management of Pain and Swelling

- Cryotherapy after play



FIGURE 12-13. Plyometric overhead soccer pass.

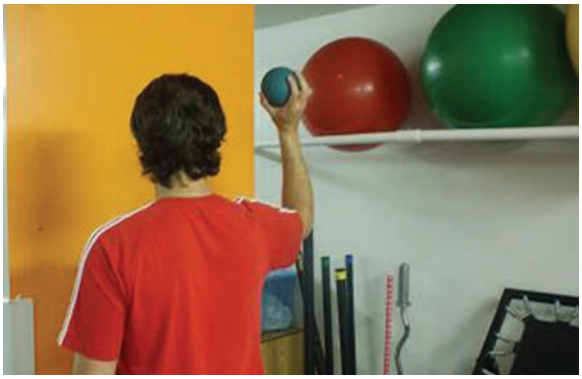

FIGURE 12-15. Plyometric one hand 90-90 position.

Techniques for Progressive Increase in Range of Motion

- Maintain full body flexibility program with the return to play.

Other Therapeutic Exercises

- Maintain full upper body, lower body and core strengthening with return to play. Decrease volume of work as play continues. In this phase, any deficits should be addressed.

Plyometrics

- Plyometrics should be phased out as play begins.

Sport-Specific Exercises

- Return to play.

Criteria for Return to Sport

General

- Pain free
- Functional elbow range of motion
- Completion of sport-specific interval program without symptoms

Sport-Specific

- Overhead athlete: normal shoulder flexibility, scapula symmetry, normal rotator cuff ratio of ER/IR of 66%.

After Return to Sport

Continuing Fitness or Rehabilitation Exercises

- Lower extremity, core strengthening and flexibility training
- Full upper extremity strengthening and flexibility training
- Elbow and forearm flexibility

Exercises and Other Techniques for Prevention of Recurrent Injury

- Improve mechanics.
- For overhead athletes, learn to use the larger body parts to absorb stresses to the upper extremity.
- Avoid activities in training that aggravate elbow symptoms.

Evidence

Ball CM, Meunier M, Galatz LM, et al: Arthroscopic treatment of post-traumatic elbow contracture. *J Shoulder Elbow Surg* 11:624–629, 2002.

In this retrospective study, 14 patients who underwent elbow arthroscopic capsular release were reviewed at a minimum of 1 year. All patients had improved function and range of motion. Satisfaction on a visual analog scale was 8.4/10 (Level IV evidence)

Bionna D, Lee GC, Driscoll SW: Arthroscopic restoration of terminal elbow extension in high-level athletes. *Am J Sports Med* 38:2509–2515, 2010.

In this retrospective review, 26 athletes whose chief complaint was limited elbow extension underwent arthroscopic contracture release. All 26 elbows improved objectively and subjectively. Twenty-two patients returned to their sport at the same level. (Level IV evidence)

Jones SG, Savoie FH III: Arthroscopic capsular release of flexion contractures (arthrofibrosis) of the elbow. *Arthroscopy* 9:277–283, 1993.

Twelve patients with flexion contractures of the elbow were managed by arthroscopic capsular release and debridement of the olecranon fossa. The mean flexion contracture improved from 38° to 3°. All patients reported a decrease in pain level. (Level IV evidence)

Sharma S, Rymaszewski LA: Open arthrolysis for post-traumatic stiffness of the elbow. *J Bone Joint Surg Br* 89B:778–781, 2007.

In this retrospective study, 25 patients with posttraumatic elbow stiffness were treated by open arthrolysis. The mean range of motion improvement was 55° at 1 year. The improvement was maintained over a mean follow-up period of 7.8 years. (Level IV evidence)

Timmerman LA, Andrews JR: Arthroscopic treatment of post-traumatic elbow pain and stiffness. *Am J Sports Med* 22:230–235, 1994.

In this retrospective study, 19 cases of posttraumatic arthrofibrosis of the elbow were treated with arthroscopic debridement and manipulation. At an average of 29 months, there was a mean improvement of extension from 29° to 11°. Flexion improved 123° to 134°.(Level IV evidence)

REFERENCES

1. Sapega AA, Quedenfeld TC, Moyer RA, et al: Biophysical factors in range of motion exercise. *Arch Phys Med Rehabil* 57:122–126, 1976.

Multiple-Choice Questions

QUESTION 1: Following capsular release for an elbow contracture, when should range of motion exercises begin?

A. Two weeks postoperatively
B. Immediately
C. Four weeks postoperatively
D. Six weeks postoperatively

QUESTION 2: In the first 2 weeks after surgery, physical therapy may include all of the above except:

A. Codman exercises
B. Low-intensity, long-duration stretch for elbow extension
C. Forearm strengthening
D. Elbow AROM

QUESTION 3: If elbow ROM allows, resistive elbow exercises may be initiated during which phase?

A. Two to 6 weeks postoperatively
B. Six to 10 weeks postoperatively

C. Ten to 14 weeks postoperatively
D. Fourteen to 24 weeks postoperatively

QUESTION 4: Which of the following is the criterion for initiating a plyometric program?

A. Functional elbow ROM
B. Minimal discomfort in the elbow
C. Normal shoulder flexibility
D. Normal upper extremity strength

QUESTION 5: All of the above are used for restoring elbow ROM after capsular release except:

A. Joint mobilization techniques
B. Elbow AROM and AAROM
C. Aggressive passive stretching by the PT
D. Low-intensity, long-duration stretch for extension

Answer Key

QUESTION 1: Correct answer: **B** (see Brief Summary of Surgical Treatment)

QUESTION 2: Correct answer: **C** (see Phase I)

QUESTION 3: Correct answer: **C** (see Phase IV)

QUESTION 4: Correct answer: **D** (see Phase V)

QUESTION 5: Correct answer: **C** (see Phase I)

Chapter 13



Forearm Nerve Entrapments

INTRODUCTION

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Epidemiology

The epidemiology of forearm nerve entrapments is dependent upon type.

- Median
  - Carpal tunnel syndrome
    - Most common nerve entrapment in upper extremity
    - Twice as common in females
    - Most commonly between ages of 45 and 54 years of age
    - Can occur frequently during pregnancy
    - Common in fast-pitch softball pitchers
    - May be related to occupational, gripping, or other athletic pursuits
  - Pronator syndrome
    - Common in athletes such as fast-pitch softball pitchers
  - Anterior interosseous nerve (AIN) entrapment
    - Entrapped in forearm
- Radial (least common form of nerve entrapment)
  - Radial tunnel syndrome
    - Only 1% to 2% of upper extremity entrapments
    - Most commonly in fourth to sixth decades of life
  - Posterior interosseous nerve (PIN) entrapment
    - Often misdiagnosed as tennis elbow
    - Seen in throwing sports
  - Superficial branch (Wartenberg's syndrome)
    - Common with handcuffs or wrist straps
- Ulnar
  - Cubital tunnel
    - Second most common entrapment location in upper extremity
    - More commonly seen in males than females
    - Common in throwing athletes but can also be seen in skiing, weight lifting, and racquet sports
  - Guyon's canal
    - Often seen in bicyclists from gripping handlebars (especially off-road)

Pathophysiology

Intrinsic Factors

- Median
  - Repetitive or overuse
  - Underlying disease such as diabetes mellitus, thyroid myxedema, rheumatological disease, acromegaly, amyloidosis, renal dialysis, and alcoholism increase risk
  - Size of median nerve and contents inside carpal tunnel exceed that of space available or are too large
  - Large forearm musculature increases risk of pronator syndrome or AIN entrapment
- Radial
  - Vulnerable to injury at several points along anatomical course:
    - Proximally at axilla
    - Shaft of humerus in spiral groove (Saturday night palsy)
    - Compression by lateral head of triceps
    - At radial tunnel by fibrous bands or edge of extensor carpi radialis brevis—PIN
    - Arcade of Frohse, sometimes called the supinator arch, is a fibrous arch over the PIN
    - Supinator muscle—PIN
    - Between brachioradialis and extensor carpi radialis longus—PIN
    - Superficial branch at distal radial forearm
- Ulnar
  - Vulnerable to injury at several points along anatomical course:
    - Proximally at axilla
    - Arcade of Struthers, a canal formed by a short band of fibrous tissue proximal to medial epicondyle
    - Medial head of triceps muscle
    - Medial epicondyle
    - Ulnar groove
    - Cubital tunnel

- Flexor aponeurosis
- Guyon's tunnel, a bony tunnel in the proximal wrist formed by the pisiform and the hamate bones

Extrinsic Factors

- Median
  - Direct trauma—AIN
  - Overuse injury causing swelling to finger/wrist/forearm musculature
  - Vibration at the hand and wrist
- Radial
  - Direct trauma to distal radial forearm—superficial branch
  - Fracture of humeral shaft—proximal radial nerve
  - Compression from hypertrophy of muscles/tennis elbow straps—PIN
- Ulnar
  - Direct trauma—Guyon's canal
  - Traction following ulnar collateral ligament insufficiency
  - Fracture callus

Traumatic Factors

- Median
  - Carpal tunnel syndrome
  - Direct trauma
  - Compression by other tendons of extrinsic finger flexors
  - Fractures
- Radial
  - Direct trauma to distal radial forearm—superficial branch
  - Direct trauma to proximal arm—Saturday night palsy
  - Fracture of humeral shaft
- Ulnar
  - Direct trauma in axilla—crutches
  - Direct trauma in hand/wrist—Guyon's canal
  - Compression from muscles/tendons (medial head of triceps)
  - Fracture callus
  - Bone spurs
  - Pressure from combined movements of wrist extension and elbow flexion

Classic Pathological Findings

- Median
  - Carpal tunnel syndrome
    - Aching, burning and paraesthesia in thumb, forefinger, middle finger, and wrist
    - Symptoms worse at night
    - Grip weakness
    - Weakness in hand and wrist
    - Thenar muscle atrophy if chronic
    - Loss of two-point discrimination
    - Pain with fast-pitch softball
  - Pronator syndrome
    - Forearm pain with similar symptoms
  - AIN
    - Weakness of flexion of first and second DIP joints so cannot make the O-sign
- Radial
  - Proximal injury
    - Weakness of elbow flexion or extension
    - Mild weakness of wrist/finger extension
    - Loss of sensation of posterior arm, forearm, and hand
    - Wrist drop
  - PIN
    - Forearm pain despite its being a purely motor nerve
  - Superficial branch
    - Radial wrist and index finger/thumb numbness/tingling
- Ulnar
  - Sensory changes fourth and fifth digits
  - Hypothenar muscular atrophy if chronic
  - Pincer grip weak—Froment sign
  - Problems opening jars
  - Fatigue with repetitive hand finger motions

Clinical Presentation

History

- Median
  - Trauma or repetitive activities
  - Sports or vocation that involves repetitive gripping/vibration
  - Sports or vocation that involves repetitive supination or pronation
- Radial
  - Compression at axilla such as falling asleep with arm over back of chair
  - Repetitive wrist and forearm movements
  - Repetitive gripping, pinching, or grasping activities
- Ulnar
  - Trauma or repetitive activities
  - Throwing or overhead sports that require elbow flexion/extension
  - Occupation involving repetitive elbow flexion/extension
  - Repetitive gripping/vibration

Physical Examination

Abnormal Findings

- Median
  - Carpal tunnel syndrome
    - Paraesthesia and numbness in hand (fingers 1 to 3) and wrist
    - Atrophy of abductor pollicis brevis if chronic
    - Positive Phalen's test (Figure 13-1A)
    - Positive Tinel's test (Figure 13-1B)
    - Hypertrophy of pronator teres muscle (pronator teres syndrome)
    - Weakness of flexion first and second finger DIP joints (AIN)
- Radial
  - Posterior interosseus nerve
    - Dull ache in lateral elbow
    - Pain over extensor mass

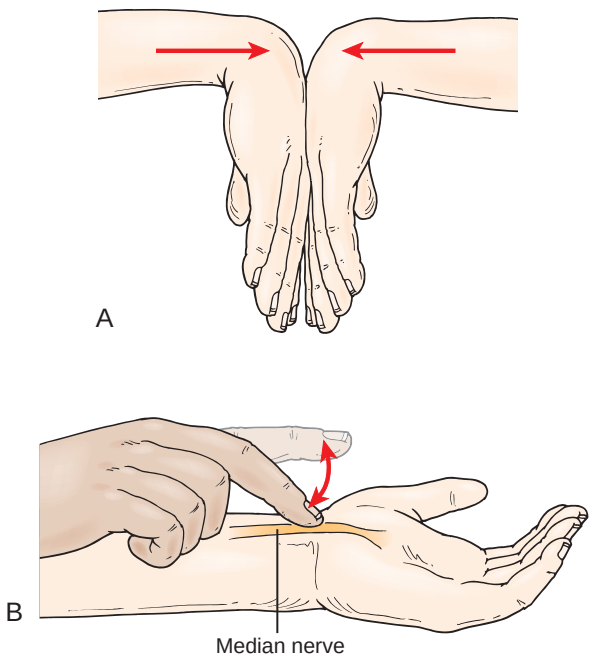

FIGURE 13-1. A, Diagram of Phalen's test. **B,** Diagram of Tinel's test. *(Redrawn from Brotzman SB: Hand and wrist injuries: Nerve compression syndromes. In Brotzman SB, Manske RC, editors: Clinical orthopaedic rehabilitation, ed 3. Philadelphia, 2011, Elsevier, Fig 1-24AB.)*

  - Pain with resisted supination
  - Pain with extension of middle finger
  - Paraesthesia over dorsal hand and radial forearm (superficial branch)
- Ulnar
  - Cubital tunnel syndrome
    - Pain to palpation/Tinel's sign of medial elbow in cubital fossa
    - Paraesthesia in ulnar side of fourth and fifth digits
    - Loss of fine motor control of hand and fingers
    - Pain to palpation/Tinel's sign at Guyon's canal

Pertinent Normal Findings

- Median, radial, and ulnar
  - Normal sensation in remaining fingers
  - Usually no signs of autonomic nervous system dysfunction

Imaging

- Median, radial, and ulnar
  - Electrodiagnostic studies—both electromyography/nerve conduction study (EMG/NCS)
  - Routine radiographic series to evaluate for bone spurs
  - Ultrasonography for tenosynovitis or nerve swelling
  - Magnetic resonance imaging

Differential Diagnosis

- Median
  - Anterior interosseous syndrome—jersey finger
  - Pronator syndrome—medial epicondylitis
  - Carpal tunnel syndrome—flexor tendon tenosynovitis
  - Brachial neuritis
  - Humeral supracondylar process syndrome
  - Medial epicondylitis
  - Myopathies
  - Thoracic outlet syndrome
  - Tumor or space-occupying lesion
- Radial
  - PIN—lateral epicondylitis
  - Brachial neuritis
  - De Quervain's/intersection tenosynovitis
  - Humeral supracondylar process syndrome
  - Myopathies
  - Thoracic outlet syndrome
  - Tumor or space-occupying lesion
- Ulnar
  - Cubital tunnel syndrome—subluxing ulnar nerve
  - Brachial neuritis
  - Cervical radiculopathy
  - Medial epicondylitis
  - Myopathies
  - Thoracic outlet syndrome
  - Tumor or space-occupying lesion—Guyon's canal
  - Ulnar artery aneurysms or thrombosis—Guyon's canal

Treatment

Nonoperative Management

- Median, radial, and ulnar
  - Counterforce bracing
  - Splinting/casting to reduce swelling and active inflammation
  - Electrical modalities to treat pain and swelling
  - Ice for pain control and prevention of swelling
  - Soft-tissue stretching and mobilization to reduce tension/fibrosis in muscles surrounding nerves
  - Neural mobilization or nerve gliding techniques
  - Total arm strengthening and localized strengthening for dynamic control
  - Avoid or eliminate aggravating factors
  - Ergonomic assessment for work
  - Sports biomechanical assessment (tennis racquet assessment, throwing assessment)
  - Antiinflammatory medications—nonsteroidal antiinflammatory drugs (NSAIDs)/steroids
  - Perineural steroid injections
  - Iontophoresis or phonophoresis
  - Neurolysis

Guidelines for Choosing Among Nonoperative Treatments

- Choose the best option for each patient in an individualized fashion by involving the patient in the decision-making process
- Need to discern if the etiology of the entrapment is inflammatory or mechanical or both and the underlying etiology before deciding on a management plan

Surgical Indications

- Median, radial, and ulnar
  - No absolute surgical indications—it is always the patient's decision
  - Relative surgical indications
    - Severe or worsening neurological symptoms
    - Failure to respond to appropriate conservative treatment
    - Unexplained symptoms inconsistent with pathology
    - EMG/NCS showing moderate to severe nerve injury that is consistent with the symptoms

Aspects of History, Demographics, or Exam Findings That Affect Choice of Treatment

- Treatment options are based on the best options for pain management, correction of the underlying etiology of the problem, and rehabilitation to help prevent future reoccurrences from the preceding list
- Avoid NSAIDs/steroids if history of abdominal pain/ulcers/gastritis/gastrointestinal (GI) bleed
- If pain with neural tension testing—add nerve glides

Aspects of Clinical Decision Making When Surgery Is Indicated

- Muscle atrophy/weakness
- Inability to work secondary to the loss of function or pain
- Worsening symptoms despite appropriate conservative care
- Moderate or severe nerve damage by EMG/NCT

Evidence

El Miedany Y, Ashour S, Youssef S, et al: Clinical diagnosis of carpal tunnel syndrome: Old tests-new concepts. *Joint Bone Spine* 75(4):451–457, 2008.

Two-hundred and thirty-two patients with carpal tunnel syndrome and 182 control subjects were assessed to examine relationship between clinical manifestations with outcomes of diagnostic tools and physical examination procedures. One-hundred and seventy-seven out of 232 (76.3%) had abnormal nerve conduction studies. Forearm symptoms and tenosynovitis confirmed by ultrasound examination was found in 51.3% of cases. No difference was seen on comparing anthropometric measures in the affected hands with control group hands. Sensitivity of Tinel's, Phalen's, reverse Phalen's, and carpal tunnel compression tests was higher for diagnosis of tenosynovitis than for the diagnosis of carpal tunnel syndrome. Similarly higher specificity of these tests was found with tenosynovitis than for carpal tunnel syndrome. (Level III evidence)

Finanneschi F, Filipou G, Milani P, et al: Ulnar nerve compression neuropathy at Guyon's canal caused by crutch walking: Case report with ultrasonographic nerve imaging. *Arch Phys Med Rehabil* 90(3):522–524, 2009.

A case report of Guyon's syndrome after the bilateral use of forearm crutches. Crutch palsy can be neurapraxic in nature with clinical recovery. This case study presents history following a pattern of recovery of nerve function. In this case establishment of a diagnosis of focal compression neuropathy through a combination of clinical assessment and neurophysiological studies was used. An additional application of ultrasound imaging was used to verify the diagnosis and track recovery. (Level IV evidence)

Karata A, Apaydin N, Uz A, et al: Regional anatomic structures of the elbow that may potentially compress the ulnar nerve. *J Shoulder Elbow Surg* 18:627–631, 2009.

This study examined 12 cadaver upper limbs to determine length of any fibrous bands and their distance to medial epicondyle. On five cases a fibrous band ran from medial intramuscular septum to cross over ulnar nerve. Mean length of band was 5.7 cm. In four cases ulnar nerve was covered with muscle fibers from flexor digitorum superficialis and flexor carpi ulnaris. In five cases there were fibrous thickenings, and in eight cases there were vascular structures crossing the ulnar nerve. These anatomical variances could cause recurrent symptoms following surgical release of attachment sites. (Level IV evidence)

Multiple Choice Questions

QUESTION 1. Which upper extremity nerve entrapment is most commonly entrapped along the lateral head of the triceps at the lateral intermuscular septum?

A. Radial
B. Median
C. Ulnar
D. Musculocutaneous

QUESTION 2. A 17-year-old baseball pitcher complains of medial elbow discomfort that occurs with repetitive throwing. His other complaint is of loss of sensation in the fourth and fifth digits. This history would most likely correspond to compression of which upper extremity nerve?

A. Radial
B. Median
C. Ulnar
D. Musculocutaneous

QUESTION 3. A 16-year-old softball player complains of proximal forearm pain that has been exacerbated by increasing intensity and number of fast-pitch softball pitches. What would be her most likely pathology?

A. Carpal tunnel syndrome
B. Cubital tunnel syndrome
C. Arcade of Struthers' syndrome
D. Pronator syndrome

QUESTION 4. What is the first and foremost primary immediate goal in treatment of any of the upper extremity nerve entrapment syndromes?

A. Total arm strengthening
B. Regaining lost forearm power
C. Elimination of aggravating activities
D. Getting sports assessment

QUESTION 5. A 56-year-old female recreationally competitive tennis player is being seen for complaint of forearm and hand pain and numbness and tingling. She reports that additionally she seems to lose her

grip during serves and hard volleys. You notice immediately that she has atrophy of the thenar muscles on the involved side. This would most likely be caused by entrapment of which peripheral nerve?

A. Radial
B. Median
C. Ulnar
D. None of the above

Answer Key

QUESTION 1. Correct answer: **A** (see Pathology: Intrinsic Factors)

QUESTION 2. Correct answer: **C** (see Clinical Presentation)

QUESTION 3. Correct answer: **D** (see Epidemiology and Classic Findings)

QUESTION 4. Correct answer: **C** (see Treatment)

QUESTION 5. Correct answer: **B** (see previous sections)

NONOPERATIVE REHABILITATION FOR FOREARM NERVE ENTRAPMENTS

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GUIDING PRINCIPLES OF NONOPERATIVE REHABILITATION

- Pain—Every attempt should be made to decrease pain and symptoms of nerve entrapments.
- Sensation—Serial assessment of sensation can guide the nonoperative rehabilitation indicating either worsening or lessening of entrapment and compression.
- Strength—Maintain or advance strength and minimize strength loss caused by associated entrapped nerves.
- Function—Restore function through gaining or maintaining motion and strength.

Phase I (weeks 0 to 6 dependent on acuteness of injury and degree of neurological involvement)

Protection

- Bracing, casting, or splinting may be helpful to rest extremity and provide support to allow decreased inflammation and swelling.

Management of Pain and Swelling

- RICE: rest, ice, compression, elevation
- Modalities such as pulsed ultrasound, electrical stimulation, iontophoresis or phonophoresis may be also helpful.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Gentle active assistive range of motion as tolerated

Soft-Tissue Techniques

- Gentle distal to proximal massage to create retro drainage from swollen tissues

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Very gentle stretching to affected area because neurological tissue is very unforgiving if stretched too far and symptoms exacerbated

Other Therapeutic Exercises

- Cardiovascular exercise (bike)
- Upper extremity total arm strength
- Total body strength

Activation of Primary Muscles Involved

- Gentle active or active assistive range of motion exercises as tolerated
- Total arm strength to proximal muscles of arm and shoulder as tolerated

Milestones for Progression to the Next Phase

- Minimal to no swelling
- Pain free range of motion
- Improvement of strength

Phase II (weeks 6 to 12)

Protection

- Protection of bracing and splinting gradually removed

Management of Pain and Swelling

- RICE and ultrasound, electrical stimulation

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Progression from active assistive to active range of motion
- Gentle joint mobilization techniques to increase passive joint mobility

Soft-Tissue Techniques

- Dependent upon degree of swelling. May continue as per Phase I if swelling and edema persist.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Gentle stretching of forearm and wrist musculature if tolerated without an increase in symptoms
- Nerve glide or flossing techniques to increase nerve mobility or decrease adhesions around peripheral nerves

Other Therapeutic Exercises

- Continue as Phase I
- May begin elliptical or treadmill as tolerated

Activation of Primary Muscles Involved

- Concentric submaximal isometric followed by submaximal isotonic progressive resistive exercises with light weight or bands. Start exercises such as wrist extensor muscles by initiating strengthening with isometrics, which if tolerated can be followed by isotonic movements through a safe range of motion for wrist extension.
- Exercises done in cardinal planes; for example, starting isotonic exercises in frontal plane only versus using total arm movements that might incorporate multiple planes of movement of the forearm
- Putty exercises
- Gripping (ball squeeze)
- Rice bucket exercises

Open and Closed Kinetic Chain Exercises

- Place hand wrist on table top and slowly and gently load in various weight-bearing directions

Techniques to Increase Muscle Strength, Power, and Endurance

- Continue to progress total arm strength by working proximal musculature. Ensure proper proximal muscle control by working elbow flexors, extensors, and glenohumeral and scapular shoulder muscles

Functional Exercises

- Grasping, pushing, and pulling motions
- Holding sports/vocational equipment for short durations in effort to build endurance

Milestones for Progression to the Next Phase

- No swelling
- No pain
- Full range of motion
- No loss of sensation
- 4/5 manual muscle test of affected muscles

TIMELINE 13-1: **Nonoperative Rehabilitation of Upper Extremity Nerve Entrapment Syndromes**

PHASE I (weeks 0 to 6)	PHASE II (weeks 6 to 12)
• Sling, splint, brace • RICE: rest, ice, compression, elevation • Physical Therapy (PT) modalities • Gentle AAROM forearm, hand, and wrist • Distal to proximal massage • Very gentle stretching • Cardiovascular exercises • Total body strengthening (TBS) • Upper extremity total arm strengthening (TAS) • Total leg strength (TLS) • Rotator cuff exercises, progressive resistive exercises (PREs) • Scapular exercises (PREs)	• Sling, splint, brace as needed but gradually removed • PT modalities as needed • Progress from AAROM to AROM • TBS/TAS/total leg strength (TLS) activities as recommended and tolerated • Rotator cuff exercises (PREs) • Scapular exercises (PREs) • Concentric submaximal isometric exercises • Progression to submaximal isotonic progressive resistive exercises • Putty exercises • Gripping exercises • Rice bucket exercises • Gently load hand and wrist in closed kinetic chain positions • Gentle pushing, pulling motions • Light weight wrist flexion/extension, pronation/supination

Phase III (weeks 12 to 18)

Management of Pain and Swelling

- As previously described if pain and swelling continue

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- As previously described if needed
- If limitation of motion are capsular (joint restrictions) in nature, can begin joint mobilization techniques to restore normal joint arthrokinematics

Soft-Tissue Techniques

- As previously described if needed

Stretching and Flexibility Techniques for the Musculotendinous Unit

- As previously described if needed
- Should be able to tolerate gentle stretching now without re-exacerbation

Other Therapeutic Exercises

- Begin trunk/core strengthening with emphasis on requirements for activities of sports or vocation
- Continued cardiovascular conditioning
- Continued total arm strength as tolerated

Activation of Primary Muscles Involved

- Submaximal isotonic progressive resistive exercises with light weight or bands
- Concentric or eccentric wrist extension exercises with 3-lb weights or red resistance band, three sets of 20 repetitions

Open and Closed Kinetic Chain Exercises

- Progressively load upper extremity in more provocative patterns
- Start leaning on wall, to bilateral upper extremity in quadruped, to unilateral extremity in tripod

Techniques to Increase Muscle Strength, Power, and Endurance

- Increase strength and endurance as tolerated by modulating dosage of exercises as appropriate for activities of daily living and sports

Plyometrics

- Gentle plyometric "type" exercises with light weights, bilaterally progressing to unilaterally.
- Bilateral chest pass into PlyoBack device, throwing and catching chest height with two hands, light weight. When this becomes easier, athlete can progress to unilateral pass to PlyoBack device.

Functional Exercises

- Incorporate more functional movement specific tasks (D2 flexion/extension patterns for shoulder while gripping band for forearm exercise; swinging hammer without full weight hammer head).

Sport-Specific Exercises

- Incorporate more functional movement specific tasks (D2 flexion/extension patterns for shoulder while gripping band for forearm exercise).
- Begin with gentle throwing or hitting motions.
- Motions may be done initially without ball (baseball, softball) or racquet (tennis) progressing to motions with equipment.

TIMELINE 13-1: **Nonoperative Rehabilitation of Upper Extremity Nerve Entrapment Syndromes** (Continued)

PHASE III (weeks 12 to 18)	PHASE IV (weeks 18 to 24)
• D/C sling, splint, or brace • PT modalities as needed • AROM, AAROM, PROM—full • Mobilizations as needed • Trunk and core exercises as tolerated • TBS/TAS activities as recommended and tolerated • Rotator cuff exercises (PREs) • Scapular exercises (PREs) • "Plyometric-like" exercises • Light weight, bilateral progressing to unilateral • Functional exercises (90/90 shoulder) for throwers • Putty exercises • Gripping exercises • Rice bucket exercises • Pushing and pulling-type exercises • Wrist flexion/extension and pronation and supination PREs	• AROM, AAROM, PROM full • TBS/TAS/TLS activities as recommended and tolerated • Mobilizations as needed • Trunk and core exercise as tolerated • Rotator cuff exercises (PREs) • Scapular exercises (PREs) • Plyometric exercises • Functional exercises • Proprioceptive neuromuscular facilitation (PNF) exercises • Progress Closed kinetic chain (CKC) exercises • Sports progression as tolerated

- Gentle golfing motions can be started swinging 50% effort progressing to 75% over several visits or weeks.
- Use elastic tubing around tennis racquet while moving into positions of cocking for forehand and backhand tennis strokes.

Milestones for Progression to the Next Phase

- No swelling
- No pain
- Full range of motion
- No loss of sensation
- 5/5 strength of affected muscles

Phase IV (weeks 18 to 24)

Management of Pain and Swelling

- As previously described if pain and swelling continue

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- As previously described if needed
- If limitations of motion are capsular (joint restrictions) in nature, can begin joint mobilization techniques to restore normal joint arthrokinematics

Soft-Tissue Techniques

- As previously described if needed

Stretching and Flexibility Techniques for the Musculotendinous Unit

- As previous if needed. Should be able to tolerate gentle stretching now without re-exacerbation.

Other Therapeutic Exercises

- Continued trunk/core strengthening with emphasis on requirements for activities of sports or vocation
- Continued cardiovascular conditioning
- Continued total arm strength as tolerated using larger movements and proximal musculature, such as during upper body ergometer or push up progressions

Activation of Primary Muscles Involved

- Submaximal isotonic progressive resistive exercises with light weight or bands
- Continuance of program to maintain or increase strength and/or endurance as needed for full unrestricted return to activity. This program should be continued until the patient has full unrestricted strength and the ability to return to previous activity.

Open and Closed Kinetic Chain Exercises

- Progression as previously described
- Increased resistance from heavier dumbbells, thicker resistance bands, or more provocative position such as overhead movements, movements away from body. Can also add loaded exercises, such as pushups with feet elevated 12 inches or pushups with clap between.

Techniques to Increase Muscle Strength, Power, and Endurance

- Increase strength and endurance as tolerated by modulating dosage of exercises as appropriate for activities of daily living and sports.
- Increase speed and/or resistance with exercises as appropriate to allow increased power during activities. Use light tubing while swinging bat or racquet in simulated game-type situations.

Plyometrics

- If tolerated, "gentle plyometric-type" exercises in previous stage can progress to heavier weights and unilateral exercises
- Increase weight of Plyoball to add resistance and overload. Additionally, Plyoball can be done in more provocative positions such as overhead motions.

Functional Exercises

- Incorporation of more functional movement specific tasks (e.g., use of actual hammer or saw)
- All done in slow progression from 50% to 75% to 100% effort
- One set of 25 repetitions progressing to up to three sets of 25 repetitions at each intensity level

Sport-Specific Exercises

- Incorporation of more functional movement specific tasks (throwing baseball, football, swinging bat)
- All done in slow progression, from 50% to 75% to 100% effort
- One set of 25 repetitions progressing to up to three sets of 25 repetitions at each intensity level

Milestones for Progression to Advanced Sport-Specific Training and Conditioning

- No swelling
- No pain
- Full range of motion
- No loss of sensation
- 5/5 strength of affected muscles

Criteria for Abandoning Nonoperative Treatment and Proceeding to Surgery or More Intensive Intervention

- Continued pain
- Continued swelling
- Continued numbness and tingling

- No return of strength
- Progression of symptoms

Tips and Guidelines for Transitioning to Performance Enhancement

- Ensure that symptoms do not return.
- Slow progression if any neurological symptoms return.
- These symptoms could show up as excessive fatigue, burning, loss of sensation, or feelings of clumsiness.
- Gradual slow progression is always more reliable than a rushed, hurried approach to return to function without creating setbacks.

Performance Enhancement and Beyond Rehabilitation: Training/Trainer and Optimization of Athletic Performance

- Gradual progression to full return of functional activities involving total body movement patterns with no return of symptoms
- Hitting or serving progressions. Use of weight equipment or bands or cables to challenge muscular control of trunk and full body

Specific Criteria for Return to Sports Participation: Tests and Measurements

- No swelling
- No pain
- Full range of motion
- No loss of sensation
- 5/5 strength of affected muscles

Evidence

Garfinkel MS, Singhal A, Katz WA, et al: Yoga-based intervention for carpal tunnel syndrome. A randomized trial. *JAMA* 280(18):1601–1603, 1998.

A randomized, single-blind, controlled study that studied 42 employed or retired individuals with carpal tunnel syndrome. Subjects were assigned to a yoga group or a control group. Yoga group subjects received a yoga-based intervention consisting of 11 yoga postures designed for strengthening, stretching, and balance in each joint in upper body along with relaxation given twice weekly for 8 weeks. Control group patients were offered a wrist splint to supplement their current treatment. Outcome measures included grip strength, pain intensity, sleep disturbance, Phalen's and Tinel's signs, and median nerve motor and sensory conduction time. Subjects in the yoga group had significant improvement in grip strength and pain reduction, whereas these were not significant for control the group. Yoga group had significantly more improvement in Phalen's sign. No difference was seen in Tinel's sign, and median nerve motor and sensory conduction time. (Level II evidence)

Irvine J, Chong SL, Amirjani N, et al: Double-blind randomized controlled trial of low-level laser therapy in carpal tunnel syndrome. *Muscle Nerve* 40:182–187, 2004.

Double-blinded randomized controlled trial of low-level laser therapy in fifteen carpal tunnel syndrome patients. Patients randomly assigned to either control group (8) or treatment group (7). Both groups received treatment three times per week for 5 weeks. Control groups were treated with sham treatment, whereas the treatment group received 860 nm gallium/aluminum/arsenide laser at a dosage of 6 J/cm^2 over the carpal tunnel. Primary outcomes were subjective outcomes. All participants completed study with no adverse effects. Significant symptomatic improvement occurred in both controls and patients. However, there was no significant difference in outcome measures between the two groups. Thus, low-level laser therapy is no more effective in the reduction of symptoms of carpal tunnel syndrome. (Level II evidence)

Lopes MM, Lawson W, Scott T, et al: Tendon and nerve excursion in the carpal tunnel in healthy and CTD wrists. *Clin Biomech* 26(9):930–936, 2011.

Study looked at size of median nerve and excursion of flexor digitorum superficialis tendon via use of Doppler ultrasound imaging. Twenty-five participants, including 16 healthy, six self-reported with cumulative trauma disorders, and three wheelchair users, were analyzed. The median nerves in symptomatic wrists were larger than healthy wrists by 4.2 mm^2 (right) and 4.1 mm^2 (left) proximally to less than 1.4 mm^2 distally. Tendon excursion differences in healthy wrists ranged from 0.7 mm to 4.3 mm, whereas those in the symptomatic wrists ranged over 22.2 mm. (Level III evidence)

Oskay D, Meric A, Kirdi N, et al: Neurodynamic mobilization in the conservative treatment of cubital tunnel syndrome: Long-term follow-up of 7 cases. *J Manipulative Physiol Ther* 33(2): 156–163, 2010.

This is a case series that describes the effect of nerve mobilization techniques in a standard conservative management of cubital tunnel syndrome. Seven patients with cubital tunnel syndrome participated in the study. Physical therapy treatments consisted of cold application, pulsed ultrasound, nerve mobilization techniques, strengthening exercises, postural adaptations, patient education, and ergonomic modifications. Outcome measurements included strength, pain scales, sensation testing, and objective outcome scales. Pain; Tinel's sign; and Disability of Arm, Shoulder and Hand index scores were decreased, whereas grip and pinch strength increased in the observation period of these patients. (Level IV evidence)

Oztas O, Turan B, Bora I, et al: Ultrasound therapy effect in carpal tunnel syndrome. *Arch Phys Med Rehabil* 79(12):1540–1544, 1998.

Investigation to assess overall effects of repeated ultrasound treatment in carpal tunnel syndrome. A patient-blinded, placebo-controlled, pre- and posttreatment trial assessing 18 women (30 hands) with diagnosis of carpal tunnel syndrome. Three groups each with 10 cases were randomly established. Groups included continuous ultrasound, with intensities of 1.5 W/cm^2 (group a), 0.8 W/cm^2 (group b), and 0.0 W/cm^2 (group c). Outcome measures were clinical exam and electrophysiological tests before and after treatment. Statistically significant improvement was obtained in clinical tests in all groups. Pain, pain/paresthesia at night/day, and frequency of awakening at night all improved. There was no difference in electrophysiological studies. (Level II evidence)

Multiple Choice Questions

QUESTION 1. In which phase may forearm muscle stretching be contraindicated when utilizing conservative treatment for nerve entrapments?

A. Phase I
B. Phase II
C. Phase III
D. Phase IV

QUESTION 2. During early phases of rehabilitation, when a decrease in the offending activity is required as part of treatment approach, which of the following forms of immobilization would be beneficial for a forearm nerve entrapment?

A. Splint
B. Brace
C. Sling
D. Any of the above

QUESTION 3. Which of the following rehabilitation concepts would apply to a 22-year-old college pitcher with chronic ulnar nerve compression resulting from attenuation of the medial collateral ligament of the elbow?

A. Cardiovascular conditioning
B. Total arm strengthening
C. Total body strengthening
D. All of the above

QUESTION 4. A 17-year-old female tennis player is being seen for radial tunnel syndrome. She has been slowly improving to the point where she wants to start swinging her racquet again. What criteria should be met before she begins a tennis interval program?

A. 80% return of flexibility
B. Less than 4/10 complaint of pain
C. 5/5 strength of affected muscles
D. Minimal forearm swelling after therapy

QUESTION 5. Joint mobilization techniques to elbow, forearm, or wrist may be appropriate for a patient with a forearm nerve entrapment when the following condition occurs:

A. Stretching becomes too painful
B. No response to passive overpressure
C. Motion limitation is from contractile tissue
D. Motion limitation is from capsular tissue

Answer Key

QUESTION 1. Correct answer: **A** Phase I (see Phase I).

QUESTION 2. Correct answer: **D** Any of the above (see Phases I and II)

QUESTION 3. Correct answer: **D** All of the above (see all Phases of Rehabilitation)

QUESTION 4. Correct answer: **C** Should have return of full strength (see Milestones to Progress to Phase IV)

QUESTION 5. Correct answer: **D** Motion limitation is from capsular tissue (see Phase IV)

Chapter 14



Forearm Tendinitis

INTRODUCTION

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Epidemiology

The epidemiology of forearm tendinitis is dependent upon its type.

Intersection Syndrome

Overuse syndrome of the area in which occurs a crossover of the first and second dorsal compartments of the wrist. First compartment consists of the abductor pollicis longus (APL) and extensor pollicis brevis (EPB) and second compartment consisting of the extensor carpi radialis longus (ECRL) and the extensor carpi radialis brevis (ECRB).

- Prevalence of 11.9% in group of 42 skiers with symptoms developing within first 2 days of activity
- Found equally in men and women
- Most common in rowers, so it is often called "rower's wrist"; caused by repetitive feathering of the oar out of the water

De Quervain's Syndrome

A thickening of the sheath encompassing the tendons of the EPB and the APL

- Prevalence equal among races
- More common in women than men
- Often seen in new mothers resulting from their lifting their babies repetitively

Humeral Epicondylitis

This is an overuse inflammatory condition causing pain and dysfunction at the common extensor or flexor origin. Also, there may be a chronic degeneration, regeneration with microtears of the tendinous tissue, resulting in tendinosis.

- Affects tennis players (5% to 10%) of those diagnosed
- 1% to 2% of general population affected
- Lateral epicondylitis (tennis elbow) more common than medial epicondylitis (golfer's elbow)
- Median age of affected persons is 41 years of age
- Incidence in tennis players higher if they play more than 2 hours per day
- Equal male-to-female ratio
- Older patients more likely to have chronic symptoms

Pathophysiology

Intrinsic Factors

Intersection Syndrome

- Repetitive overuse
- Friction between muscle bellies of first extensor compartment tendon (APL and EPB) and adjacent tendons of the second extensor compartment (Figure 14-1)
- Entrapment stenosis
- Tightness of sheath of ECRL and ECRB tendons
- Adventitial bursa

De Quervain's Syndrome

- Repetitive overuse
- Entrapment of EPB and the APL as they pass deep to extensor retinaculum
- First dorsal compartment entrapment of tendons

Humeral Epicondylitis

- Repetitive overuse
- Lateral epicondylitis (tennis elbow): primary muscles involved are the ECRL and ECRB; secondary muscle involved is the extensor digitorum communis (Figure 14-2)

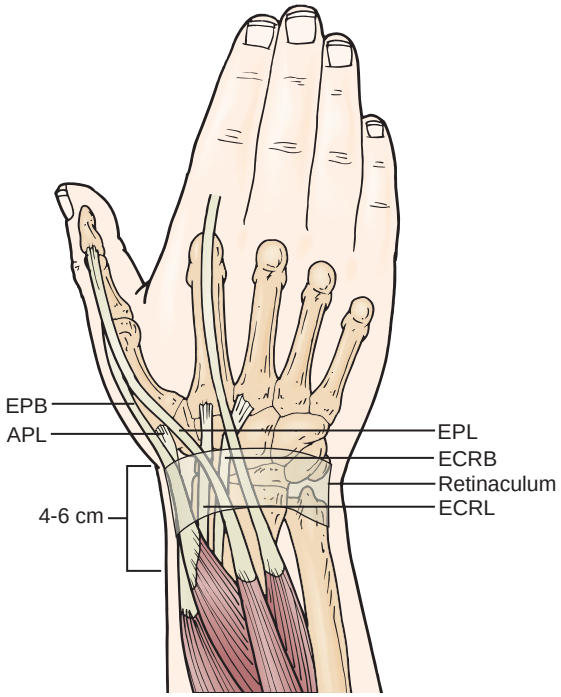

FIGURE 14-1. Intersection syndrome at a point 4 to 6 cm proximal to the wrist joint. *APL,* abductor pollicis longus; *ECRB,* extensor carpi radialis brevis; *ECRL,* extensor carpi radialis longus; *EPB,* extensor pollicis brevis. *(Redrawn from Cox K, Brotzman SB: Hand and wrist injuries: Intersection syndrome of the wrist. In Brotzman SB, Manske RC, eds: Clinical orthopaedic rehabilitation: An evidence-based approach. 3rd ed. Philadelphia: Elsevier; 2011.)*

- Medial epicondylitis (golfer's elbow): primary muscles involved are the forearm flexors, including the flexor carpi radialis longus, flexor carpi ulnaris, and pronator teres (Figure 14-3)

Extrinsic Factors

Intersection Syndrome

- Single bout of acute overuse
- Chronic repetitive overuse

De Quervain's Syndrome

- Single bout of acute overuse
- Chronic repetitive overuse
- Activities that require gripping and ulnar deviation

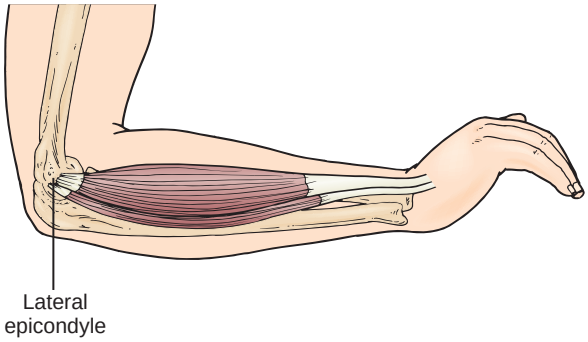

FIGURE 14-2. Lateral epicondylitis.

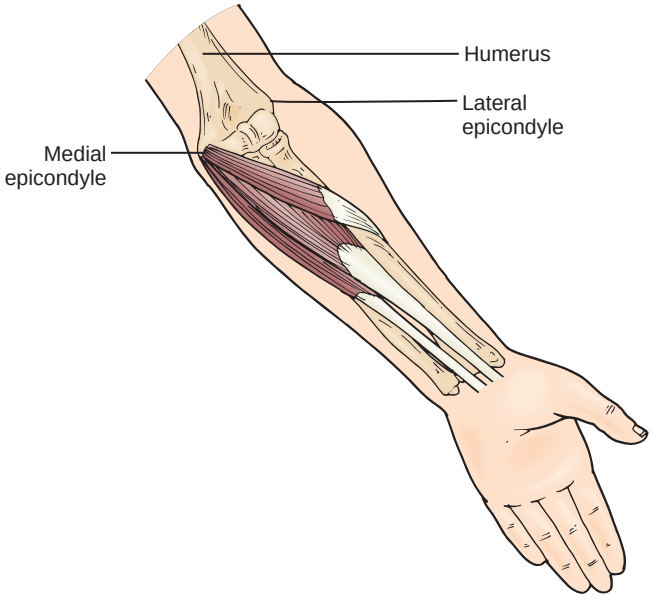

FIGURE 14-3. Medial epicondylitis.

Humeral Epicondylitis

- Repetitive gripping
- Repetitive supination/pronation at forearm
- Novice tennis players because of poor form

Traumatic Factors

Intersection Syndrome

- Acute single incident
- Repeated wrist extension
- Repetitive wrist motions in any plane
- Pressure over distal wrist

De Quervain's Syndrome

- Blow to wrist
- Repetitive ulnar deviation

Humeral Epicondylitis

- Concentric/eccentric overload
- Insidious onset
- Repetitive wrist extension

Classic Pathological Findings

Intersection Syndrome

- Pain and swelling in region 4 to 8 cm proximal to Lister's tubercle, dorsal aspect of forearm
- Pain with thumb extension and abduction
- Pain with wrist extension
- Crepitus with wrist movements
- Location where first and second extensor compartment tendons cross
- Palpation may produce crepitus
- Palpation painful
- Erythema
- Edema
- Squeaking sound with wrist motion

- Known as "squeakers"; common in rowers and those involved in grip activities

De Quervain's Syndrome

- Tenderness at APL, EPB (first dorsal compartment)
- Pain on radial side of wrist
- Pain may radiate up into forearm
- Pain with resisted thumb movements
- Squeaky feeling (snowball crepitus caused by tenosynovitis) with thumb movements
- Motion may produce crepitus
- Palpation may produce crepitus
- Palpation painful
- Erythema
- Edema or swelling on radial side of wrist

Humeral Epicondylitis

- Tenderness at medial or lateral epicondyle
- Pain with repetitive wrist motions including extension and radial deviation
- Pain with resisted wrist extension or supination
- Pain aggravated with strong gripping
- Pain with passive stretch during wrist motions
- Pain may radiate down into forearm
- Grip strength reduced

Clinical Presentation

History and Physical Examination

Intersection Syndrome

- Acute single episode such as a weekend of skiing, bowling, rowing
- Repetitive unaccustomed overuse such as machinist
- Secretaries
- Carpenters
- Maintenance workers
- Filing workers
- Rice-harvesting workers
- Weightlifters
- Rowing or canoeing
- Raking
- Shoveling
- Pain and swelling in region 4 to 8 cm proximal to Lister's tubercle
- Pain with thumb extension and abduction
- Pain with wrist extension
- Squeaky sound with wrist movements
- Location where first and second extensor compartment tendons cross
- Motion may produce crepitus
- Palpation may produce crepitus
- Palpation painful
- Erythema
- Edema

De Quervain's Syndrome

- Acute single episode
- Repetitive unaccustomed overuse
- Repetitive wrist radial deviation
- Repetitive thumb palmar or radial abduction
- Pain with resisted thumb movements
- Squeaky feeling with thumb movements
- Motion may produce crepitus
- Palpation may produce crepitus
- Palpation painful
- Erythema
- Edema or swelling on radial side of wrist

Humeral Epicondylitis

- Athletic individuals
- Baseball players
- Tennis players
- Swimmers
- Laborers who have to frequently grip tools
- Plays sports or recreation greater than 2 hours per day
- Pain with active motions of elbow and forearm

Abnormal Findings

Intersection Syndrome

- Squeak with radial-ulnar deviation of the wrist with crepitus
- Localized swelling at the intersection of the first/second dorsal compartments
- Tenderness at intersection of the first/second dorsal compartments

De Quervain's Syndrome

- Tenderness at the first dorsal compartment
- Localized swelling to the first dorsal compartment
- Positive Finkelstein's test

Humeral Epicondylitis

- Tenderness at musculotendinous junction just distal to the medial and lateral epicondyles
- Pain with wrist flexion (medial epicondylitis) and wrist extension or power grip (lateral epicondylitis)
- Cyrix's muscle tendon unit testing

Pertinent Normal Findings

Intersection Syndrome

- Negative Tinel's sign at posterior interosseous nerve, median nerve, and ulnar nerve

De Quervain's Syndrome

- Negative Tinel's sign at posterior interosseous nerve, median nerve, and ulnar nerve

Humeral Epicondylitis

- Negative Tinel's sign at posterior interosseous nerve, median nerve, and ulnar nerve

Imaging

- Routine radiographic series
- Ultrasonography
- Magnetic resonance imaging

Differential Diagnosis

Intersection Syndrome

- De Quervain's tenosynovitis
- Wrist ligament sprain

- Forearm muscle strain
- Arthritis of first carpometacarpal (CMC) joint
- Fracture of radial styloid
- Fracture of scaphoid
- Ganglion cyst
- Infection
- Soft tissue neoplasm
- Entrapment of the superficial radial sensory nerve
- Cellulitis
- Forearm contusion

De Quervain's Syndrome

- Intersection syndrome
- Scaphoid fracture
- Thumb CMC arthritis
- Thumb metacarpophalangeal arthritis
- Superficial radial sensory nerve irritation
- Posterior interosseous nerve entrapment
- C6 radiculopathy
- Forearm contusion

Humeral Epicondylitis

- Posterior interosseous syndrome
- Radial tunnel syndrome
- Pronator syndrome
- Synovitis
- Chondromalacia of radiocapitellar joint
- Lateral collateral ligament sprain
- Ulnar collateral ligament sprain or tear
- Cervical spine pathology
- C6–C7 nerve root compression causing radiculopathy
- Ulnar nerve entrapment
- Elbow bursitis
- Elbow fracture
- Elbow arthritis

Treatment

Nonoperative Management

Intersection Syndrome

- Activity/recreation modification
- Work modification
- Splinting
- Physical therapy
- Forearm stretching
- Electrical stimulation
- Ultrasound
- Iontophoresis
- Phonophoresis
- Oral NSAID
- Topical ice massage
- Steroid injection

De Quervain's Syndrome

- Activity/recreation modification
- Work modification
- Splinting
- Physical therapy
- Forearm stretching
- Electrical stimulation
- Ultrasound
- Iontophoresis
- Phonophoresis
- Oral nonsteroidal antiinflammatory drug (NSAID)
- Topical ice massage
- Steroid injection

Humeral Epicondylitis

During the initial 4 weeks, when pathology is a peritendinitis:

- Activity/recreation modification
- Work modification
- Splinting
- Physical therapy
- Forearm stretching
- Electrical stimulation
- Ultrasound
- Iontophoresis
- Phonophoresis
- Oral NSAID
- Topical ice massage
- Steroid injection in tendon sheath

After 4 weeks, when pathology is a tendinosis:

- Eccentric exercises beneficial once inflammation resolves
- Forearm stretching
- Physical therapy
- Cross-friction massage
- Augmented soft tissue mobilization/Graston technique/gua sha
- Extracorporeal shockwave therapy
- Percutaneous tenotomy
- Autologous blood injection
- Prolotherapy injection
- Platelet-rich plasma injection
- Sclerosing injection (polidocanol)

Guidelines for Choosing Among Nonoperative Treatments

- Intersection syndrome and De Quervain's tenosynovitis are best treated to reduce the inflammation present causing the crepitus.
- The treatment of choice is steroid injection and avoiding the movement pattern that led to the inflammation.
- All of the other treatments listed in the preceding are also reasonable options.

Surgical Indications

There are no absolute surgical indications. It is always the patient's decision. Relative surgical indications are listed in the following.

Intersection Syndrome

- Failure of conservative measures after 6 months
- Inability to work secondary to the loss of function or pain
- Worsening symptoms despite appropriate conservative care

De Quervain's Syndrome

- Failure of conservative measures after 6 months
- Inability to work secondary to the loss of function or pain

- Worsening symptoms despite appropriate conservative care

Humeral Epicondylitis

- Failure of conservative measures after 6 months
- Inability to work secondary to the loss of function or pain
- Worsening symptoms despite appropriate conservative care

Aspects of History, Demographics, or Exam Findings That Affect Choice of Treatment

- Treatment options are based on the best options for pain management, correction of the underlying etiology of the problem, and rehabilitation to help prevent future reoccurrences from the preceding list.
- Avoid NSAIDs/steroids if there is a history of abdominal pain, ulcers, gastritis, or gastrointestinal bleeding.
- Timing of humeral epicondylitis determines most likely pathology and treatment method.

Aspects of Clinical Decision Making When Surgery Is Indicated

- Failure of conservative measures after 6 months
- Inability to work secondary to the loss of function or pain
- Worsening symptoms despite appropriate conservative care

Evidence

Knobloch K, Spies M, Busch KH, et al: Sclerosing therapy and eccentric training in flexor carpi radialis tendinopathy in a tennis player. *Br J Sports Med* 41(12):920–921, 2007.

Case study of 35-year-old tennis player from pain rating of 9/10 visual analog scale (VAS) at the flexor carpi ulnaris tendon with adjacent calcification in close proximity to the pisiform bone. Doppler assessment revealed neovascularization at the origin of pain. Sclerosing therapy using polidocanol under laser Doppler guidance was initiated, with immediate decreased capillary blood flow by 25% within resolution of neovascularizations. Immediately afterward, sclerosing pain on VAS dropped from 9/10 to 4/10. Following a short period of rest, eccentric training of forearm muscles was initiated. After 12 weeks a functional complete recovery and complete resolution of pain had occurred. (Level IV evidence)

Peters-Veluthamaningal C, Winters JC, Groenier KH, et al: Randomised controlled trial of local corticosteroid injections for de Quervain's tenosynovitis in general practice. *BMC Musculoskeletal Disord* 10:131, 2009.

This study evaluated the effectiveness of local corticosteroid injections for de Quervain's tenosynovitis by general practitioners. Eleven general practitioners enrolled 21 wrists in 21 patients. Short-term outcomes were assessed (1 week postinjection) in a randomized, placebo-controlled trial. Long-term effectiveness was evaluated in an open prospective cohort study of responders during a 12-month follow-up. Treatment was randomized into one to two local injections of either triamcinolonacetonide (treatment) or 1 NaCl 0.9% (placebo). The triamcinolonacetonide group had better results for short-term outcomes, including treatment response, perceived improvement, and severity of pain but not for the Dutch-AIMS-HFF. Long-term responses were sustained for severity of pain and scores of Dutch AIMS-2-HFF but not for perceived improvement. Authors report short-term benefits of corticosteroid injections for patients with de Quervain's tenosynovitis are better than with placebo. (Level I evidence)

Sasinopoulos D, Stasinopoulos I, Pantelis M, et al: Comparison of effects of a home exercise programme and a supervised exercise programme for the management of lateral elbow tendinopathy. *Br J Sports Med* 44(8):579–583, 2010.

This study compared the effectiveness of a home and supervised exercise program for lateral elbow tendinopathy. Seventy patients with chronic lateral elbow tendinopathy were placed into either home exercise or supervised exercise program five times per week for 4 weeks. Outcome measures were pain and function. At the end of treatment (12 weeks), there was a decline in pain and increase in function of both groups compared with baseline. The supervised treatment group had significant increases in function and decreases in pain at the 3-month follow up. (Level II evidence)

Walton MJ, Mackie F, Fallon M, et al: The reliability and validity of magnetic resonance imaging in the assessment of chronic lateral epicondylitis. *J Hand Surg Am* 36(3):475–479, 2011.

This study of 21 consecutive subjects with diagnosis of lateral epicondylitis assessed the observer reliability of magnetic resonance imaging (MRI) to detect this condition. Moderate to severe signal changes were consistent with tendinosis in 189 of 21 patients. Significant interobserver reliability and intraobserver agreement were demonstrated for MRI interpretation of grade of tendinosis and length of tendon separation. (Level I evidence)

Multiple Choice Questions

QUESTION 1. In which compartment(s) does intersection syndrome occur?

A. First and second
B. Second and third
C. Third and fourth
D. Only first

QUESTION 2. A 32-year-old factory worker has been diagnosed with intersection syndrome. What is a classic symptom that would indicate or point to intersection syndrome being his pathology?

A. Acute injury from golfing
B. Numbness and tingling in radial nerve distribution
C. History of repetitive radial and ulnar deviation
D. Increased symptoms with elbow extension overpressure

QUESTION 3. You suspect your new hand/wrist pain patient has de Quervain's syndrome. Which of the following symptoms would be seen in a patient with de Quervain's syndrome?

A. Tenderness at APL, EPB
B. Pain on radial side of wrist
C. Pain may radiate up into forearm
D. Pain with resisted thumb movements
E. All of the above

QUESTION 4. What is the first and foremost primary immediate goal in treatment of any of the upper extremity tendonitis or bursitis?

A. Total arm strengthening
B. Regaining lost forearm power
C. Elimination of aggravating activities
D. Getting sports assessment

Answer Key

QUESTION 1. Correct answer: **A** (see Pathology)

QUESTION 2. Correct answer: **C** (see Clinical Presentation)

QUESTION 3. Correct answer: **E** (see Classic Pathological Findings)

QUESTION 4. Correct answer: **C** (see Treatment)

NONOPERATIVE REHABILITATION FOR FOREARM TENDINITIS

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Mark Stovak, MD, FAAFP, FACSM, CAQSM

GUIDING PRINCIPLES OF NONOPERATIVE REHABILITATION

- Pain—Every attempt should be made to decrease pain and symptoms of forearm overuse.
- Strength—Maintain and increase strength and minimize loss due to forearm overuse.
- Function—Restore function through gaining or maintaining motion and strength.

Phase I (weeks 0 to 2)

Protection

- Counterforce bracing or splinting may be helpful to rest extremity and provide support to allow decreased inflammation and swelling.
- Do not want to rely on this because it can lead to atrophy and contractures.
- Activity modification very important to allow relative rest from offending activity.

Management of Pain and Swelling

- RICE: rest, ice, compression, elevation
- Modalities such as pulsed ultrasound, electrical stimulation, and ionto/phonophoresis may be helpful.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Gentle active assistive range of motion as tolerated.

TIMELINE 14-1: **Nonoperative Rehabilitation of Forearm Tendinitis**

PHASE I (weeks 0 to 2)	PHASE II (weeks 2 to 4)
• Sling, splint, brace • RICE: rest, ice, compression, elevation • Physical therapy modalities • Gentle active assisted range of motion (AAROM) forearm, hand, and wrist • Distal to proximal massage • Very gentle stretching • Cardiovascular exercises • Total body strengthening (TBS) • Upper extremity total arm strengthening (TAS) • Total leg strength (TLS) • Rotator cuff exercises—progressive resistive exercise (PREs) • Scapular exercises—PREs	• Sling, splint, brace as needed but gradually removed • PT modalities as needed • Progress from AAROM to AROM • TBS/TAS/TLS activities as recommended and tolerated • Rotator cuff exercises—PREs • Scapular exercises—PREs • Concentric submaximal isometric exercises • Progression to submaximal isotonic progressive resistive exercises • Putty exercises • Gripping exercises • Rice bucket exercises • Gently load hand and wrist in closed kinetic chain positions • Gentle pushing, pulling motions • Light weight wrist flexion/extension, pronation/supination

Soft Tissue Techniques

- Gentle distal to proximal massage to create retro drainage from swollen tissues

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Very gentle stretching to affected area. Try to achieve or maintain full active range of motion (AROM)/passive range of motion (PROM).

Other Therapeutic Exercises

- Cardiovascular exercise (bike)
- Upper extremity total arm strength
- Total body strength

Activation of Primary Muscles Involved

- Gentle active or active assistive range of motion exercises as tolerated
- Total arm strength to proximal muscles of arm and shoulder and elbow as tolerated

Milestones for Progression to the Next Phase

- Minimal to no swelling
- Pain free range of motion
- Improvement of strength

Phase II (weeks 2 to 4)

Protection

- Protection of bracing and splinting gradually removed

Management of Pain and Swelling

- RICE and ultrasound, electrical stimulation

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Progression from active assistive to active range of motion

Soft Tissue Techniques

- Depend on degree of swelling. May continue as per Phase I if swelling and edema persists. If tolerable, may begin more deep tissue massage to decrease sore muscles or muscle spasm associated with tendinitis conditions.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Gentle stretching of forearm and wrist musculature if tolerated without an increase in symptoms

Other Therapeutic Exercises

- Continue as Phase I
- May begin elliptical or treadmill as tolerated.
- Begin trunk/core strengthening with emphasis on requirements for activities of sports or vocation
- Continued cardiovascular conditioning
- Continued total arm strength as tolerated through use of shoulder and elbow exercise including rotator cuff and scapular control exercises.

Activation of Primary Muscles Involved

- Concentric submaximal isometric followed by submaximal isotonic progressive resistive exercises with light weight or bands. Start exercises such as wrist extensor muscles by initiating strengthening with isometrics, which if tolerated can be followed by isotonic movements through a safe range of motion for wrist extension.
- Exercises done in cardinal planes. For example, starting isotonic exercises in frontal plane only versus using total arm movements that might incorporate multiple planes of movement of the forearm.

TIMELINE14-1: **Nonoperative Rehabilitation of Forearm Tendinitis** (Continued)

PHASE III (weeks 4 to 6)	PHASE IV (weeks 6 to 12)
• D/C sling, splint or brace • PT modalities as needed • AROM, AAROM, PROM—full • Mobilizations as needed • Trunk and core exercises as tolerated • TBS/TAS activities as recommended and tolerated • Rotator cuff exercises—PREs • Scapular exercises—PREs • "Plyometric-like" exercises • Light weight, bilateral progressing to unilateral • Functional exercises (90/90 shoulder) for throwers • Putty exercises • Gripping exercises • Rice bucket exercises • Pushing and pulling-type exercises • Wrist flexion/extension, and pronation and supination PREs	• AROM, AAROM, PROM full • TBS/TAS/TLS activities as recommended and tolerated • Mobilizations as needed • Trunk and core exercise as tolerated • Rotator cuff exercises—PREs • Scapular exercises—PREs • Plyometric exercises • Functional exercises • PNF exercises • Progress CKC exercises • Sports progression as tolerated

- Putty exercises
- Gripping (ball squeeze)
- Rice bucket exercises

Open and Closed Kinetic Chain Exercises

- Place hand wrist on table top and slowly and gently load in various weight-bearing directions.

Techniques to Increase Muscle Strength, Power, and Endurance

- Continue to progress total arm strength by working proximal musculature. Ensure proper proximal muscle control by working elbow flexors, extensors, glenohumeral, and scapular shoulder muscles.
- Mild symptoms may occur and be alright as long as they do not persist or worsen.

Neuromuscular Dynamic Stability Exercises

- Increase exercise intensity, working on enhancing control during tendon loading.
- Gradually control intensity and duration of exercises.

Functional Exercises

- Grasping, pushing, and pulling motions
- Holding sports/vocational equipment for short durations in effort to build endurance

Milestones for Progression to the Next Phase

- No swelling
- No pain
- Full range of motion
- No loss of sensation
- 4/5 manual muscle test of affected muscles
- Prepare elbow for advanced activity

Phase III (weeks 4 to 6)

Management of Pain and Swelling

- As described previously if pain/swelling continues

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- As described previously if needed
- If limitations of motion are capsular (joint restrictions) in nature, can begin joint mobilization techniques to restore normal joint arthrokinematics

Soft Tissue Techniques

- As described previously if needed
- Continue deep tissue massage as needed for muscle spasm.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- As described previously if needed
- Should be able to tolerate gentle stretching now without re-exacerbation.

Other Therapeutic Exercises

- Continue trunk/core strengthening with emphasis on requirements for activities of sports or vocation
- Continued cardiovascular conditioning
- Continued total arm strength as tolerated

Activation of Primary Muscles Involved

- Submaximal isotonic progressive resistive exercises with light weight or bands. Concentric or eccentric wrist extension exercises with 3-lb weights or red resistance band, three sets of 20 repetitions.
- Begin eccentric strengthening to promote higher load tolerance to tendon. Progressing to eccentric only exercises with 4-lb weights or green resistance band three sets of 20 repetitions.

Open and Closed Kinetic Chain Exercises

- Progressively load upper extremity in more provocative patterns.
- Start leaning on wall, to bilateral upper extremity in quadruped, to unilateral extremity in tripod.

Techniques to Increase Muscle Strength, Power, and Endurance

- Increase strength and endurance as tolerated by modulating dosage of exercises as appropriate for activities of daily living and sports. Depending on specific needs, patient may require more of a strengthening training load, including increased resistance and higher repetitions, but others may need more endurance by manipulating to lower resistance but higher repetitions.

Plyometrics

- Gentle plyometric "type" exercises with light weights, bilaterally progressing to unilaterally
- Bilateral chest pass into PlyoBack device, throwing and catching chest height with two hands, light weight. When this becomes easier, athlete can progress to unilateral pass to PlyoBack device.

Functional Exercises

- Incorporation of more functional movement–specific tasks (D2 flexion/extension patterns for shoulder while gripping band for forearm exercise; swinging hammer without full-weight hammer head)

Sport-Specific Exercises

- Incorporation of more functional movement–specific tasks (D2 flexion/extension patterns for shoulder while

gripping band for forearm exercise); swinging sport-specific instruments
- Light swinging of tennis racquet
- Assess racquet weight, size, fit, length, structure
- Gentle throwing/hitting motions
- Motions starting may be initially done without ball (baseball, softball) or racquet (tennis), progressing to motions with equipment.
- Gentle golfing motions can be started with swinging 50% effort progressing to 75% over several visits or weeks.
- Use of elastic tubing around tennis racquet while moving into positions of cocking for forehand and backhand tennis strokes.

Milestones for Progression to the Next Phase

- No swelling
- No pain
- Full range of motion
- No loss of sensation
- 5/5 strength of affected muscles
- Prepare for full return of activities

Phase IV (weeks 6 to 12)

Management of Pain and Swelling

- As described previously if pain/swelling continues

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- As described previously if needed
- If limitation of motion are capsular (joint restrictions) in nature, can begin joint mobilization

Soft Tissue Techniques

- As described previously if needed

Stretching and Flexibility Techniques for the Musculotendinous Unit

- As described previously if needed
- Should be able to tolerate more progressive stretching now without re-exacerbation

Other Therapeutic Exercises

- Continue trunk/core strengthening with emphasis on requirements for activities of sports or vocation
- Continued cardiovascular conditioning
- Continued total arm strength as tolerated using larger movements and proximal musculature such as during upper body ergometer or pushup progression

Activation of Primary Muscles Involved

- Maximal isotonic progressive resistive exercises with light weight or bands. This is done through the use of heavier resistance with use of weights or bands for decreased number of repetitions in order to gain physical strength.
- Continuance of program to maintain or increase strength and or endurance as needed for full, unrestricted return to activity. The program should be continued until the patient has full, unrestricted strength and the ability to return to previous activity.

Open and Closed Kinetic Chain Exercises

- Progression as described previously
- Increased resistance from heavier dumbbells, thicker resistance bands, or more provocative position such as overhead movements or movements away from body. Can also add loaded exercises such as pushups with feet elevated 12 inches or pushups with clap between.

Techniques to Increase Muscle Strength, Power, and Endurance

- Increase strength and endurance as tolerated by modulating dosage of exercises as appropriate for activities of daily living and sports.
- Increase speed and or resistance with exercises where appropriate to allow increased power during activities. Use of light tubing while swinging bat or racquet in simulated game type situations.

Neuromuscular Dynamic Stability Exercises

Progressive increase in dynamic stability drills for entire upper extremity.

Plyometrics

- If tolerated "gentle plyometric-type" exercises in previous stage can progress to heavier weights and to unilateral exercises
- Increase weight of Plyoball to add resistance and overload. Additionally Plyoball can be done in more provocative positions such as overhead motions.

Functional Exercises

- Incorporation of more functional movement–specific tasks (e.g., use of actual hammer or saw)
- All done in slow progression from 50% to 75% to 100% effort
- One set of 25 repetitions progressing to up to three sets of 25 repetitions at each intensity level

Sport-Specific Exercises

- Incorporation of more functional movement-specific tasks (e.g., use of throwing baseball, football, swinging racquet or bat)
- All done in slow progression from 50% to 75% to 100% effort
- One set of 25 repetitions progressing to up to three sets of 25 repetitions at each intensity level

Milestones for Progression to Advanced Sport-Specific Training and Conditioning

- No swelling
- No pain
- Full range of motion
- No loss of sensation
- 5/5 Strength of affected muscles

Criteria for Abandoning Nonoperative Treatment and Proceeding to Surgery or More Intensive Intervention

- Continued pain
- Continued swelling
- Continued numbness and tingling
- No return of strength
- Progression of symptoms

Tips and Guidelines for Transitioning to Performance Enhancement

- Ensure that symptoms do not return.
- Gradual slow progression is always more reliable than a rushed approach to return to function without creating setbacks.

Performance Enhancement and Beyond Rehabilitation: Training/Trainer and Optimization of Athletic Performance

- Gradual progression to full return of functional activities involving total body movement patterns with no return of symptoms
- Hitting or serving progressions. Use of weight equipment or bands or cables to challenge muscular control of trunk and full body

Specific Criteria for Return to Sports Participation: Tests and Measurements

- No swelling
- No pain
- Full range of motion
- No loss of sensation
- 5/5 strength of affected muscles

Evidence

Batteson R, Hammond A, Burke F, et al: The de Quervain's screening tool: Validity and reliability of a measure to support clinical diagnosis and management. *Musculoskeletal Care* 6(3):168–180, 2008.

This study was performed in an outpatient hand unit of a district hospital. The study was done to provide evidence for content and construct validity and test-retest reliability and interrater reliability of a de Quervain's syndrome screening tool (DQST). Sample of convenience of 59 patients with de Quervain's were recruited. Additionally, 16 with osteoarthritis of the carpometacarpal joint and 18 with carpal tunnel syndrome were recruited. Diagnostic criteria were initially generated from literature review and content validity was established by seven expert doctors with interest in upper limb. The DQST was tested on those with de Quervain's syndrome. Construct validity was tested with all patients. The median score was five out of a possible seven diagnostic criteria. Interrater reliability was excellent. Test-retest reliability was good. Sensitivity and specificity demonstrated that the DQST discriminated between pathologies. (Level IV evidence)

Blanchette MA, Normand MC: Augmented soft tissue mobilization vs natural history in the treatment of lateral epicondylitis: A pilot study. *J Manipulative Physiol Ther* 34(2):123–130, 2011.

Randomized clinical trial of 27 subjects with lateral epicondylitis. Subjects were randomly placed into one of two groups. The experimental group (n = 15) received augmented soft tissue mobilization (ASTYM) twice a week for 5 weeks. Control group received advice on the natural evolution of pathology, ergonomics and stretching exercises. Outcomes were assessed at baseline and after 6 weeks and 3 months using visual analog scale (VAS). Function was tested with pain-free grip strength at baseline and after 6 weeks. Both groups improved in pain-free grip strength, VAS, and patient-reported outcomes. (Level II evidence)

Kaneko S, Takasaki H: Forearm pain, diagnosed as intersection syndrome managed by taping: A case series. *J Orthop Sports Phys Ther* 41(7):514–519, 2011.

Case series of five patients who were treated for intersection syndrome by the use of taping. Therapist used nonstretch sports tape with ulnarly directed tension across dorsal aspect of forearm. Crepitus was completely eliminated. Disability identified by disability/symptom subscale of DASH decreased at 3-week follow-up, and reduction was maintained at 4-week and 1-year follow-ups. (Level IV evidence)

Tagliafico AS, Ameri P, Michaud J, et al: Wrist injuries in nonprofessional tennis players: Relationships with different grips. *Am J Sports Med* 37(4):760–767, 2009.

A cross-sectional study that evaluated 370 nonprofessional division III and IV tennis players to determine if the use of different grips determined a pattern of wrist injuries. Screening of players consisted of a questionnaire to investigate wrist injuries. Medical records of players who reported a wrist injury were reviewed. Fifty participants incurred injuries. Ulnar-sided wrist injuries were more common. These were associated with Western or semi-Western grips, whereas the radial side injuries were associated with the Eastern grip. No differences were observed regarding body mass index, years of practice, weekly hours of training, racket weight, and strings. (Level III evidence)

Tyler T, Thomas GC, Nicholas SJ, et al: Addition of isolated wrist extensor eccentric exercise to standard treatment of chronic lateral epicondylosis: A prospective randomized trial. *J Shoulder Elbow Surg* 19:917–922, 2010.

Twenty-one patients with chronic unilateral epicondylosis were randomly placed into either an eccentric training

group (n = 11) or a standard treatment group (n = 10). Outcomes were the Disability of Arm Shoulder and Hand Questionnaire, visual analog scale, tenderness, and wrist and middle finger extension. Measurements were taken at baseline and end of treatment. Improvements in all variables were greater for the eccentric training group. (Level II evidence)

Multiple Choice Questions

QUESTION 1. In which phase may forearm muscle submaximal isotonic strengthening begin following a conservative approach to lateral epicondylitis?

A. Phase I
B. Phase II
C. Phase III
D. Phase IV

QUESTION 2. During late phases of rehabilitation for tendinitis, what percentage of full effort should the patient use while swinging a tennis racquet during a gradual progression or return to activity phase of rehabilitation?

A. 25
B. 50
C. 75
D. 100

QUESTION 3. Which of the following rehabilitation concepts would apply to a 22-year-old college pitcher with chronic ulnar nerve compression caused by attenuation of the medial collateral ligament of the elbow?

A. Cardiovascular conditioning
B. Total arm strengthening
C. Total body strengthening
D. All of the above

QUESTION 4. A 15-year-old male golfer is being seen for medial epicondylitis. He has been slowly improving to the point where he wants to start swinging his golf club again. What criteria should be met before he begins a return to golfing program?

A. 80% return of flexibility
B. Less than 4/10 complaint of pain
C. 5/5 strength of affected muscles
D. Minimal forearm swelling after therapy

QUESTION 5. When treating a patient with a limitation of passive motion of elbow extension, when would it be appropriate to use a contract and relax technique versus a joint mobilization technique to the elbow?

A. Motion limitation is from contractile tissue.
B. Stretching is extremely painful.
C. No response to passive overpressure
D. Motion limitation is inert tissue.

Answer Key

QUESTION 1. Correct answer: **B** (see Phase II)

QUESTION 2. Correct answer: **A** Almost all progressions start with a slow and easy progression at minimal levels to ensure success at lower levels before progression to higher levels. (see Phase IV)

QUESTION 3. Correct answer: **D** (see all phases of rehabilitation)

QUESTION 4. Correct answer: **C** He should have return of full strength. (see Phase IV)

QUESTION 5. Correct answer: **A** Motion limitation is contractile tissue. Using a joint mobilization technique would be better for someone with a capsular limitation (inert tissue) to motion.

Chapter 15



Triangular Fibrocartilage Complex Injuries

INTRODUCTION

Sidney M. Jacoby, MD, Paul A. Sibley, DO, and Leo T. Kroonen, MD

Epidemiology

Age

- Acute tears are most common in the active individual during the second and third decades of life.
- Degenerative tears begin in the third decade of life, with increasing frequency and severity with each passing decade.
- No completely normal triangular fibrocartilage complex (TFCC) after seventh decade, based on a cadaveric study

Sex

- Predominantly males but is most often sport specific, with a preponderance in athletic individuals

Sport/Position

- Most common in athletes who grip bats, clubs, sticks, etc. In particular, baseball players, golfers, racquet sports, hockey, gymnastics, boxing, pole-vaulting
- No position-specific factors; however, tears commonly occur in dominant wrist

Pathophysiology

Intrinsic Factors

- TFCC composed of a confluence of soft-tissue elements that surround and stabilize the distal radioulnar joint (DRUJ)
- Wedge-shaped disc of fibrocartilage with thick cartilaginous attachments to sigmoid notch of radius
- Very little stability provided by bony elements
- Anatomy (Figures 15-1 and 15-2)
  - Dorsal and volar radioulnar ligament (main stabilizers of DRUJ)
    - Superficial attachment to mid-point of styloid
    - Deep attachment to the fovea
  - Central articular disc
    - Extends from sigmoid notch of radius to its insertion at the base of the ulnar styloid

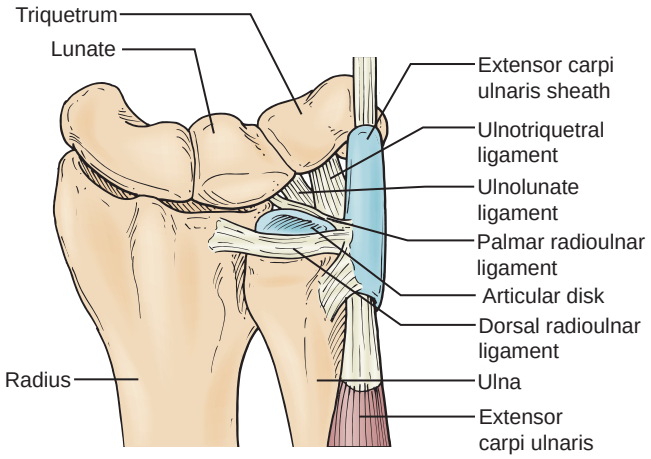

FIGURE 15-1. Schematic components of the triangular fibrocartilage complex. R, radius; U, ulna; ECU, extensor carpi ulnaris; DRUL, dorsal radioulnar ligament; PRUL, palmar radioulnar ligament; L, lunate; T, triquetrum; UL, ulnolunate ligament; UT, ulnotriquetral ligament.



FIGURE 15-2. Meniscus homologue is an irregularly shaped soft tissue structure that variably fills the space between the ulnar capsule, disk, and proximal aspect of the triquetrum. L, lunate; R, radius; Tq, triquetrum; U, ulna; 1, articular disk of triangular fibrocartilage; 2, meniscus homologue. *(From Adams BD: Distal radioulnar joint instability. In Wolfe SW, Pederson WC, Hotchkiss RN, Kozin SH, editors: Green's operative hand surgery, 6th ed, Philadelphia, 2010, Elsevier, Figure 16-7.)*

- Meniscus homologue
  - Function is ill-defined
  - Vascularized tissue between the ulnar capsule, TFCC, and triquetrum
- Ulnar collateral ligament
- Extensor carpi ulnaris (ECU) subsheath
  - TFCC acts as a pulley for the ECU tendon
- Ulnocarpal ligament complex
  - Lunocapitate (LC), ulnolunate (UL) and ulnotriquetral (UT) ligaments
- Blood supply (Figure 15-3)
  - Peripheral 10% to 40% is well vascularized (ulnar more than radial aspect)
    - Dorsal and palmar branches of anterior interosseous artery
    - Dorsal and palmar radiocarpal branches of ulnar artery
  - Central portion is avascular
- Ulnar positivity (positive ulnar variance)
  - Normal axial loading has 20% of load through ulna, with 80% through radius
  - +2.5 mm ulnar positivity can increase load through the ulna to 40%
  - Positivity increases with pronation and grip

Extrinsic Factors

- Power drills, whereby the drill rotates the wrist instead of the drill-bit
- Rotational torque such as those that occur with athletics or a fall on outstretched wrist
- Sports activities that involve high level of grip activities

Traumatic Factors

- Palmer Type I (traumatic)
  - Mechanism
  - Sudden, rotational traumatic event
  - Racquet sports with sudden, abrupt supination
  - Most common is fall on extended wrist with forearm pronation
  - Traction injury to ulnar side of wrist
  - Distal radius fractures
- Palmer Type II (degenerative)
  - Associated with positive ulnar variance

Classic Pathological Findings

- Palmer Classification (Figure 15-4), Type I (traumatic)
  - IA: isolated central perforation or tear, no instability
    - Pain, mechanical clicking
  - IB: peripheral tear at base of ulnar styloid (with or without ulnar styloid fracture), mild DRUJ instability, may have ECU instability
    - Painful forearm rotation

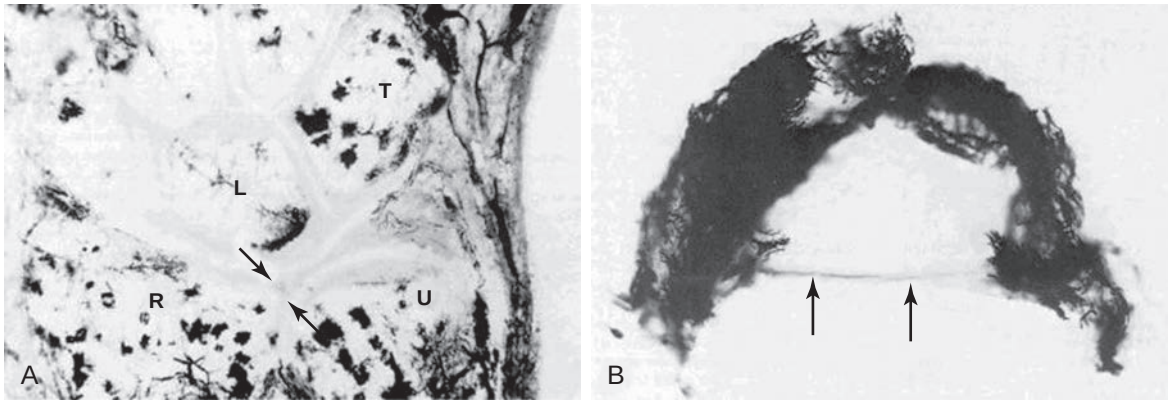

FIGURE 15-3. TFCC is well vascularized in its periphery, whereas only the outer 15% of the disk has vascular penetration. *Arrows* in **A** and **B** identify avascular regions of TFCC at its attachment to radius. **A,** Coronal section through wrist. **B,** Axial view of TFCC. L, lunate; R, radius; T, triquetrum; U, ulna. *(From Adams BD: Distal radioulnar joint instability. In Wolfe SW, Pederson WC, Hotchkiss RN, Kozin SH, editors: Green's operative hand surgery, 6th ed, Philadelphia, 2010, Elsevier, Figure 16-8.)*

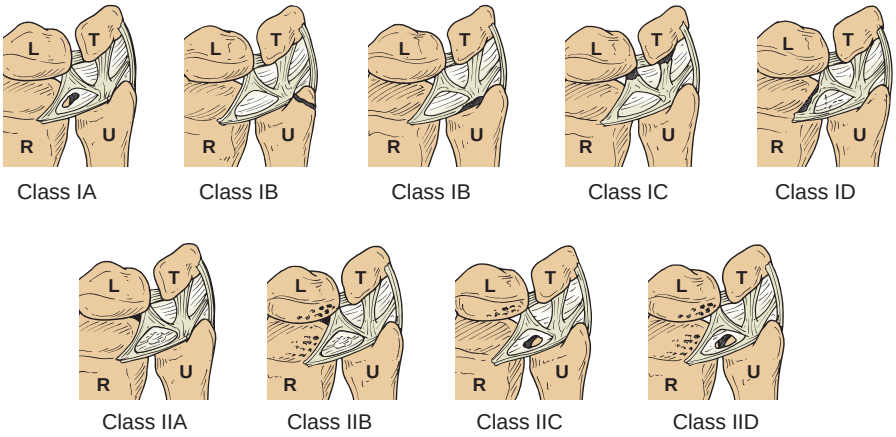

FIGURE 15-4. Palmer's classification separates TFCC lesions into two broad categories: traumatic (class IA-D) and degenerative (class IIA-E). See text for descriptions. *(Redrawn from Palmer AK: Triangular fibrocartilage complex lesions: a classification, J Hand Surg [Am] 14:594–606, 1989.)*

- IC: distal avulsion of origin of ulnar extrinsic ligaments (UL and LT ligaments)
  - Least common
  - Painful rotation
  - May be associated with IB tear
- ID: radial detachment of the TFCC from the sigmoid notch of the distal radius
  - May be associated with distal radius fracture
  - May include both radioulnar ligaments
  - Often in the avascular zone
- Palmer Type II (degenerative [developmental or acquired] with ulnar impaction)
  - IIA: TFCC wear and thinning without perforation, tear, or chondromalacia
  - IIB: TFCC wear with lunate and/or ulnar head chondromalacia
  - IIC: TFCC perforation with lunate chondromalacia
  - IID: TFCC perforation with ulna and/or lunate chondromalacia and LT ligament injury but without carpal instability
    - No volar intercalated segment instability (VISI)
  - IIE: TFCC perforation with arthritic changes involving ulnocarpal and DRUJ (Figure 15-5)
    - LT ligament injury

Clinical Presentation

History

- Traumatic
  - Fall on outstretched, pronated hand
  - Acute or chronic rotational wrist injury
  - Forced ulnar deviation
  - Radial deviation traction injury
  - Ulnar-sided wrist pain often accompanied with clicking
  - Baseball players, golfers have pain during hitting
- Nontraumatic
  - Pain with activities that require forearm pronation
    - Gripping and twisting doorknobs, trying to open jars, or turning a door key is often painful.
    - Deep, aching discomfort
    - May be associated with mechanical elements of locking, clicking, or catching
    - Firm gripping activities are painful, especially in patients with dynamic ulnar impaction.

Physical Examination

Abnormal Findings

- Examine patient where she or he can rest both elbows on a flat surface with hands toward ceiling
  - Enables examiner to access forearm rotation with the wrist in any position and compare to uninvolved wrist

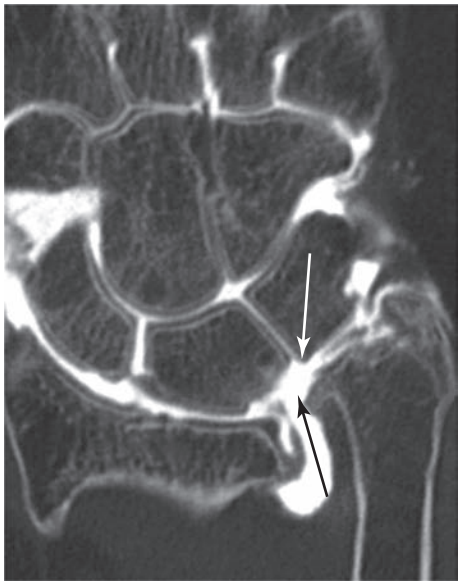

FIGURE 15-5. Palmer class IIE lesion (ulnocarpal osteoarthritis). Ulnocarpal impaction with positive ulnar variance. The TFCC is completely absent, and large communication between ulnocarpal and distal radioulnar joints is seen in this Multidetector CT arthrography coronal view obtained after single- compartment injection (black arrow). The lunotriquetral ligament is completely disrupted (*white arrow*), and communication between the midcarpal and ulnocarpal joints is also seen. No articular cartilage is observed at the ulnar aspect of lunate or at the radial aspects of the ulnar head and triquetrum. Subchondral bone attrition is visible at ulnar aspect of lunate, and a large osteophyte is seen at ulnar head. *(From Crema MD, Marra MD, Guermazi A, et al: MDCT arthrography features of ulnocarpal impaction syndrome. AJR Am J Roentgenol 193(5):1376–1381, 2009.)*



FIGURE 15-6. Tenderness at the ulnar fovea. *(Courtesy of Sidney Jacoby, MD.)*



FIGURE 15-8. TFCC grind test. *(Courtesy of Sidney Jacoby, MD.)*

- Inspect
  - Usually no visible deformity
  - Subtle fullness or swelling of ulnar wrist
  - Visible swelling may be evident in patients with synovitis of ulnocarpal joint
- Palpate (most important)
  - Localize area of maximal tenderness
  - Also palpate pisotriquetral articulation, lunotriquetral articulation, soft tissue elements (ECU, dorsal sensory branch of ulnar nerve)
  - Point foveal tenderness located at base of ulnar snuffbox between triquetrum and ulnar styloid (Figure 15-6)
    - Most common finding
    - Soft spot on ulnar side between FCU and ECU
    - Palpate dorsal TFCC with pronation, volar portion with supination
- Provocative maneuvers
  - Assess volar/dorsal stability of DRUJ with shuck test (Figure 15-7)
    - Compare to uninvolved side
    - Piano key sign
      - Prominent dorsal distal ulna with full pronation
  - Ulnocarpal stress test (rotation with ulnar deviation) (Figure 15-8)
    - Pain suggests ulnocarpal impaction
  - "Press test"
    - Pushing up on chair rails from a seated to a standing position elicits pain (Figure 15-9)
  - Rule out coexisting pisotriquetral or lunotriquetral abnormalities
  - ECU subluxation
    - Tendon should be stable within its groove
    - Forearm rotation with wrist flexion will elicit instability
  - Pain elicited with ulnar deviation (TFCC compression) or radial deviation (TFCC tension)
  - Decreased range of motion

Pertinent Normal Findings

- Radial snuffbox and radial wrist often nontender

Imaging

- Radiographs—initial screening tool
  - Neutral rotation PA is usually best
  - Usually negative
    - DRUJ
    - Ulnar variance (Figure 15-10)
      - Beware of ulnar positivity (high incidence of ulnar impaction and TFCC tears)



FIGURE 15-7. Shuck test. *(Courtesy of Sidney Jacoby, MD.)*

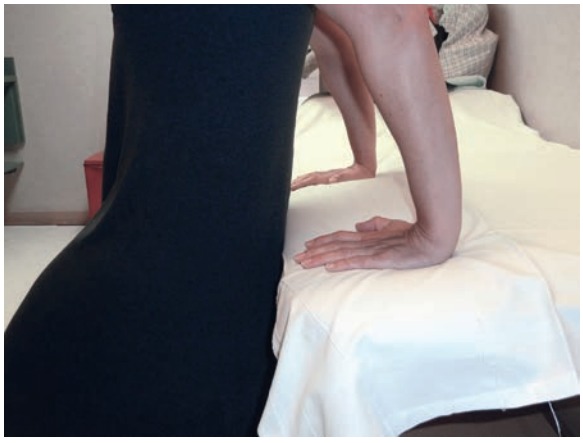

FIGURE 15-9. Press test. *(Courtesy of Sidney Jacoby, MD.)*

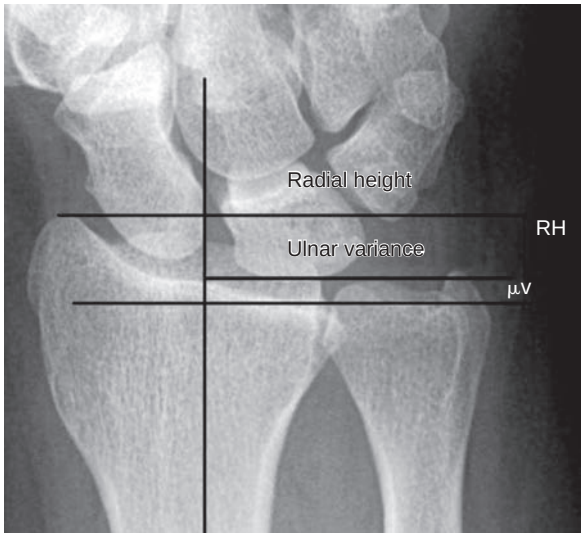

FIGURE 15-10. AP radiograph demonstrating measurement of ulnar variance. *(Courtesy of Sidney Jacoby, MD.)*

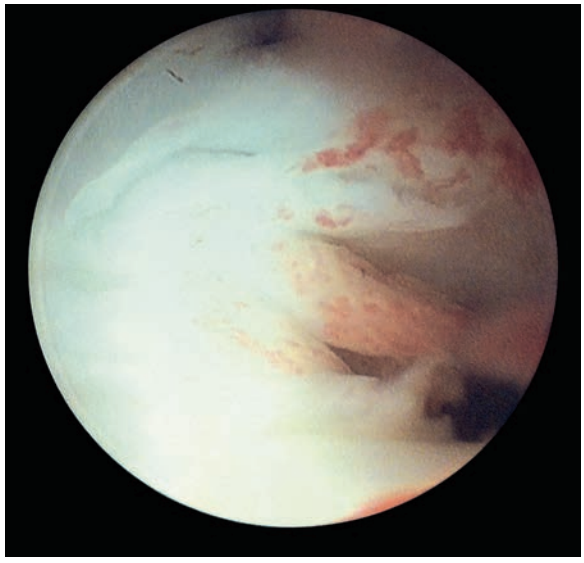

FIGURE 15-12. View of peripheral TFCC tear with ulnar-sided synovitis. *(Courtesy of Sidney Jacoby, MD.)*

  - Dynamic PA grip view with forearm pronation also helpful to assess dynamic ulnar impaction
  - Assess volar ulnar portion of lunate for lucency often seen in those with chronic ulnar impaction

- If diagnosis still unclear order advanced imaging
  - MRI with or without gadolinium-enhanced arthrogram—has largely replaced plain arthrography (Figure 15-11)
    - Tears and signal changes in the ulnar aspect of the lunate
    - Consistent with ulnocarpal impaction
    - Asymptomatic patients may have pathology, so correlate with history and physical exam
    - Helps distinguish impaction lesions from osteonecrosis
  - Plain arthrography—joint injection shows extravasation
    - Sensitivity 74% to 100%
  - Other studies: three-compartment cinearthrography, plain tomography, CT, CT arthrogram
    - Less diagnostic compared with MR arthrogram
  - Arthroscopy—gold standard for visualizing size and stability of tear (Figures 15-12 and 15-13)
    - Diagnostic and therapeutic
    - Detects concomitant ligament or chondral injuries
    - Detects peripheral vs. central tears
    - Identification and treatment of loose bodies
    - Types of treatment:
      - Repair, debridement, and tissue ablation



FIGURE 15-11. MRI of an ulnar-sided peripheral tear of the TFCC demonstrated by a high intensity signal on a T_2-weighted image (*red arrow*). *(Courtesy of Sidney Jacoby, MD.)*

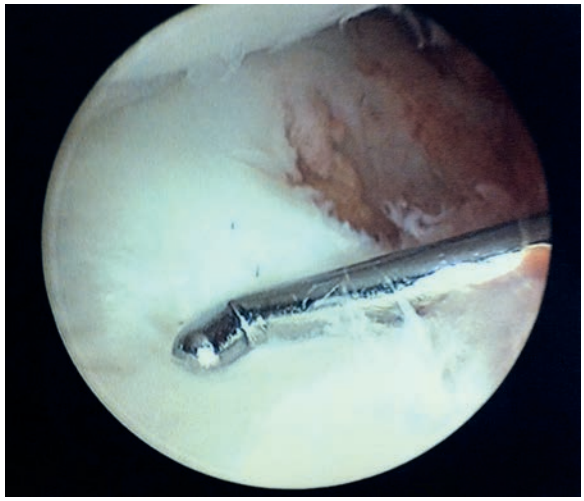

FIGURE 15-13. Probe entering from 6R portal revealing TFCC tear and lack of normal "trampoline" effect. *(Courtesy of Sidney Jacoby, MD.)*

Differential Diagnosis

- Extraarticular
  - ECU tendonitis
  - ECU instability
  - Neuritis of dorsal sensory branch of ulnar nerve ("cyclist's palsy")
  - Ulnar nerve entrapment at Guyon's canal
  - Hypothenar hammer syndrome
  - Osseous
    - Hamate fracture
    - Pisiform fracture
    - Ulnar styloid fracture
    - Fracture of base of fifth metacarpal
- Periarticular
  - TFCC tears
  - Ulnocarpal impaction
  - Impingement
  - ECU subsheath
  - Disc-carpal ligament injuries
  - LT ligament injuries
  - Synovitis
- Articular
  - DRUJ arthrosis
  - DRUJ instability
  - LT arthrosis
  - CMC arthrosis
  - PT arthrosis
  - Midcarpal instability
  - Loose bodies
  - Ulnar chondrosis
  - Lunate chondrosis
  - Kienbock's disease

Treatment

Nonoperative Management

- Type I with no instability
  - Long arm immobilization with forearm in a semi-supinated position, slight flexion, and slight ulnar deviation (Figure 15-14)
  - NSAID's, ice
  - Repeat exam in 4 to 6 weeks
- Type I with instability and concentric reduction of DRUJ and ulnocarpal relationship
  - Long arm cast in full supination for 6 weeks followed by long arm splinting for 6 weeks



FIGURE 15-14. Muenster splint which prevents forearm rotation. *(Courtesy of Sidney Jacoby, MD.)*

- Type II (initial)
  - Activity modification and elimination of offending activities
  - Long arm splinting to control rotation
  - NSAIDs
  - Elastic compression strap in those who work and may find the long arm splint cumbersome and impractical
  - Steroid injections (diagnostic and therapeutic)
    - Usually temporary relief
    - Useful when associated with synovitis

Guidelines for Choosing Among Nonoperative Treatments

- Start with activity modification and NSAIDs
- Steroid injections if continued pain
- Monitor pain while immobilized to continue nonsurgical treatment vs. pursuing surgery
  - Be more aggressive with high-level athletes

Surgical Indications

- Absolute
  - Failure of nonoperative treatment (several months of wrist splinting and activity modification)
    - Can be more aggressive with higher-level athletes (waiting as soon as 2 to 3 weeks if conservative measures fail)
  - TFCC instability with malreduced DRUJ and ulnocarpal joint
  - Congruent reduction, but with dorsal instability with 30° supination
- Relative
  - TFCC instability with reduced DRUJ and ulnocarpal joint
- Palmer classification grade: see below

Aspects of History, Demographics, or Exam Findings that Affect Choice of Treatment

- Based primarily on the severity of ulnar sided wrist pain and stability of the TFCC
- Age
- Activity level/level of competition
- Occupation
- Time since injury

Aspects of Clinical Decision Making When Surgery Is Indicated

- After trying several months of wrist splinting and activity modification without a significant result
- Type IA
  - Arthroscopic debridement of unstable portion
    - Leave at least 2 mm peripherally to avoid instability
- Type IB (Figure 15-15)
  - Arthroscopic repair of TFCC tear (all inside vs. outside-in); if ulnar styloid non-united with tear, need open procedure
    - Pathognomonic finding is loss of "trampoline" tension effect as determined with a probe

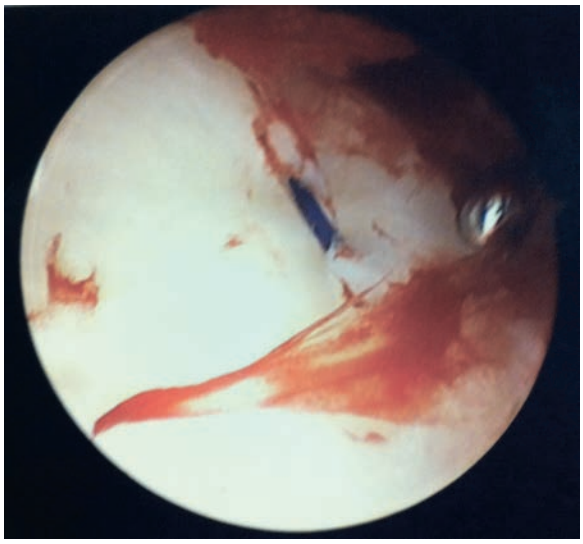

FIGURE 15-15. TFCC repair with restoration of normal "trampoline" effect and healthy bleeding after debridement of peripheral rim and repair of large tear following release of tourniquet. *(Courtesy of Sidney Jacoby, MD.)*

- Type IC
  - Arthroscopic reefing or tenodesis procedure
  - Open repair for large defect
    - Can augment with a strip of FCU
- Type ID
  - Open radial-sided TFCC repair with Munster cast for 4 weeks
- Type II
  - Decompression of ulnocarpal articulation
  - Correction of concomitant positive ulnar variance recommended
  - IIA/IIB
    - Arthroscopic evaluation and synovectomy
    - Open ulnar diaphyseal shortening
      - Indicated if ulnar positive variance greater than 2 mm
      - Advantage of effectively tightening the ulnocarpal ligaments and is favored with LT instability is present
  - IIC
    - Debridement of central tear
    - Arthroscopic wafer procedure (can be performed through a central tear) vs. open ulnar shortening osteotomy
      - Only if ulnar positive variance less than 2 mm
  - IID
    - Debridement and arthroscopic wafer
    - Open ulnar shortening if LT ligament unstable
    - Limited open ulnar head resection (Bowers' hemiarthroplasty)
      - Leads to creation of proximal pseudoarthrosis at the level of the ulnar neck
      - TFCC needs to be intact or reconstructable
  - IIE
    - Ulnar shortening osteotomy with LT debridement
    - LT pinning if unstable after ulnar shortening
    - Sauve-Kapandji procedure (DRUJ fusion with proximal ulnar pseudoarthrosis)
    - Darrach procedure (distal ulna resection)
      - Avoided because of problems with distal ulnar stump instability and radio-ulnar impingement (convergence)

Evidence

Anderson ML, Larson AN, Moran SL, et al: Clinical comparison of arthroscopic versus open repair of triangular fibrocartilage complex tears. *J Hand Surg [Am]* 33(5):675–682, 2008.

In a study of 75 patients with TFCC repair by arthroscopic or open technique between 1997 and 2006, Anderson et al. found that there was no statistical difference in clinical outcome for arthroscopic and open techniques for TFCC repair. They did note an increased rate of postoperative superficial ulnar pain in patients who underwent open repair (14 of 39 patients with open technique versus 8 of 36 patients with arthroscopy). Females had a statistically significant higher rate of reoperation. (Level III evidence)

Chen AC, Hsu KY, Chang CH, et al: Arthroscopic suture repair of peripheral tears of triangular fibrocartilage complex using a volar portal. *Arthroscopy* 21(11):1406, 2005.

Surgical repair of a Palmer type IB TFCC tear can be difficult using conventional dorsal portals and it may need special repair kits. The authors describe an arthroscopic technique using an additional volar portal that allows quick access and a secure purchase of peripheral TFCC tears as well as a distinct approach to dorsal wrist structures. (Level V evidence)

Hulsizer D, Weiss AP, Akelman E: Ulna-shortening osteotomy after failed arthroscopic debridement of the triangular fibrocartilage complex. *J Hand Surg [Am]* 22(4):694–698, 1997.

Over a 4-year period, 160 wrist arthroscopies were performed at 1 institution. Ninety-seven patients had central or nondetached ulnar peripheral tears of the TFCC and underwent arthroscopic debridement. Thirteen of the 97 had persistent pain in the TFCC region for more than 3 months after surgery. At an average of 8 months after failed arthroscopic debridement of the TFCC, all 13 patients underwent a 2-mm ulna-shortening osteotomy with fixation by a 3.5-mm 6-hole dynamic compression plate. At follow-up examination (average 2.3 years), 12 of the 13 had complete relief of pain at the ulnar side of the wrist. There was no statistically significant difference between the arthroscopic debridement alone cohort and the arthroscopy/ulna-shortening subgroup relative to ulnar variance or incidence of associated LT ligament tears. On the basis of these findings the authors recommend a 2-mm ulna-shortening osteotomy for patients whose previous arthroscopic debridement for central or nondetached peripheral TFCC was unsuccessful in eliminating ulnar-sided wrist pain. (Level IV evidence)

McAdams TR, Swan J, Yao J: Arthroscopic treatment of triangular fibrocartilage wrist injuries in the athlete. *Am J Sports Med* 37(2):291–297, 2009.

This case series looked at 16 athletes (mean age 23) with TFC injuries treated arthroscopically. Repair was performed for unstable tears, whereas all others underwent debridement alone. Pre and postsurgery mini-DASH scores and clinical evaluation demonstrated that arthroscopic debridement or repair provides predictable pain relief and return to play in competitive athletes. Return to play may be delayed in athletes with other concomitant ulnar-sided wrist injuries. (Level IV evidence)

Osterman AL, Terrill RG: Arthroscopic treatment of TFCC lesions. *Hand Clin* 7(2):277–281, 1991.

This review followed 133 patients looked at the natural history of symptomatic tears. Traumatic tears with neutral ulnar variance did not worsen over time, and one third of patients were asymptomatic at 9.5 years of follow-up. In persons with traumatic tears with ulnar positive variance, two thirds of patients worsened over time both symptomatically and radiologically. (Level IV evidence)

Papapetropoulos PA, Wartinbee DA, Richard MJ, et al: Management of peripheral fibrocartilage complex tears in the ulnar positive patient: Arthroscopic repair versus ulnar shortening osteotomy. *J Hand Surg [Am]* 35(10):1607–1613, 2010.

This retrospective review of prospectively collected data of 51 patients with Palmer 1B tears and ulnar positivity compared arthroscopic repair to ulnar shortening osteotomy (USO). At final follow-up, they found no statistically significant difference between the repair and USO groups with regard to range of motion. Likewise, there was no significant difference in grip strength, DASH scores, or visual analog scores. When analyzing each cohort individually, both groups improved significantly after surgery with regard to DASH score, visual analog scores, and wrist extension. There was also a trend toward improved motion in all other directions except for an insignificant decrease in postoperative pronation in the repair group. (Level III evidence)

Reiter A, Wolf MB, Schmid U, et al: Arthroscopic repair of Palmer 1B triangular fibrocartilage complex tears. *Arthroscopy* 24(11):1244–1250, 2008.

This was a retrospective study of 46 patients who underwent arthroscopic repair of Palmer class IB tears to determine patients' functional and subjective outcomes, as well as whether clinical outcomes were related to ulnar length. Good to excellent results were achieved in 63% of the patients, including increased range of motion and grip strength and pain relief. Ulnar neutral or positive variance was not a contraindication for repair and did not necessitate simultaneous ulnar shortening. (Level IV evidence)

Slade JF, III, Gillon TJ: Osteochondral shortening osteotomy for the treatment of ulnar impaction syndrome: A new technique. *Tech Hand Upper Ext Surg* 11(1):74–82, 2007.

A new technique for ulnar shortening osteotomy is described that preserves the articular surface of the distal ulnar. The osteotomy is secured with headless compression screws and therefore complications associated with plating are avoided. (Level V evidence)

Yao J: All-arthroscopic triangular fibrocartilage complex repair: Safety and biomechanical comparison with a traditional outside-in technique in cadavers. *J Hand Surg [Am]* 34(4):671–676, 2009.

This cadaveric study compared an all-arthroscopic TFCC repair technique with an outside-in technique in 10 matched pairs of fresh-frozen cadaveric wrists and found that the all-arthroscopic technique resulted in decreased operative time, reduced postoperative immobilization, and decreased irritation from suture knots below the skin. (Level V evidence)

Multiple-Choice Questions

QUESTION 1. Which of the following is NOT considered part of the TFCC?

A. Meniscus homologue
B. Volar radioulnar ligament
C. FCU tendon sheath
D. Central articular disc

QUESTION 2. A 22-year-old soccer player presents to your office after a fall. He has pain and ulnar-sided catching. He has no tenderness over the ECU tendon. X-rays, including a carpal tunnel view, are normal. The most likely mechanism for his fall is

A. Forearm supination, wrist flexion
B. Forearm supination, wrist extension
C. Forearm pronation, wrist flexion
D. Forearm pronation, wrist extension

QUESTION 3. Which of the following is the gold standard for diagnosing stability of a TFCC tear?

A. Zero rotation PA radiograph
B. MR arthrogram
C. Three compartment cinearthrography
D. Arthroscopy

QUESTION 4. Which of the following should be on your differential for periarticular ulnar-sided wrist pain (besides a TFCC tear)?

A. Ulnar impaction
B. Neuritis of dorsal sensory branch of ulnar nerve
C. Kienbock's disease
D. DRUJ instability

QUESTION 5. Which of the following is an appropriate treatment in a 27-year-old professional athlete who has been diagnosed with a peripheral TFCC tear at the base of the ulnar styloid and an associated ulnar styloid fracture with normal ulnar variance?

A. Debridement alone
B. Arthroscopic versus open outside-in repair
C. Ulnar shortening osteotomy
D. Short arm splint

Answer Key

QUESTION 1. Correct answer: **C** (see Pathophysiology)

QUESTION 2. Correct answer: **D** (see Pathophysiology)

QUESTION 3. Correct answer: **D** (see Clinical Presentation)

QUESTION 4. Correct answer: **A** (see Differential Diagnosis)

QUESTION 5. Correct answer: **B** (see Treatment)

NONOPERATIVE REHABILITATION OF WRIST SPRAINS AND TRIANGULAR FIBROCARTILAGE COMPLEX INJURIES

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GUIDING PRINCIPLES OF NONOPERATIVE REHABILITATION

- In a suspected triangular fibrocartilage complex (TFCC) injury presenting with ulnar-sided wrist pain and normal radiographs, a period of rest, activity modification, ice, splint immobilization for 3 to 6 weeks, nonsteroidal antiinflammatory medications and/or corticosteroid joint injections followed by therapy aimed at restoring normal range, power, endurance, and function may be effective.
- Specific to TFCC injuries, rehabilitation consists of four key phases:
  - The first phase aims to limit further injury, decrease pain, and minimize inflammation and edema.
  - The strength and flexibility of relevant structures are improved throughout the second phase.
  - The third phase targets an improvement in strength, flexibility, proprioception, and endurance until normal activities of daily living can be performed relatively pain free.
  - The final phase focuses on return to sport and prevention of injury with an increase in sport-specific skill, co-ordination and flexibility. This final phase targets the individual needs of the athlete with emphasis on their specific sport.

Phase I (weeks 1–4)

Goals

- To limit further injury through education and activity modification, decrease pain and minimize inflammation and edema, and last, optimize healing through splint immobilization

Protection

- Reduces pain by limiting movements that exacerbate the injury and second, places the wrist in a protective position to aid restoration and maintenance of normal anatomical alignment
- Gripping activities, ulnar deviation, and pronation may be limited, where appropriate, by use of splints.
  - Ulnar gutter orthosis is sufficient to alleviate pain.
  - Some patients will require a splint limiting forearm rotation.
  - Custom made or prefabricated splints (sugar-tong or Muenster type) are frequently used (Figure 15-16). Both allow for midrange elbow flexion and extension. The sugar-tong splint provides greater limitation in pronation and can be adjusted to allow for changes in edema.
- Duration of immobilization
  - For TFCC tears of degenerative etiology a period of 4 weeks of immunization is required. If the tear is of a traumatic etiology, immobilization ranging from 4 to 6 weeks may be required.
  - When distal radioulnar joint instability is observed on physical examination and the patient opts for a trial of nonsurgical management, the forearm should be immobilized in a position that reduces the instability (typically supination) for at least 4 weeks. Afterward, the wrist alone should be immobilized for an additional 2 weeks before initiating therapy.

Management of Pain and Swelling

- Pain and swelling must be adequately optimized with simple oral analgesics, with quantities tailored in response to the individual athlete's pain scores.
- Use of NSAIDs (e.g., ibuprofen, diclofenac) can limit this acute phase inflammatory response and optimize pain management.

TIMELINE 15-1: **Nonoperative Rehabilitation of Wrist Sprains/Triangular Fibrocartilage Complex Injuries**

PHASE I (weeks 1 to 4)	PHASE II (weeks 4 to 8)
• Education • Analgesia/NSAIDs • Activity modification • Immobilization: splint (gutter or forearm) • Cryotherapy • AROM exercises for joints not immobilized • Consider unilateral training of free limb	• Education • Soft splint for nighttime support • Tapering of analgesia/ NSAIDs • AROM or AAROM exercises all joints • Passive accessory movements or MWMs • Tendon gliding exercises • Functional exercises or light ADLs • Early proprioception exercises • Soft tissue techniques



FIGURE 15-16. Types of forearm splints. **A,** Sugar-tong splint. **B,** Muenster splint.

- Intraarticular corticosteroid injections may be of benefit in the setting of severe symptoms.
- Cryotherapy (e.g., application of cold packs, crushed ice over the site of injury) may optimize pain control and limit the symptomatic effects of tissue edema.

Patient Education and Advice

- Essential to ensure the patient understands the injury and the rationale behind the treatments selected

Patient Engagement

- Patient participation and compliance are essential to achieving timely progress through each phase and prevention of future injury.

Activity Modification and Identification of Targets

- Removes the inciting force of injury and prevents future injury recurrence
- Realistic milestones are outlined and agreed between athlete and therapist.
- Several factors are important to consider when treatment is initiated for a TFCC injury:
  - The athlete's specific sport
  - His/her desires regarding return to play
  - The impact of injury management on the athlete's future participation in his/her sport

Specific Therapeutic Exercises

Maintenance Exercises

- Full active range of movement of fingers and thumb should be encouraged within the splint to prevent small joint stiffness and muscle atrophy and to assist in the resolution of soft tissue edema.

Free Limb Strength Training

- Total arm strength training the free limb may attenuate the strength loss acquired in unilateral immobilization while also maintaining muscle bulk.
- Cross-education effect may provide another tactic in the management of the patient during this phase of immobilization.

Early Intervention

- For high-level (elite high school, collegiate, or professional) athletes who have negative initial imaging yet persistent symptoms limiting participation, diagnostic (and potentially therapeutic) arthroscopy may be indicated after as little as 2 to 3 weeks of splinting.

Milestones for Progression to the Next Phase

- Significant alleviation of pain as demonstrated by decreased requirements for analgesics and antiinflammatory medications
- Splint independence: Adequate pain control and minimal edema when splint is removed

Phase II (weeks 4–8)

Goals

- This phase aims to ameliorate residual stiffness and edema from phase I immobilization; to restore range

TIMELINE 15-1: Nonoperative Rehabilitation of Wrist Sprains/Triangular Fibrocartilage Complex Injuries (Continued)

PHASE III (weeks 8 to 12)	PHASE IV (weeks 12+)
• Static progressive or dynamic splinting as needed • Progress PROM to full • MWMs in weightbearing • Isokinetic exercises • Isometric exercises • Eccentric/concentric exercises • Grip strengthening exercises • Proprioception: conscious and unconscious neuromuscular rehabilitation • Early low level plyometrics—gravity eliminated/reduced • Progression of functional exercises	• Activity modification • Wrist protection • Maintain full AROM/PROM • Good flexibility • TAS or TBS activities as recommended • Progression of plyometrics—"single arm bounce back" • Sport-specific exercises • OKC rhythmic stabilization exercises • CKC exercises in weightbearing position • Simulation of game or competition needs • Use of periodization training model

of motion, flexibility, co-ordination, and function of the wrist joint; and commence early muscle strengthening work.

Protection

- Therapists should strongly advocate the use of removal splints to protect the injury in this early phase of rehabilitation and prevention of reinjury.
- The use of night splinting is crucial.

Management of Pain and Swelling

- Patient feedback during passive assessment is essential to prevent irritation of recently healed structures.
- It may be suitable to defer measurement of resisted activities to a later phase.
- Use of analgesics and NSAIDs should be tailored to allow maximal pain-free participation in the exercise program.

Establishment of Functional Losses

- Once the splint is removed, physiotherapy is the key determinant of post-rehabilitation functional outcome.
- A comprehensive assessment of the wrist and the joints above and below determines baseline measurements and is vital in developing an individualized exercise program that will form the core of the athlete's rehabilitation to competitive sport.
- Active range of motion (AROM), assisted AROM, and passive range of motion (PROM) of the wrist joint, stiffness and swelling, muscle strength, forearm length, and painful movements are determined.

Patient Education

- Protection of joints during demanding activities or vocational duties should be highlighted by therapists to prevent reinjury.
- Pamphlets should be provided with schematic/photographic representation and instructions of the exercises to be performed.

Techniques for Progressive Increase in Range of Motion

- The following techniques aim to achieve the two main goals of initial physiotherapy rehabilitation: increased range of motion and decreased swelling. These exercises should be prescribed in sets of 3 to 5 per day, with the amount of repetitions and sets adjusted to meet the individual athlete's desired level of function.

Active and Assisted Active Range of Motion Exercises

- Most activities of daily living (ADLs) are performed within a range that utilizes midcarpal rather than radiocarpal joint motion, known as *dart-thrower's motion*. Joint range is typically from 40° wrist extension, 20° radial and ulnar deviation, and 0° flexion.
- AROM exercises should initially target these goals to allow for increased pain-free function before advancing to the next level.
- AROM and assisted AROM exercises include wrist (flexion/extension, ulnar/radial deviation), fingers/thumb (flexion/extension), forearm (pronation/supination), and elbow (flexion/extension).

Tendon Glide Exercises

- Prolonged periods of immobilization can cause tightness within the musculotendinous unit.
- This can be overcome by using tendon glide exercises directed at both wrist and finger flexor and extensor tendons. Differential glides should be included to allow progressive increase in range of motion (Figure 15-17).

Functional Exercises

- Functional exercises, to include fist formation, opposition, and grip, are essential in increasing strength, endurance, and dexterity.
- Assessment of the management of carpal instability by Australian hand therapists[1] revealed grip strength to be 67% of the contralateral uninjured side. Basic ADLs should therefore be encouraged to aid strength and restore patient confidence. The use of a soft splint may help facilitate this process.

Mobilizations with Movement/Passive Accessory Movement Glides

- Mobilizations with movement (MWM) that apply a sustained force or accessory glides while performing a previously painful movement may be of use in achieving end-range movements. Initially performed with the wrist non–weight-bearing and progressed as tolerated.
- Passive accessory movement glides, particularly of the wrist (AP, PA, and medial/lateral) and distal radioulnar joint (AP/PA), can help restore joint range but care must be taken with healing tissue and appropriate grades of movement used.

Soft Tissue Techniques

- Lymphatic massage and gentle cross-friction massage can be applied at the site of the lesion to increase mobility of collagen fibers without longitudinally stressing the ligament and to promote lymphatic drainage.
- Application of nonthermal ultrasound promotes increased tissue perfusion, thereby reducing inflammation and swelling at the site of injury. Thermal ultrasound therapy can also be employed to decrease localized pain stimuli.

Other Therapeutic Exercises

Sensorimotor Exercises

- Early proprioception exercises address joint position sense and kinesthesia, controlling range and protecting healing structures. These include mirror therapy,

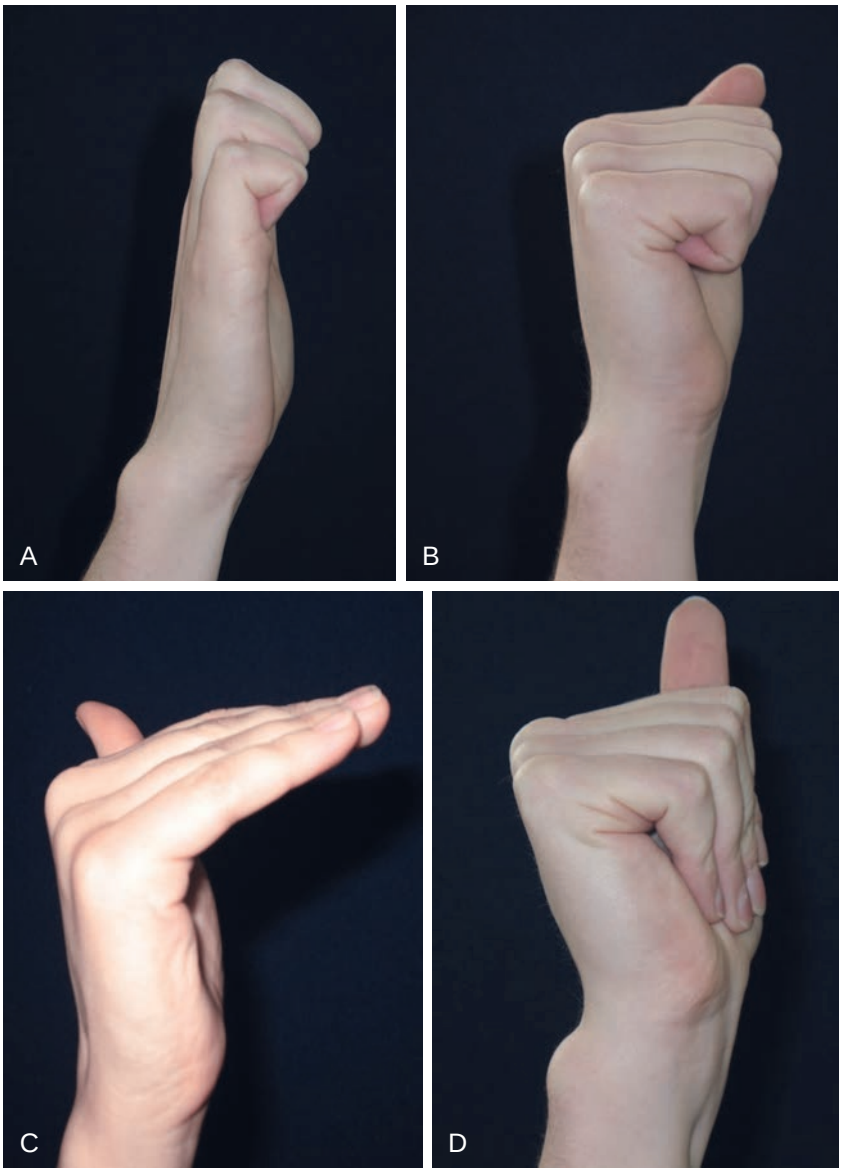

FIGURE 15-17. Differential tendon glide exercises. Progress in sequence from right to left, top to bottom. **A,** Hook grip. **B,** Full fist. **C,** Table top. **D,** Straight fist.

blinded passive and active reproduction of joint angle, and motion detection.
- These can be achieved using an exercise machine, such as an upper limb exerciser or manual passive motion.
- They may be an appropriate addition to the rehabilitation of gymnasts who specifically require a high level of proprioceptive function in their wrists.

Milestones for Progression to the Next Phase

- Improvement in comfort: Significant reduction in pain and decreased swelling at the site of injury with simple ADLs
- Increased ROM: Displays good tolerance through progressive range of exercises along a spectrum of gentle AROM to beginning strengthening exercises

Phase III (weeks 8–12)

Goals

- This phase aims to achieve a progressive improvement in strength, flexibility, proprioception, and endurance of the injured structures until near-normal function is achieved. This can only be initiated when a significant improvement in wrist ROM, has been consistently demonstrated.

Protection

- Static/dynamic splinting
  - If ROM improvement has plateaued before reaching functional ROM, incorporation of a static or dynamic progressive splint is recommended.
  - This additional support promotes increases in movements in desired directions by placing the targeted

joint(s) in a gentle stretch. Typically such splints are applied in a forearm supination or wrist extension position.
- Removal splints
  - The use of removal splints is strongly recommended, encouraged specifically during sleeping and ADLs that may reinjure the TFCC.
  - In addition to injury protection, removal splints facilitate heading by promoting rest of the arm and forearm.

Guidelines for Strengthening, Proprioception, and Endurance Rehabilitation

Mobilizations with Movement

- MWM can now be performed in a weight-bearing position to gain full pain-free end range movements at the wrist.
- Once this full ROM target has been reached, strengthening prescription should begin with progression onto more resistance-based exercises as tolerated.

Isometric Exercises

- Strengthening exercises should focus on the wrist, forearm, hand, elbow, and shoulder. In particular, grip strength exercises are of critical functional value in most daily activities and occupational duties.
- Isometric exercises (strength training in which the joint angle and muscle length do not change during contraction) against the therapist can be instituted initially.
- Isometric exercise promotes early neuromuscular control and prevents excessive joint motion. Unilateral isometric exercises of the wrist have been shown to increase voluntary muscle activation bilaterally.
- A TFCC injury with concomitant distal radioulnar joint instability can be treated with isometric exercise designed to target pronator quadratus in supinated and neutral wrist positions. Hence, the isometric exercises appear to have a key role in early wrist proprioception reeducation.

Eccentric/Concentric Exercises

- Eccentric and concentric exercises with progressive resistance can be introduced to improve muscle bulk, endurance, and joint stability. Generally higher repetitions with low load are effective. Prescription of such exercises should be based on initially building muscle mass, using moderate repetitions (6 to 10 reps) and eccentric loading (3 seconds down and 1 second up phase) for initially 3 to 5 sets per day.
- To improve endurance, the athlete should be performing high repetitions (greater than 10 reps) of a low weight, pain permitting, in between or after strength exercise sets.
- Pronation/supination exercises may be performed both concentrically and eccentrically using a hammer, held in the hand, as a lever.
- Progressive gripping activities from a supinated position, through neutral and finally in a pronated position has been recommended to prevent irritation of the TFCC.
- Wrist flexion/extension exercises should be performed with a small dumbbell (or resistive bands) starting at 500g and progressing to higher masses as tolerated.
- Elbow and shoulder strengthening should be addressed.
- Eccentric exercises of wrist extensors influence the coactivation pattern of wrist flexors, enhancing the stability of the wrist.
- Coactivation exercises demand the use of concentric, eccentric, and isometric exercises. This can be reproduced by performing balance exercises with both hands on a ball. Slow and controlled motion of the ball on a table will allow the patient to simultaneously exercise flexors and extensors to produce a balanced wrist position in early proprioceptive training.

Isokinetic Dynamometry

- Isokinetic training involves optimal loading of muscles in dynamic conditions and consistent preselected velocity of movement. This is an ideal treatment option for those individuals who put extreme demands on their wrists.
- Exercises should start with submaximal contraction intensity and slow speed movement and progressively intensify (increase in intensity contraction and speed movement).
- Program effectiveness can be assessed through pain score evaluation, muscle strength measurement, and ultrasonographic examination.

Proprioceptive Rehabilitation

- For athletes such as gymnasts in whom wrist "balance" is vital, more complex proprioceptive rehabilitation is required to maximize wrist functional outcome.
- Human proprioception comprises three major senses: kinesthesia, joint position sense (JPS), and unconscious neuromuscular control.
- Kinesthesia constitutes the ability to sense motion of a joint and is measured as the smallest change in joint angle needed to elicit a conscious awareness of joint motion. The joint is placed at a certain angle and then moved passively and slowly at a speed of 0.5° to 2° per second, until the patient signals that joint motion occurs. This is referred to as *threshold to detection of passive movement* (TTDPM).
- Accurate control of the degree and speed of motion can be achieved using professional training devices such as an Upper Limb Exerciser (Biometrics Ltd, Ladysmith, VA) or Biodex Dynamometer (Biodex Medical Systems Inc., Shirley, NY). Joint position sense is defined as the ability to accurately reproduce a specific joint angle.
- JPS training can be performed passively or actively, with visual cues or blinded. Passive JPS is when the therapist moves the wrist and the patient signals when the target position is reached. Active JPS is when the patient moves the wrist to the predetermined target position.
- Unconscious proprioceptive sense is the feed-forward anticipatory control of muscles around a joint, the ability to unconsciously maintain an adequate posture, joint stability, and equilibrium. Reactive muscle activation (RMA) therapy aims to restore the neuromuscular reflex patterns that exist in a normal joint.

- Suggested strategies to stimulate RMA include use of gyroscopic tools such as Powerball (NSD Powerball, RPM Sports, Tipperary, Ireland). The multidirectional motion generated by the gyroscope, demands a reflex activation of the wrist muscles and an unconscious activation of both the agonist and antagonist muscles, to increase muscle endurance.

Plyometric Exercise

- The identifying feature of plyometric exercise is lengthening of the muscle-tendon unit followed directly by shortening (stretch-shortening cycle) (Figure 15-18). This enhances the ability of the muscle tendon unit to produce maximal force in the shortest amount of time, prompting the use of plyometric exercise as a bridge between pure strength and sports-related speed.
- Clinical milestones such as pain-free moderate loading during traditional strengthening exercise and functional movement patterns with proper form should be achieved before safe implementation.
- The progression of low- to higher-intensity plyometric exercise will prepare the musculoskeletal system for rapid movements and high forces that may equate to the demands imposed during sport participation, thus assisting the athlete with return to full function.

Incorporation of Functional Activities

- These activities will progress rehabilitation to a level of pain-free function, enabling integration back into independent living. Such functional activities include folding, washing, using cutlery, using tools such as screwdrivers, and incorporation of other occupational/sport-specific tasks.
- Use of computerized work simulators, such as the Baltimore Therapeutic Equipment Work Simulator, may allow stepwise task-based rehabilitation in a safe manner.

Milestones for Progression to Phase IV

- At the end of phase III, patients should have normal joint range, power, and endurance compared to the noninjured side and be able to perform all ADLs without pain. They should be fit to return to work and progress to phase IV sport-specific training.

Phase IV (12 weeks onward)

Goals

- The final phase (Phase IV) of rehabilitation involves progression toward functional independence and focus on sport-specific training and conditioning. Athlete education and development of injury prevention measures are key factors to successful rehabilitation.

Activity Modification

- As sport-specific skill and functional demands are reintroduced in this final phase of rehabilitation, it is imperative that a comprehensive reassessment of wrist function is performed.
- Athletes should continue to perform both AROM and PROM exercises for isolated upper extremity strengthening, with close attention to tissue reaction.

Patient Education and Protection

- Injury prevention, education, and application of wrist protection principles are important features of this phase.
- Daily protection of the wrist during demanding ADLs or vocational duties should be highlighted to include

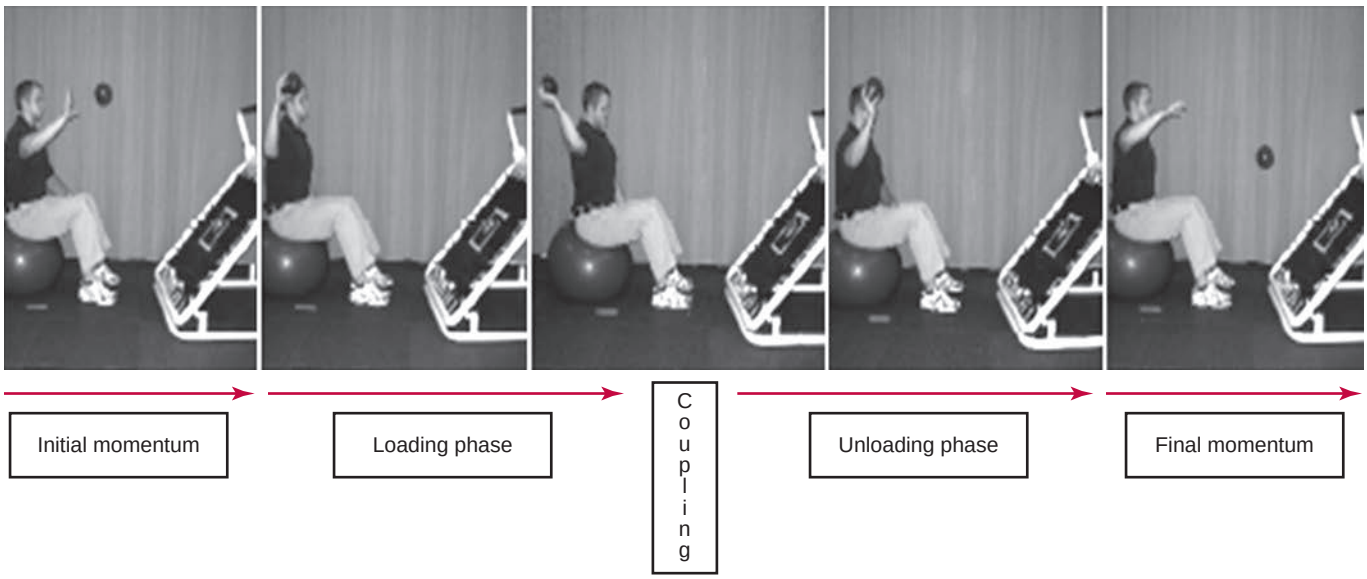

FIGURE 15-18. Upper extremity plyometric exercise. The three phases of plyometric activity include loading, coupling and unloading. The loading phase involves stretch on the muscle-tendon unit, which initiates the stretch-shortening cycle. The coupling phase is the transition between loading and unloading and is characterized by quasi-isometric muscle activity. The unloading phase involves shortening of the muscle-tendon unit and capitalizes on the mechanisms of the stretch-shortening cycle. *(From Chmielewski TL, Myer GD, Kauffman D, Tillman SM: Plyometric exercise in the rehabilitation of athletes: Physiological responses and clinical application. J Orthop Sports Phys Ther 36(5):308–319, 2006.)*

use of the strongest joint available for noncompetitive activities, use of each joint in its most stable anatomical and functional plane, and maintenance of muscle balance and correct patterns of motion.
- Although avoidance of static positioning of joints is encouraged, wrist supports may be used to facilitate training but only temporarily and under the strict guidance of the coach/rehabilitation team.

Periodization Training

- Decisions regarding return to competition should be agreed upon by the multidisciplinary rehabilitation team and optimal strength training and conditioning achieved through a sport-specific training program.
- *Periodized strength training* refers to varying the training program at regular time intervals in an attempt to bring about optimal resistance gains in strength, power, motor performance, and/or muscle hypertrophy. It is conceptualized by programmed variation in the training stimuli (i.e., volume, intensity, frequency) with the use of planned rest periods to augment recovery and restoration of an athlete's potential.
- Periodization training programs are designed according to two different models: the linear model and the nonlinear model.
- The undulating (nonlinear) model enables variation in intensity and volume within each 7- to 10-day cycle and is deemed superior to linear training (volume decrease, intensity increase with program progression).
- Implementation of undulating periodization requires an initial adaptation phase. Thus the athlete performs a base program for 4 to 6 weeks using lighter weights, allowing climitization to the resistance training program, before an undulating progression of varying intensities.
- An active rest or recovery period (halt resistance training and remain active with other sporting activities) of 2 to 3 weeks commences after the 16-week cycle. The most common undulating periodization model is shown in Table 15-1.

Sport-Specific Rehabilitation

- Strengthening exercises should be further developed throughout phase IV to include overhead, torqueing, and weightbearing activities. These activities will effectively assess the impact of additional strain on the TFCC, thus providing key prognostic information on readiness to return to competitive sport.
- It is imperative that proprioceptive rehabilitation is maintained throughout this phase of reconditioning to achieve maximal wrist function and injury prevention for athletes placing high demands on their wrists. This is exemplified by gymnastics, wherein a high level of wrist flexibility and strength is required.
- Handstands against the wall allow for some support to aid strength and flexibility before moving to supporting full body weight against gravity. Nonprofessional tennis players have been shown to stress radial or ulnar aspects of the wrist depending on the individual's racket grip. Activity modification and wrist supports should therefore compliment initial return to sport.
- Simulation training or positive imagery representative of game or competition conditions can help prepare the athlete for return to the sport.

Table 15-1 Sample Protocol of Undulating Periodization in a 16-Week Mesocycle*

Monday	**Monday**
4 sets of 12 to 15 RM	4 or 5 sets of 1 to 3 RM
Wednesday	**Wednesday**
4 sets of 8 to 10 RM	Power day
Friday	**Friday**
3 or 4 sets of 4 to 6 RM	2 sets of 12 to 15 RM

From Kraemer WJ, Fleck S: *Optimizing strength training, Champaign,* Illinois, 2007, *Human Kinetics.*
*This protocol uses a 6-day rotation. Active rest for 2 to 3 weeks after the 16-week mesocycle is completed.

Plyometric Exercise

- Ongoing progression of plyometrics can encourage total body engagement, enhancing stability around the wrist with motion generated in the whole upper limb.
- Activities such as the single arm bounce back (throwing a weighted ball against a screen, catching the ball as it bounces back, and throwing it immediately) are effective. These are particularly useful if the sport requires explosive power and control.
- An upper extremity stretch shortening drill has been described consisting of warmup, throwing, trunk flexion/extension exercises, and medicine ball wall exercises.

Open-/Closed-Chain Kinetic Exercises

- Athletes who are unable to perform plyometric exercise usually struggle to attain preinjury level of functioning.
- Closed-chain exercises incur compressive forces and are typically weight bearing (e.g., pushups for gymnasts and wrestlers).
- Open-chain rhythmic stabilization exercises incur shearing forces (e.g., biceps curl, lateral raise) and work well for baseball athletes, particularly pitchers. The act of throwing a baseball is itself an open-chain movement in which the pitching arm rotates extremely quickly around the glenohumeral joint and the ball is released at high velocities.

Criteria for Abandoning Nonoperative Treatment and Proceeding to Surgery or More Intensive Intervention

- Persistent symptoms
  - Several factors are key determinants of rehabilitation outcomes post-TFCC injury, including the extent of the TFCC injury, the athlete's motivation and

adherence to program milestones, and the presence of medical comorbidities.
  - Failure of symptom (pain, edema) resolution 4 to 6 weeks post injury despite optimization with immobilization, and analgesic and antiinflammatory medications warrants prompt surgical intervention.
- High-level athletes
  - Professional athletes who have negative initial imaging yet persistent symptoms limiting participation despite compliance require surgical intervention after as little as 2 to 3 weeks of immobilization.

Guidelines for Progression to Sport-Specific Training and Conditioning

- Each athlete will have different goals, varying skill levels, and different levels of competition. This may influence progression in an individualized rehabilitation model. The following criteria should be fulfilled before commencement of reconditioning.
  - Normal joint range, power and endurance
  - Pain-free moderate loading during traditional strengthening exercise and functional movement patterns with proper form
  - Normal pain-free activities of daily living
  - Fulfillment of basic plyometric activity
  - Incorporation of routine functional activities into standard exercise prescription
  - Integration into independent living: return to work/vocational activities

Performance Enhancement and Beyond Rehabilitation: Optimization of Athletic Performance

- Optimization of athletic performance following strength training and reconditioning is multifactorial. It is imperative that performance goals and methodology are agreed upon by the rehabilitation team to prevent reinjury. Means of achieving maximal athletic performance include:
  - Maintenance of cardiovascular fitness and agility skills to help prepare the athlete for advanced conditioning
  - Progression from muscle conditioning, flexibility, functional exercises to sport-specific skills and incorporation into the standard periodization program
  - Maintenance of proprioceptive training to increase wrist stability and thus injury prevention
  - Upper limb assessment: A comprehensive upper limb assessment is required. This will identify abnormal biomechanics (e.g., shoulder instability). In such cases motor reeducation with focus on scapular stability improves overall upper limb function.
  - Sports psychology: Use of simulation and imagery promotes sports motivation and performance enhancement.
  - Visual cues: Video analysis to assess biomechanical problems and implement corrective strategies

Criteria for Return to Sport

- Complete resolution of pain and edema with return to full range of movement
- Strength, flexibility, and endurance at preinjury status with plyometrics
- Good proprioception: normal kinesthesia, joint position sense, and unconscious control
- Stepwise completion of training program without reinjury/symptom exacerbation
- Maintenance of cardiovascular fitness throughout the rehabilitation period
- Psychological preparedness for return to competitive status

Evidence

Ahn A, Chang D, Plate AM: Triangular fibrocartilage complex tears: A review. *Bull NYU Hosp Jt Dis* 64(3–4):114–118, 2006.

A comprehensive review of the etiology, biomechanics, and treatment options available following triangular fibrocartilage tears. (Level IV evidence).

Chmielewski TL, Myer GD, Kauffman D, et al: Plyometric exercise in the rehabilitation of athletes: Physiological responses and clinical application. *J Orthop Sports Phys Ther* 36(5):308–319, 2006.

A review of the mechanisms involved in plyometric exercise, considerations for implementing plyometric exercise into rehabilitation protocols. Evidence supporting the use of plyometric exercises and recommendations for future research are discussed. (Level IV evidence).

Hagert E: Proprioception of the wrist joint: A review of current concepts and possible Implications on the Rehabilitation of the Wrist. *J Hand Ther* 23:2–17, 2010.

Narrative review of novel research findings on the subject of wrist joint proprioception. The concept of proprioception is explored as it relates to neuromuscular control, joint stability, and therapeutic application in the context of wrist rehabilitation. (Level IV evidence).

Henry MH: Management of acute triangular fibrocartilage complex injury of the wrist. *Am Acad Orthop Surg* 16(6):320–329, 2008.

A comprehensive systematic review of the management of triangular fibrocartilage complex injuries in the acute setting. Anatomy, biomechanics, imaging, and conservative and operative strategies are thoroughly explored. (Level IV evidence).

Hendy AM, et al: Cross education and immobilization: Mechanisms and implications for injury rehabilitation. *J Sci Med Sport* 15(2):94–101, 2012.

This review examines the impact of immobilization on muscle tissue and the central nervous system, the possible mechanisms that may contribute to cross-education strength transfer, and the practical application of unilateral training to maintain strength during immobilization. (Level IV evidence).

Parmelee-Peters K, et al: The wrist: Common injuries and management. *Prim Care* 32(1):35–70, 2005.

A review of the epidemiology of wrist injuries in the active population and appropriate management options for each type of injury. (Level IV evidence).

Rhea MR, Ball SD, Phillips WT, et al: A comparison of linear and daily undulating periodized programs with equated volume and intensity for strength. *J Strength Cond Res* 16(2):250–255, 2002.

A randomized control trial comparing strength gains following linear periodization and daily undulating periodization training. Daily program alterations were more effective in eliciting strength gains than monthly alterations, supporting the use of daily undulating periodized programs as the superior method of strength training. (Level II evidence).

Slaughter A, Miles L, Fleming J, et al: A comparative study of splint effectiveness in limiting forearm rotation. *J Hand Ther* 23:241–248, 2010.

A case series exploring the effectiveness of Muenster, sugar-tong, antipronation distal radioulnar joint, and standard wrist splints in restricting forearm pronation. The sugar-tong splint is recommended for maximal restriction in pronation, but individual patient characteristics require consideration in splint choice. (Level IV evidence).

Watanabe A, Souza F, Vezeridis PS, et al: Ulnar-sided wrist pain. II. Clinical imaging and treatment. *Skeletal Radiol* 39(9):837–857, 2010.

A review of the etiology, mechanisms, imaging, and treatment options available for the common diseases that cause ulnar-sided wrist pain. (Level IV evidence).

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1. Prosser R, Herbert R, LaStayo PC: Current practice in the diagnosis and treatment of carpal instability—results of a survey of Australian hand therapists. *J Hand Ther* 20(3):239–242, 2007.

Multiple-Choice Questions

QUESTION 1. Phase I rehabilitation following a TFCC injury does not involve

A. Immobilization
B. Analgesia and antiinflammatory medications
C. Active range of motion exercises
D. Education
E. Activity modification

QUESTION 2. Milestones for progression to phase IV rehabilitation include:

A. Return to work/vocational activities
B. Removal of forearm splints
C. Commencement of soft tissue techniques
D. Progression to eccentric/concentric exercise
E. Progression to isokinetic exercise

Answer Key

QUESTION 1. Correct Answer: **C** (see Phase I)

QUESTION 2. Correct Answer: **A** (see Milestones for progression to Phase IV)

POSTOPERATIVE REHABILITATION AFTER TRIANGULAR FIBROCARTILAGE COMPLEX REPAIR/DEBRIDEMENT AND WRIST LIGAMENT REPAIR/WRIST ARTHROSCOPY

Dominic Gomez-Leonardelli, MD, Jack Browne, OT, CHT, and Leo T. Kroonen, MD

Indications for Surgical Treatment

Triangular Fibrocartilage Complex Injuries

- Patients with traumatic injuries (Type I) or degenerative pathology (Type II) to the Triangular Fibrocartilage Complex (TFCC) who do not respond to nonoperative treatment (see Box 15-1 below and Figure 15-4 in the Introduction for a description of the Palmer classification of TFCC abnormalities)
- Peripheral or ulnar-sided repairs may benefit from early arthroscopic repair.
- Arthroscopic repair of acute (within 3 months) radial and peripheral tears gives the best prognosis.
- An aggressive approach can be considered in elite athletes with distinct distal radial ulnar joint instability.

Scapholunate Ligament (SL) Injuries

- Acute ligament disruption as indicated by mechanism of injury, clinical examination, and radiographic evidence of complete or partial rupture
- Subacute and chronic ligament disruption with persistent pain unresponsive to nonoperative treatment attempts

Lunotriquetral Ligament Injuries

- Arthroscopy is indicated for staging and treatment of acute lunotriquetral (LT) ligamentous injuries with dynamic or static instability, with improved healing potential seen with early intervention.
- Suspected lunotriquetral ligamentous injuries with persistent painful symptoms unresponsive to nonoperative treatment

BOX 15-1 The Palmer Classification of TFCC Abnormalities

Class I: Traumatic

A. Central perforation
B. Ulnar avulsion
   With distal ulnar fracture
   Without distal ulnar fracture
C. Distal avulsion
D. Radial avulsion
   With sigmoid notch fracture
   Without sigmoid notch fracture

Class II: Degenerative (ulnocarpal abutment syndrome)

A. TFCC wear
B. TFCC wear
   + Lunate and /or ulnar chondromalacia
C. TFCC perforation
   + Lunate and/or ulnar chondromalacia
D. TFCC perforation
   + Lunate and/or ulnar chondromalacia
   + L-T ligament perforation
E. TFCC perforation
   + Lunate and/or ulnar chondromalacia
   + L-T ligament perforation
   + Ulnocarpal arthritis

- Chronic, symptomatic lunotriquetral ligamentous injuries are appropriate candidates for arthroscopic debridement, and possible ulnar shortening osteotomy

Brief Summary of Surgical Treatment

Major Surgical Steps

Treatment of TFCC Injuries

- With the wrist in an arthroscopy tower under 12 to 15 lbs of traction, standard wrist arthroscopy portals are used (we prefer 3 to 4 and 6R portals for the radiocarpal joint and both radial and ulnar midcarpal portals for evaluation of the midcarpal joint).
- Standard of care includes a midcarpal arthroscopy in all wrist arthroscopy cases.
- Decision to debride or repair is based upon the location and stability of the TFCC tear based on the Palmer classification (see Box 15-1)
- Debridement is considered adequate when no loose edges or a smooth rim of TFCC has been fashioned.
- IA injuries' (central tears) accepted surgical treatment involves removal of unstable tissue via arthroscopic portals and debridement.
- IB injuries (ulnar sided peripheral tears) may be repaired arthroscopically via outside-in or inside-out techniques employing vertical or longitudinal sutures tied over the capsule.
- IC injuries (distal tear away from the carpus) may be repaired arthroscopically or via open technique. Arthroscopic repair utilizes looped 2-0 PDS sutures through ulnocarpal ligaments then tied over the capsule.
- ID injuries (radial tears) surgical debridement includes debridement or repair with reported similar clinical outcomes. Arthroscopic repair techniques involve drilling suture tunnels via the sigmoid notch through the distal radius metaphysis for suture repair of the radial edge of the TFCC.
- Patients who present with a traumatic TFCC injury and ulnar positive variance should receive consideration for combined arthroscopic TFC repair and ulnar shortening osteotomy.

Treatment of Scapholunate Ligament Injuries

- Partial ligament injury in acute phase wherein inherent healing potential of ligamentous structures is the favorable treatment includes percutaneous or arthroscopic debridement or electrothermal shrinkage followed by guided percutaneous fixation of the scapholunate joint after reduction with Kirschner wire or compression screw fixation.
- Complete ligament injury with a repairable ligament may be repaired after reduction of the scapholunate joint via transosseous sutures or suture anchor fixation, potentially augmented with dorsal capsulodesis. Repair is protected with K wire fixation of the scapholunate and scaphocapitate joints, or with screw fixation across the scapholunate interval.
- Complete ligament injury with nonrepairable ligamentous structures and normal carpal alignment may be treated by various approaches:
  - Reconstruction of the SL ligament with locally harvested portions of the dorsal intercarpal ligament or the dorsal radiocarpal ligament
  - Reconstruction of the SL ligament with locally harvested half of the flexor carpi radialis (triligament tenodesis)
  - Bone ligament bone grafts involving transferring bone-retinaculum-bone autograft harvested from the carpus of the foot
  - Dorsal capsulodesis: tightening radioscaphoid capsule in which a dorsal capsular flap is created and imbricated after reduction of the SL joint
- Complete ligament injury with nonrepairable ligamentous structures and reducible subluxation of the scaphoid may be treated with various SL ligament reconstruction techniques utilizing slips of the ECRB, ECRL, and FCR and various bone tunnels.
- Complete ligament injury with nonrepairable ligamentous structures and irreducible carpal alignment and normal cartilage may be treated with various arthrodesis techniques:
  - Scaphoid-trapezium-trapezoid
  - Scaphoid-capitate
  - Scaphoid excision and midcarpal fusion (four-corner fusion)
- Complete ligament injury with nonrepairable ligamentous structures, irreducible carpal alignment and advanced cartilage degeneration may be treated by various approaches, depending on the extent of the arthrosis:
  - Radial styloidectomy
  - Scaphoidectomy with midcarpal fusion
  - Proximal row carpectomy

- Total wrist arthrodesis
- Total wrist arthroplasty

Treatment of Lunotriquetral Ligament Injuries

- Partial lunotriquetral ligament injuries (LTIL) may be treated with arthroscopic debridement with excellent reported resolution of pain.
- Ulnar shortening osteotomy results in tightening of secondary restraints and theoretic stabilization of the lunotriquetral joint.
- Lunotriquetral arthrodesis has been described as a treatment option with an anticipated loss of 20° to 30° range of motion.
- Complete LTIL tears may be treated with arthroscopic reduction and pinning of the lunotriquetral joint, arthroscopic extrinsic ligament plication, or reconstruction with locally harvested extensor carpi ulnaris.

Factors That May Affect Rehabilitation

TFCC

- Debridement: Motion may begin immediately with use of splinting as needed for pain.
- Repair: typically 6 weeks of immobilization

Scapholunate Ligament and Lunotriquetral Ligament Injuries

- Debridement: Motion may begin immediately with use of splinting as needed for pain.
- Repair or reconstruction: Motion should not commence until 6 weeks postoperative. If pins are in place, motion should not commence until removal at 12 weeks postoperative. Our preference is to use screw fixation, which will allow for gentle early motion at 6 weeks postoperative, while still providing mechanical support to prevent early diastasis of the affected joint

Other Surgical Techniques and Options

Other TFCC Injuries/Treatments

- IB injuries more chronic in nature as well as those directly involving TFCC anatomic insertion to the fovea; consider open repair techniques
- ID injuries with large displaced radial avulsion fractures involving the sigmoid notch indicate an open repair via a dorsal approach.

Overview of Goals, Milestones, and Guidelines[1]

GUIDING PRINCIPLES OF POSTOPERATIVE REHABILITATION

- Understand the anatomy and wrist kinematics in order to appreciate how particular wrist movements may exacerbate existing pathology or challenge areas of repair.
- Respect ROM and strengthening limitations to allow appropriate healing and minimize postoperative inflammatory responses.

Goals Before Surgery

- Avoid exacerbation of initial injury.
- Immobilization for soft tissue rest and pain control—may include formal short arm cast or soft splint.
- Gentle range of motion to avoid stiffness

Goals After Surgery

TFCC Repair

- Immobilization in Munster or sugar-tong splint for 6 weeks with forearm in supination, wrist in 15° extension, and the finger MCP joints free.
- Begin AROM for the wrist and forearm at 6 weeks postoperative. Short arm wrist splint between exercise sessions for pain if needed
- Begin strengthening at 8 weeks postoperative.
- Return to full activity is anticipated at 12 weeks.
- Return to sports at 14 to 18 weeks
- Early return to activity may result in exacerbation of postoperative synovitis.

Debridement

- Splinting and immobilization as needed for pain
- Immediate ROM
- Return to sports unprotected 2 to 6 weeks

Scapholunate Ligament Injury

- Partial injury, SL joint with screw fixation: immobilization in below elbow cast with finger ROM immediately, screw removal at 12 weeks postoperative with protection in removable splint, ROM, and grip exercises beginning at 6 weeks postoperative.
- Complete injuries with repairable SL ligament: immobilization in below elbow cast for 6 weeks, immediate finger ROM, wrist ROM at 6 weeks, screw removal 5 to 6 months, additional protection in removable splint as needed beginning at 6 weeks
- Complete injuries with nonrepairable SL ligaments and reducible scaphoid subluxation: immobilization in below elbow thumb spica splint/cast for 6 weeks, screw removal at 5 to 6 months. Gentle wrist ROM can commence at 6 weeks, contact sports resumed at 6 months postoperative with protection, 10 months unprotected.

Phase I (days 0 to 14): Immediate Postoperative Period

Clinical Pearls

Hourly active tendon gliding exercises for the fingers help to maintain finger mobility and to control edema. Encourage very light functional use of the injured extremity while lifting no more than one pound.

[1]*Prehabilitation, if appropriate, is described in the Nonoperative Rehabilitation section of this chapter.*

Goals

- Maintain finger, elbow, and shoulder mobility.
- Manage edema using elevation, compression, and active motion.
- Avoid painful posturing or sustained static positioning of the extremity.

Protection

- Munster or sugar-tong splint for repair or reconstruction, short arm removable splint for debridement procedures

Management of Pain and Swelling

- Narcotic or nonsteroidal antiinflammatory pain medications are appropriate as needed.
- Compressive tubular dressing for forearm, wrist, and fingers
- Active motion of the fingers, elbow, and shoulder
- Elevation at heart level or higher

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Low grade distraction for finger MCP, PIP, and DIP joints if fingers are stiff and swollen

Soft Tissue Techniques

- May use edema mobilization techniques

Other Therapeutic Exercises

- TBS/TAS/TLS that do not require use of the involved upper extremity

Open and Closed Kinetic Chain Exercises

- OKC Exercises
  - Hourly tendon gliding as follows
    - Straight position (fingers fully extended) (Figure 15-19*A*)
    - Table top position (MCPs fully flexed with PIPs, and DIPs in full extension) (Figure 15-19*B*)
    - Hook position (MCPs in full extension with PIPs and DIPs in full flexion) (Fig 15-19*C*)
    - Fist position (MCPs, PIPs, and DIPs in full flexion) (Fig 15-19*D*)
    - AROM for thumb IP joint and thumb MCP joint as allowed by splint

Phase II (postoperative weeks 2 to 6)

Goals

- See Phase I

Protection

- See Phase I

Management of Pain and Swelling

- Wean from narcotic pain medications if possible.
- Nonsteroidal antiinflammatories are appropriate as necessary.
- Decrease swelling per Phase I recommendations.

Techniques for Progressive Increase in Range of Motion

Manual Therapy and Soft Tissue Techniques

- See Phase I

Other Therapeutic Exercises

- See Phase I

Open and Closed Kinetic Chain Exercises

- See Phase I

Phase III (postoperative weeks 6 to 10)

Goals

- 80% of normal active range of motion
- Near pain-free for available active range of motion
- Normal use of involved extremity for light ADLs

Protection

- Wrist splint for 4 weeks, or until asymptomatic

Management of Pain and Swelling

- Cryotherapy
- Frequent active range of motion for the hand, wrist, and upper extremity
- Compression sleeve and/or edema glove if needed
- Elevation

Techniques for Progressive Increase in Range of Motion

- Active and active-assistive range of motion in flexion, extension, ulnar deviation, dart thrower's pattern, and forearm pronation/supination
- Consider static-progressive or dynamic mobilization splinting if not showing weekly progress with ROM.

Other Therapeutic Exercises

- Gentle Theraputty exercises for hand intrinsic and extrinsic muscles, or use of soft foam exerciser if near pain free

Open and Closed Kinetic Chain Exercises

- Continue tendon gliding if fingers remain stiff.

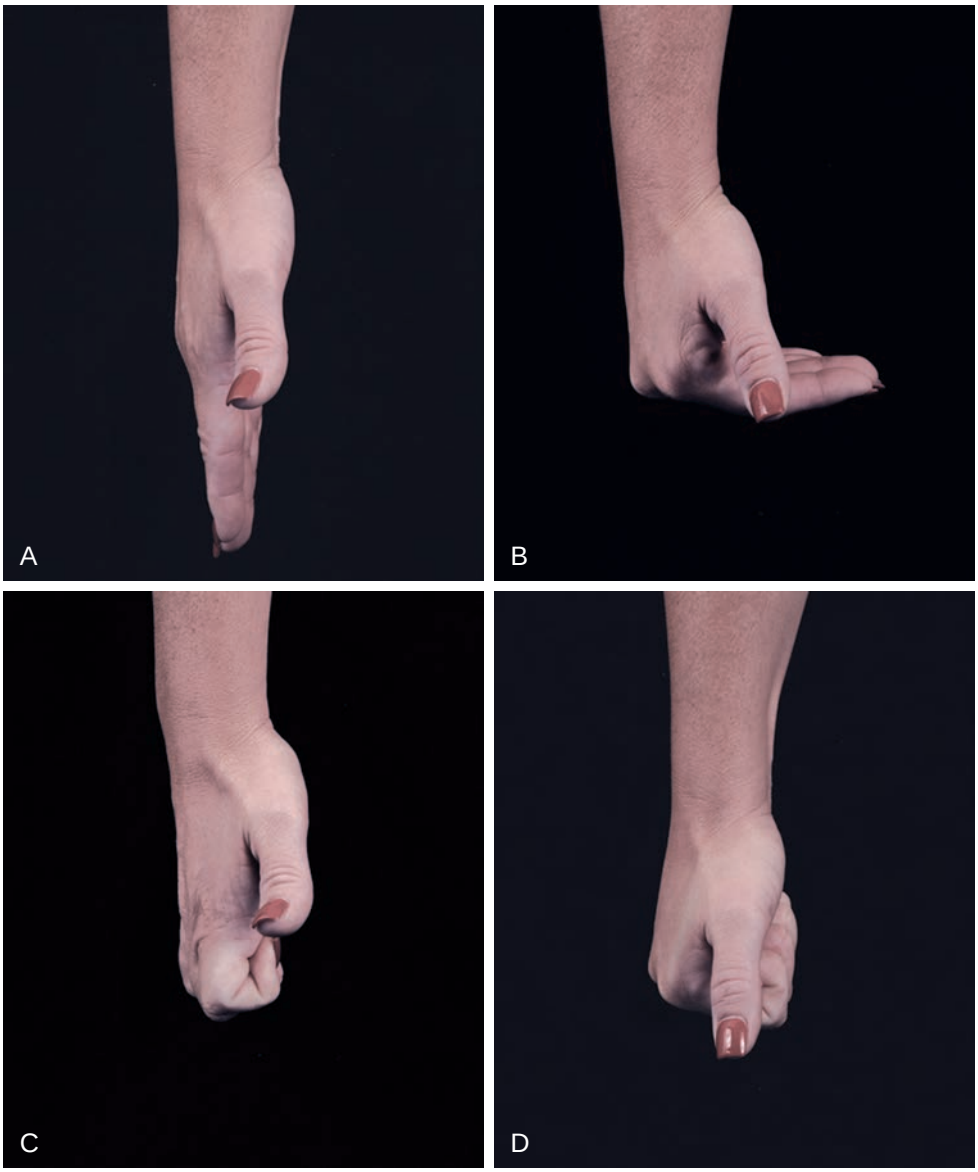

FIGURE 15-19. Tendon gliding exercise. **A,** Straight hand position**. B,** Hand in tabletop position. **C,** Hand in hook position. **D,** Hand in fist position.

TIMELINE 15-2: **Postoperative Rehabilitation after Open or Arthroscopic TFCC and Carpal Ligament Repair**

PHASE I (weeks 1 to 2 postop)	PHASE II (weeks 3 to 6 postop)	PHASE III (weeks 6 to 10 postop)

• Nonremovable splint for reconstructive; removable for debridement
• Compressive dressing to relieve swelling
• Active motion of fingers, elbow, and shoulder
• Elevation at heart or higher
• TFCC debridement: immediate active range of motion
• S-L ligament (partial): immobilization below elbow; finger ROM immediately
• TBS/TAS/TLS activities as tolerated, not involving affected extremity
	• TFCC repair: continue immobilization for 6 weeks
	• TFCC debridement:
	  • Discontinue splint
	  • Continued ROM, strengthening
	  • Return to sport unprotected week 2 to 6
	• SL ligament
	  • Immobilization 6 weeks then gentle finger ROM
	  • Grip strength exercises week 6
		• TFCC repair:
		  • Begin active range of motion for wrist and forearm week 6
		  • Begin strengthening exercises week 8
		• S-L ligament: finger and wrist ROM starting week 6
		• Active and active assist for goal 80% normal active ROM TBS/TAS/TLS activities tolerated
		• Gentle strengthening exercises for hand intrinsics and extrinsics

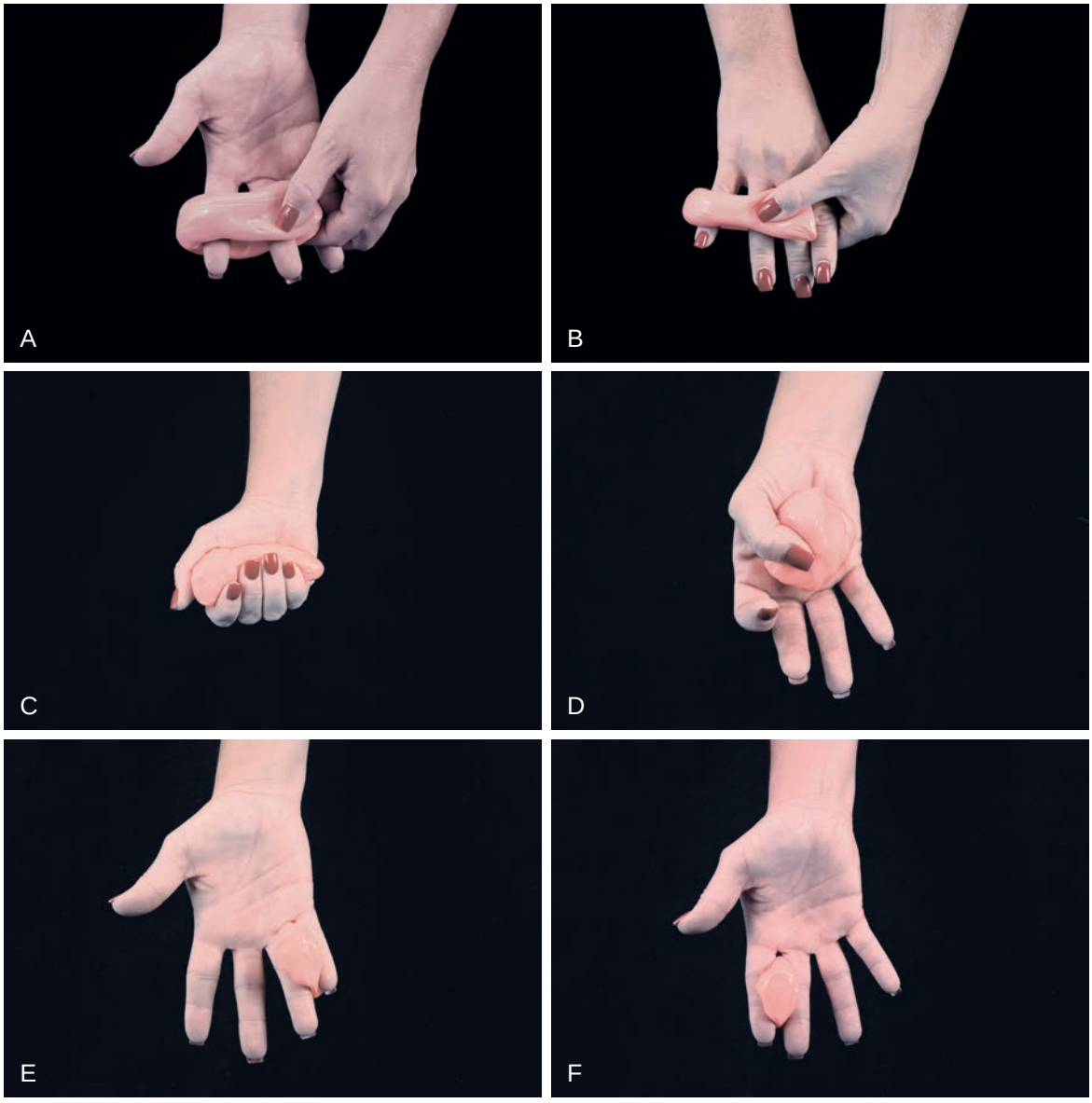

FIGURE 15-20. Interosseus Theraputty exercise. **A,** Volar view. **B,** Dorsal view. **C,** Grip Theraputty exercise. **D,** Thumb to fifth digit Theraputty exercise. **E,** Volar interosseus index finger Theraputty exercise. **F,** Volar interosseus small finger Theraputty exercise.

TIMELINE 15-2: **Postoperative Rehabilitation after Open or Arthroscopic TFCC and Carpal Ligament Repair** (Continued)

PHASE IV (weeks 10 to 14 postop)	PHASE V (weeks 14 to 24 postop)	PHASE VI (weeks 24 to 52 postop)

• TFCC repair:
  • Anticipate return to full activity week 12
  • Return to sport unprotected beginning week 14
• SL ligament (partial tear): screw/pin removal week 12, postoperative (screw removal) protect in removable splint
	• Active finger, grip, wrist and forearm strength
	• TBS/TAS/TLS activities as tolerated
		• SL ligament (complete): screw removal 5 to 6 months
		• SL ligament reconstruction:
		  • Screw removal 6 months
		  • Resume contact sports 6 months (protected)
		  • Resume contact sports 10 months (unprotected)

Techniques to Increase Muscle Strength, Power, and Endurance

- Theraputty exercises for hand intrinsic and extrinsic muscles if near pain free (Figure 15-20*A-F*)

Functional Exercises

- To be done only if near pain free
- Lifting and placing pegs or cones with forearm stabilized
- Dart thrower's motion (wrist extension + radial deviation to wrist flexion and ulnar deviation) while holding a small bottle or ball (Figure 15-21*A-C*).

Milestones for Progression to the Next Phase

- Pain-free AROM within available range of motion

Phase IV (postoperative weeks 10 to 14)

Goals

- Maintain a near pain free wrist
- 50% or better of normal grip strength
- 80% or better of normal active range of motion

Management of Pain and Swelling

- Cryotherapy ad lib
- Compressive tubular dressing for forearm, wrist, and fingers
- Active motion of the fingers, elbow, and shoulder

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Mobilization as needed

Other Therapeutic Exercises

- TBS/TAS/TLS as tolerated

Techniques to Increase Muscle Strength, Power, and Endurance

- Grip PREs

Milestones for Progression to the Next Phase

- 50% of normal grip

Phase V (postoperative weeks 14 to 24)

Goals

- 80% of normal grip strength or better
- 80% of normal wrist and forearm AROM

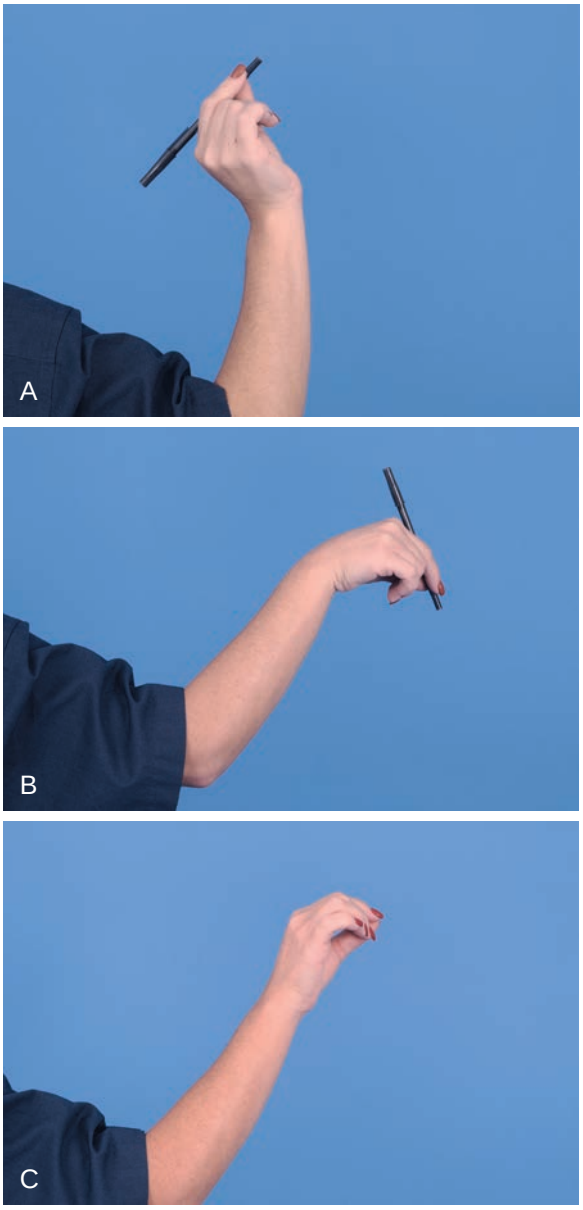

FIGURE 15-21. Dart thrower exercise. **A,** Initial phase. **B,** Midphase. **C,** End phase.

- Able to perform pain-free gentle conditioning for the upper extremity

Management of Pain and Swelling

- Cryotherapy ad lib

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Mobilization as needed

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Stretching with gentle distraction for the wrist in all planes of motion

Other Therapeutic Exercises

- TBS/TAS/TLS as tolerated

Techniques to Increase Muscle Strength, Power, and Endurance

- Pain-free, light resistance/high repetition upper extremity conditioning using dumbbells with the wrist maintained in neutral

Plyometrics

- Medicine ball thrown against trampoline, starting with two hands and progressing to one hand
- Dart thrower's motion using ball with elastic band attached

Functional Exercises

- General pain free upper extremity conditioning using dumbbells with wrist in neutral, and with very low resistance and high repetitions

Milestones for Progression to the Next Phase

- Grip strength is 80% of normal

Phase VI (postoperative weeks 24 to 52)

Goals

- Full functional use of the hand, wrist, and upper extremity
- Able to return sport or work activity
- Near pain free with all activities

Management of Pain and Swelling

- Cryotherapy as needed

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Mobilization as needed

Other Therapeutic Exercises

- TBS/TAS/TLS as tolerated

Techniques to Increase Muscle Strength, Power, and Endurance

- Grip strengthening, TAS PREs

Plyometrics

- Medicine ball thrown against trampoline, starting with two hands and progressing to one hand

Milestones for Progression to the Next Phase

- Full return to sport or activity

Criteria for Return to Sport

- Involved wrist and upper extremity is near pain free with current exercise program
- 80% of normal AROM of the wrist and forearm
- 80% of normal grip strength of the involved upper extremity

After Return to Sport

Continuing Fitness or Rehabilitation Exercises

- Stretching and range of motion exercises as demonstrated in therapy to maintain supple joint and reduce chance of subsequent injury

Exercises and Other Techniques for Prevention of Recurrent Injury

- Minimize overpressure into extremes of wrist motion

Evidence

Anderson M, Moran S, Cooney W, et al: Clinical comparison of arthroscopic versus open repair of triangular fibrocartilage complex tears. *J Hand Surg* 33A:675–682, 2008.

This is a retrospective review of outcomes for surgical repair of traumatic, peripheral TFCC comparing open versus arthroscopic techniques performed within 4 months of injury. This series assessed the results of treatment for 76 patients, 37 treated with arthroscopic management and 39 treated with open surgical management, with an average age of 32. Mean follow-up of 43 months demonstrated no significant difference in outcomes. Mayo Modified Wrist Score, DASH, VAS, and Patient Reported Wrist Evaluation score between open and arthroscopic surgical techniques with improvement in these outcomes noted for both approaches. Less postoperative loss of wrist motion noted after arthroscopic treatment.

Darlis N, Weiser R, Sotereanos D: Partial scapholunate ligament injuries treated with arthroscopic debridement and thermal shrinkage. *J Hand Surg* 30A(5):908–914, 2005.

This is a retrospective review of 16 patients treated with arthroscopic debridement and thermal shrinkage of the scapholunate ligament for Griessler grade 1 or 2 instability. Patients, average age 34 years old, were treated at mean interval of 5.4 months from injury to surgery after an unsuccessful trial of conservative treatments. At 19 months postoperative 87% of patients reported substantial pain relief. Marginal improvement in wrist flexion and significant improvement in grip strength was noted. There was no evidence of radiographic instability and 90% of patients reporting excellent or good outcomes at 19 months with no complications reported.

McAdams T, Swan J, Yao J: Arthroscopic treatment of triangular fibrocartilage wrist injuries in the athlete. *Am J Sports Med* 37(2):291–297, 2009.

This is a case series reviewing the arthroscopic repair or debridement of sixteen athletes between the years of 2001 and 2005, with an average follow-up of 32.8 months. Mean mini-DASH scores improved from 47.3 to 0 and mini-DASH sports module improved from 79.9 to 1.95. Return to play averaged 3.3 months.

Rettig A: Athletic injuries of the wrist and hand: Part I: traumatic injuries of the wrist. *Am J Sports Med* 31:1031, 2003.

This is a review of hand and wrist injuries associated with sports reviewing the cause of such injuries as well as the biomechanical findings with respect to the range of motion required in different sports. Emphasis is placed on problematic traumatic injuries such as carpal scaphoid fractures and hook of the hamate fractures as well as ligament injuries to the wrist with regard to diagnosis, treatment, and return to athletic competition.

Steinberg B: Acute wrist injuries in the athlete. *Orthop Clin North Am* 33:535–545, 2002.

This is a review of common wrist injuries encountered in the athlete, including a review of pertinent anatomy, diagnosis, and treatment of injuries including scaphoid, carpal, and distal radius fractures. The diagnosis and treatment of various ligamentous injuries are also reviewed.

Whipple T, Geissler W: Arthroscopic management of wrist triangular fibrocartilage complex injuries in the athlete. *Orthopedics* 16(9):1061–1067, 1993.

This is a review of Triangular Fibrocartilage Complex injuries, biomechanics of injury, diagnosis, and classification of these injuries. A review of surgical techniques including equipment and techniques for the debridement and repair of TFCC injuries, as well as the expected results of treatment.

Multiple-Choice Questions

QUESTION 1. When should range of motion begin after debridement of TFCC injuries?

A. Immediately as tolerated
B. 4 weeks postoperatively
C. 6 weeks postoperatively
D. 12 weeks postoperatively

QUESTION 2. When should grip strength and ROM training commence after arthroscopic treatment of partial scapholunate ligamentous injuries?

A. Immediately as tolerated
B. 6 weeks postoperatively
C. 12 weeks postoperatively
D. 20 weeks postoperatively

QUESTION 3. When should return to contact sports (unprotected) be allowed in patients undergoing SL ligament reconstruction?

A. As soon as patient obtains pain-free range of motion
B. 6 weeks postoperative
C. 12 weeks postoperative
D. 6 months postoperative

Answer Key

QUESTION 1. Correct answer: **A** (see Postoperative Rehabilitation Protocol week 0 to 2)

QUESTION 2. Correct answer: **B** (see week 4 to 6)

QUESTION 3. Correct answer: **D** (see After Surgery-Postoperative Rehabilitation: Overview of goals, important milestones and guidelines.)

Chapter 16



Jersey Finger and Mallet Finger

INTRODUCTION

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Epidemiology

Age/Sex

- Age: Predominantly in young, active individuals involved in contact sports
- Mallet finger
  - Definition: a finger injury that involves damage to the terminal extensor tendon insertion on the dorsal aspect of the distal phalanx, resulting in inability to actively extend the distal interphalangeal joint (Fig. 16-1)
  - Predominantly in young active males involved in contact sports
  - Males 1.5 times more affected than females in the general population
    - In a study by Simpson et al.[1] 851 patients presented with acute sport injuries. 18 presented with Mallet injuries, and 17 of these were men.
    - Incidence 10 to 19 year old males 1.2/10,000 per year
    - Incidence 10 to 19 year old females 0.5/10,000 per year
    - Incidence 20 to 29 year old males 1.5/10,000 per year
    - Incidence 20 to 29 year old females 0.4/10,000 per year
    - Incidence 30 to 39 year old males 1.3/10,000 per year
    - Incidence 30 to 39 year old females 0.5/10,000 per year
- Jersey finger
  - Definition: a finger injury that involves damage to the flexor digitorum profundus tendon, resulting in inability to actively flex the distal interphalangeal joint (Fig. 16-2)
  - Sex: predominantly in males, although female involvement has also been reported

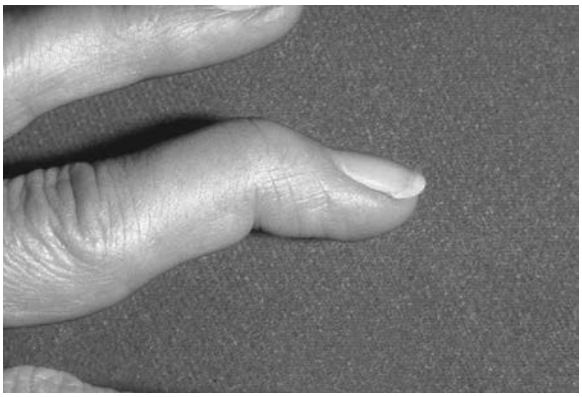

FIGURE 16-1. Small finger mallet injury characterized by loss of active extension at the DIP joint with resting posture of the DIP joint in flexion. *(Reprinted with permission from Hart RG, Kleinert HE, Lyons K: The Kleinert modified dorsal finger splint for mallet finger fracture. Am J Emerg Med 23:145–148, 2005.)*

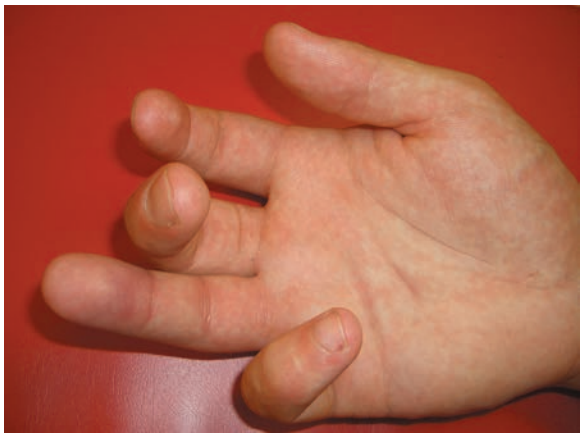

FIGURE 16-2. Jersey finger injury seen in the ring digit, causing inability to flex the DIP joint and make a full fist. *(Courtesy of Mr. Michael Hayton, MB.ChB, FRCS.)*

Sport

- Mallet finger
  - Any contact sport such as softball, baseball, football, basketball, or soccer in which the hand is subjected to force from a ball or another player
  - In most instances, the player's distal phalanx is subjected to some type of crush injury (often resulting in a distal phalanx fracture) or the distal interphalangeal joint (DIP) is forced into flexion (often resulting in a rupture of the terminal extensor tendon with or without a chip of bone).
- Jersey Finger
  - Mainly football and rugby
  - Any contact sport in which the athlete's hand is subjected to blunt forces from a ball or other player. It is seen in sports wherein an athlete's finger is forced into extension while trying to maintain a flexed position (i.e., rock climbing or when an athlete grabs another player's jersey who then quickly breaks away)
- Injury is common in any full contact sports, but mallet and jersey fingers represent a small number of traumatic injuries that occur in these sports.
- Rugby is still growing in popularity in the United States. As such, research is still lacking in the area. However, in high school students "rugby appears to have a lower injury rate than ice hockey, higher injury rates than basketball and soccer, and similar injury rates to football and wrestling."[2]

Position

- Mallet finger
  - Fielders in baseball and softball, receivers in football, goalkeeper in soccer
- Jersey finger
  - Defensive players involved in tackling
- Because of the nature of rugby, all playing positions require tackling. As such, it does not appear that any playing position results in a higher incidence of jersey or mallet finger injuries. The authors do not know of any literature that reports the predominance of these injuries with any specific position in rugby.

Pathophysiology

Intrinsic Factors

- Mallet finger
  - Extensor tendon insertion as the terminal tendon on the base of the dorsal aspect of the distal phalanx
- Jersey finger
  - The ring finger is the most frequently involved because it has the least independent motion, has a weaker flexor tendon insertion than the long finger, and absorbs most of the force during grip.

Extrinsic Factors

- Mallet Finger
  - The distal location of the finger tip
  - Catching a ball flying at a high velocity
  - Poor catching form or a lack of concentration during catching may contribute to this form of injury
- Jersey Finger
  - The player gets his or her finger caught in a jersey of a strong fabric worn by another player.
- Quarrie et al.[3] studied risk factors for injury in rugby players. They found the following factors to be associated with injury rate or time lost to injury: being in a higher grade, cigarette smoking, a history of prior injury, and a body mass index greater than 26.5. This study focused on general injuries of rugby players; it is speculated that similar factors would contribute to flexor or mallet finger in rugby players.

Traumatic Factors

- Mallet Finger
  - Can often occur when any type of force pushes the extended DIP joint into flexion. As the player extends his/her fingers to catch an incoming ball, the ball strikes the fingertips, forcing sudden flexion of the DIP joint.
  - Sudden flexion will lead to avulsion of the extensor tendon off the dorsal surface of the distal phalanx.
  - Can also occur when an athlete hits the distal end of his finger against another player, ground, or any other solid object.
- Jersey Finger
  - Forced hyperextension of the DIP joint while the finger is actively flexing.
  - The flexor digitorum profundus (FDP) tendon is avulsed off the volar surface of the distal phalanx
  - Often associated with an eccentric load on the flexed DIP joint. This is often seen when a player grabs another player's jersey who quickly pulls away, hence the name "Jersey Finger."

Classic Pathological Findings

- Mallet finger
  - Doyle[4] classified mallet finger into four types:
    - Type I: Closed trauma with loss of tendon continuity with or without avulsion fracture
    - Type II: Laceration at distal interphalangeal joint with loss of tendon continuity
    - Type III: Deep abrasion with loss of skin, subcutaneous tissue and tendon substance
    - Type IVA: Transepiphyseal fracture in children
    - Type IVB: Fracture fragment of the articular surface involving 20% to 50% of the distal phalanx
    - Type IVC: Hyperextension injury with articular fracture >50% the distal phalanx joint surface
  - Avulsion of the extensor tendon off its insertion on the base of the dorsal distal phalanx (also known as a soft tissue mallet)
  - An intraarticular bony fragment may or may not be avulsed at the insertion of the extensor mechanism (also known as a bony mallet).
  - As a result, a patient with mallet finger will have no active extension of the DIP joint and will have a significant extensor lag (see Fig. 16-1).

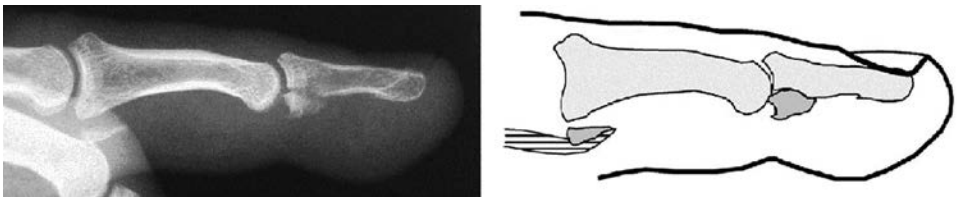

FIGURE 16-3. Type 3 Jersey finger: The avulsed tendon has a large bony fragment attached and is at the level of the A4 pulley. *(Reprinted with permission from Kang N, Pratt A, Burr N: Miniplate fixation for avulsion injuries of the flexor digitorum profundus insertion. J Hand Surg Br 28:363–368, 2003).*

- Jersey finger
  - Avulsed FDP with or without a bone fragment
  - Retraction of the FDP to a various degree
  - Ruptured vincula disrupts nutrition to the tendon
  - Muscle contraction occurs within ten days, making it difficult, if not impossible to regain original tendon length
  - Tendon sheath scarring occurs within 7 to 10 days of injury
  - There are five types of jersey finger:
    - Type I: The avulsed tendon retracts to the level of the palm. With this, the vinculum blood supply is often disrupted.
    - Type II: The avulsed tendon retracts to the proximal interphalangeal (PIP) joint. The vinculum blood supply stays intact.
    - Type III: The avulsed tendon has a large bony fragment attached and is at the level of the A4 pulley (Fig. 16-3).
    - Type IV: A combination of bone avulsion and a separate tendon avulsion. The FDP can then retract to flexor sheath or to the palm.
    - Type V: A combination of bony avulsion and a comminuted distal phalangeal fracture
  - A patient with jersey finger will have weakened grip strength and will show no active DIP motion with manual muscle testing of the FDP of the involved finger.

Clinical Presentation

History

- Mallet finger
  - Patient unable to straighten the DIP joint of the involved finger (see Fig. 16-1)
  - Pain over the DIP joint is usually present.
  - May be painless
  - Finger swelling
- Jersey finger
  - The patient often feels a pop in the finger.
  - Pain over the DIP joint may or may not be present.
  - Finger bruising may or may not be present.
  - Patients are unable to flex the DIP joint and cannot make a complete fist because the injured finger cannot flex to the palm.
- In both of the injuries, the patient often reports feeling a "pop" in the finger.
- Both injuries can result from blunt trauma to the hand. This can be the athlete's hand hitting the ball or while tackling or grappling with another player.
- Most players will continue to play the game despite the injury reporting "I just thought I jammed my hand."

Physical Examination

Abnormal Findings

- Mallet Finger
  - Loss of active DIP joint extension
  - Swelling, tenderness, and ecchymosis over the dorsal aspect of the DIP joint
  - Resting posture of DIP joint in flexion
  - Proximal interphalangeal PIP joint hyperextension can appear with attempts to extend the DIP joint, particularly in individuals with joint laxity
  - May observe a subungual hematoma in the nail of the involved finger
- Jersey finger
  - Inability to actively flex the DIP joint (see Fig. 16-2)
  - Swelling and ecchymosis over the DIP joint can be observed.
  - Tenderness can be elicited over the DIP joint.
  - Jersey Finger can sometimes involve hyperextension of the DIP joint owing to lack of balance between the flexor and extensor.
  - Limited PIP flexion can also be seen if the FDP retracts to the PIP joint. If the FDP retracts even further to the palm the athlete may then report tenderness in the palm.
  - Inability to make a fist

Pertinent Normal Findings

- Mallet Finger
  - Active flexion of the DIPJ is maintained.
  - Usually a closed injury with no break in the skin
  - Capillary refill should be normal.
  - Sensation in the fingertip should be intact.
- Jersey Finger
  - Active extension of the DIP joint is maintained.
  - Usually a closed injury without a break in the skin
  - Capillary refill should be normal, less than 2 seconds.
  - Sensation in the tip of the finger should be intact.

Imaging

- Mallet finger
  - Standard posteroanterior, oblique, and lateral x-rays of the involved finger should be sufficient to determine whether bone avulsion has occurred.
- Jersey finger
  - Standard posteroanterior, oblique, and lateral x-rays of the involved finger should be sufficient to determine whether bone avulsion has occurred.

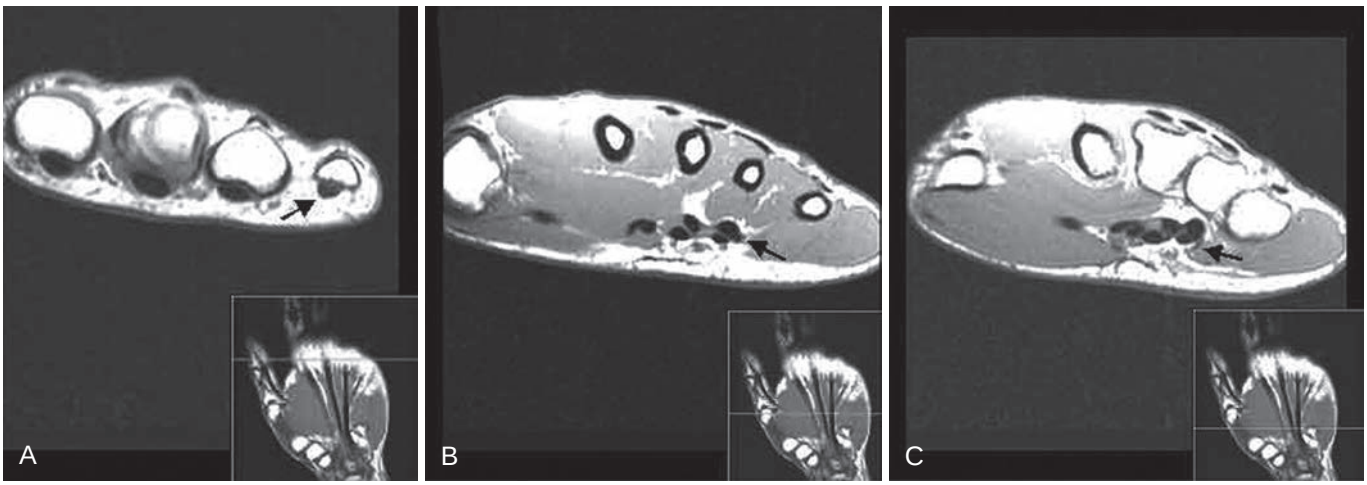

FIGURE 16-4. MRI and ultrasound of chronic jersey finger helping to determine the level of tendon retraction. *(Reprinted with permission from Masaki F, Isao T, Aya Y, Ryuuji I, Yohjiroh M: Spontaneous flexor tendon rupture of the flexor digitorum profundus secondary to an anatomic variant. J Hand Surg Am 32:1195–1199, 2007).*

- For chronic jersey finger injuries ultrasound or MRI can be useful because they can help determine the level of tendon retraction (Fig. 16-4).

Differential Diagnosis

- Mallet finger
  - Transverse distal phalangeal fracture: Radiographic findings can determine the type and nature of the distal phalangeal fracture.
  - Seymour's fracture: Open fracture through the nail bed especially in children with active growth plates. Careful physical exam and radiographs can rule out this type of frequently missed injury (Fig. 16-5).



FIGURE 16-5. Pediatric Seymour's fracture. *(Reprinted with permission from Al-Qattan MM: Extra-articular transverse fractures of the base of the distal phalanx (Seymour's fracture) in children and adults. J Hand Surg Br 26:201–6, 2001).*

  - PIP joint volar injury and/or laxity resulting in Swan neck deformity with hyperextension of the PIP joint and flexed posture of the DIP joint (Fig. 16-6)
- Jersey Finger
  - Transverse distal phalangeal fracture: Radiographic finding can determine the type and nature of the distal phalangeal fracture.

Treatment

Nonoperative Management

- Mallet finger
  - Volar or dorsal orthotic positioning of the DIP joint in full extension for 2 to 6 months, depending on the extent of injury and patient progress (Fig. 16-7).
  - Most mallet injuries can be treated with orthoses.
  - Insufficient evidence to support superiority of a specific type of orthosis.
- Jersey finger
  - Jersey finger cannot be corrected without surgery, but an athlete can still have a high level of functioning



FIGURE 16-6. PIP joint volar injury and/or laxity resulting in Swan neck deformity with hyperextension of the PIP joint and flexed posture of the DIP joint (see Fig. 16-5).



FIGURE 16-7. Mallet finger orthosis positioning the DIP joint in extension.

without active flexion of the DIP joint. However, the long-term consequences must be weighed before making this decision.
- Nonsurgical management after injury includes early mobilization emphasizing range of motion exercises.

Guidelines for Nonoperative Treatment

- Mallet Finger
  - Closed injury
  - No bony avulsion
  - Bony avulsion that is minimally displaced and is less than 30% of the articular surface of the distal phalanx
  - Patient's ability to understand and comply with the orthotic use protocol
- Jersey finger
  - Nonsurgical treatment is reserved for chronic injuries or in those individuals who are either unwilling or unable to comply with a vigorous postoperative therapy protocol.
  - Nonsurgical management requires the patient's understanding of the permanent loss of active DIP joint flexion.

Surgical Indications

- In general, jersey finger is treated surgically when diagnosed without delay.

Absolute

- Mallet finger
  - Open injuries
  - Closed fracture with more than 30% of the articular surface displaced (Fig. 16-8)
- Jersey finger
  - Open Injuries
  - Diagnosis is made early and surgery can be performed within 7 to 10 days of injury, although there are reports of successful repair in injuries outside this window of injuries.
  - Types 1 to 5 injuries

Relative

- Mallet finger
  - Chronic injuries, more than 6 months old that have failed conservative treatment
  - Demand for faster recovery and earlier return to function
  - Cosmetic preferences
  - Poor patient compliance
- Jersey finger
  - Chronic injuries

Aspects of History, Demographics, or Exam Findings that Affect Choice of Treatment

- Mallet finger
  - Patient age
  - Hand dominance
  - Patient occupational demands
  - Cosmetic preferences: Surgical treatment may lead to an improved cosmetic appearance.
  - Recovery period: Surgical treatment often leads to a faster recovery and less daily impedance as a result of no splint wear.
- Jersey finger
  - The time elapsed since injury
  - Within 7 to 10 days of injury the injured tendon retracts and scars, rendering surgical treatment less effective.
  - Size of bony fragment
  - Extent of proximal retraction of the tendon
  - Age
  - Patient demand

Aspects of Clinical Decision Making When Surgery is Indicated

- Mallet finger
  - Degree of bony displacement
  - Acuity or chronicity of the injury
  - Patient age and growth plate status
- Jersey finger
  - Type of jersey finger seen (Pathophysiology section)



FIGURE 16-8. Mallet fracture: bony avulsion that is minimally displaced and is less than 30% of the articular surface of the distal phalanx. *(Reprinted with permission from Zhang X, Meng H, Shao X, Wen S, Zhu H, Mi X: Pull-out wire fixation for acute mallet finger fractures with k-wire stabilization of the distal interphalangeal joint. J Hand Surg Am 35:1864–1869, 2010.)*

Evidence

Mallet Finger

Al-Qattan MM: Extra-articular transverse fractures of the base of the distal phalanx (Seymour's fracture) in children and adults. *J Hand Surg Br* 26(3):201–206, 2001.

This case series looked at 25 adult and pediatric patients who sustained a Seymour open fracture, which presents clinically as a mallet injury and a nail plate injury and must be ruled out. (Level IV evidence)

Clayton RA, Court-Brown CM: The epidemiology of musculoskeletal tendinous and ligamentous injuries. *Injury* 39(12):1338–1344, 2008.

This study, set in the UK, describes the epidemiology of a range of adult musculoskeletal soft tissue injuries in a well-defined catchment population of about 535,000. Demographic details over 5 years were recorded prospectively. Eighteen ligamentous injury types were studied including mallet finger and data was stratified according to age group and sex. (Level IV evidence)

Handoll HH, Vaghela MV: Interventions for treating mallet finger injuries. *Cochrane Database Syst Rev* (3):CD004574, 2004.

This review looked at randomized or quasi-randomized clinical trials evaluating different interventions, including no intervention for treating mallet finger injuries, and included four trials that involved 283 mallet finger injuries. The authors concluded that there was insufficient evidence to establish the relative effectiveness of different, either custom-made or off-the-shelf, finger splints used for treating mallet finger injury. (Review)

Pike J, Mulpuri K, Metzger M, et al: Blinded, prospective, randomized clinical trial comparing volar, dorsal, and custom thermoplastic splinting in treatment of acute mallet finger. *J Hand Surg Am* 35(4):580–588, 2010.

This prospective, randomized study of 87 with Type I mallet finger injuries randomized the patients to three conservative treatment groups: volar padded aluminum splint, dorsal padded aluminum splint, and custom thermoplastic. No lag differences were demonstrated radiographically after 12 weeks (Therapeutic Level II evidence).

Simpson D, Queen MM, Kumar P: Mallet deformity in sport. *J Hand Surg Br* 26B(1):32–33, 2001.

This article describes cases of acute sporting injuries that were treated at an orthopedic trauma unit, in a 4-month time period. Mallet finger made up a small amount of cases seen and did have excellent functional outcomes. (Level IV evidence)

Wehbe MA, Schneider LH: Mallet fractures. *J Bone Joint Surg Am* 66A(5):658–669, 1984.

In this retrospective study, 21 patients who had bone-involved mallet finger injuries were treated either conservatively or surgically. Mean follow up was 3.25 years. Radiographic assessment revealed that bone remodeling and reconstitution of the articular surface and preservation of the joint space in all digits. In addition, there was a near-normal range of painless motion in all but one finger. Surgical treatment offered no advantage over splinting and introduced more morbidity. The authors subsequently concluded that "most mallet fractures can be treated conservatively, ignoring joint subluxation and the size and amount of displacement of the bone fragment." (Level IV evidence)

Zhang X, Meng H, Shao X, et al: Pull-Out Wire Fixation for Acute Mallet Finger Fractures With K-Wire Stabilization of the Distal Interphalangeal Joint. *J Hand Surg Am* 35A(11):1864–1869, 2010.

The aim of this study was to describe and assess a surgical technique for the treatment of mallet finger fractures using a pull-out wire with K-wire stabilization of the distal interphalangeal (DIP) joint in extension. (Level IV evidence)

Jersey Finger

Evans RB: A study of the zone 1 flexor tendon injury and implications for the treatment. *J Hand Ther* 3(3):133–148, 1990.

This article describes early motion protocol for patients who have had surgical repair of Zone 1 Flexor tendon injuries then reviews the clinical results. (Level IV evidence)

Evans RB: Zone I flexor tendon rehabilitation with limited extension and active flexion. *J Hand Ther* 18(2):128–140, 2005.

This study looks at the outcomes for 41 patients who had surgical repairs of Zone 1 FDP tendon injuries. Surgery was followed by therapy in which the patient performed an early active flexion protocol with limited extension. These patients were followed for 10 years and showed a mean total active range of motion that was 81% of their normal motion. (Level IV evidence)

Kang N, Pratt A, Burr N: Miniplate fixation for avulsion injuries of the flexor digitorum. *J Hand Surg Br* 28B(4):363–368, 2003.

This article describes the use of a miniplate and cortical screws in the treatment of five cases of flexor digitorum profundus (FDP) tendon avulsion. One case was type II, three cases were type III, and one case was type IV. Near normal joint congruity was restored together with bony union in all cases. Six months after surgery four cases had near normal range of motion at the distal interphalangeal joint compared with the contralateral uninjured finger. These four patients were to return to their previous activities without restriction by 3 months. One repair of a type III avulsion ruptured but the distal interphalangeal joint was pain free and stable and the patient declined further surgery. Miniplate fixation offers some advantages over existing methods of repair and adds to the range of techniques available for reattachment of the FDP tendon in these injuries. (Level IV evidence)

Leddy JP, Packer JW: Avulsion of the profundus tendon insertion in athletes. *J Hand Surg Am* 2A(1):66–69, 1977.

This article looked at 36 jersey fingers retrospectively and developed the early classification system for flexor tendon avulsion injuries (Types 1, 2, and 3). The authors found that Type 1 injuries should be repaired within 7 days, whereas Type 2 injuries can be repaired within a few months. They suggested that prompt diagnosis and surgical repair within 1 week result in the best outcomes. (Level IV evidence)

Lunn PG, Lamb DW: "Rugby finger"—avulsion of profundus of ring finger. *J Hand Surg Br* 9B(1):69–71, 1984.

This is a study of nine patients who sustained an isolated avulsion injury of the FDP tendon, all to the ring finger while playing rugby. The patients all presented later than 4 weeks and were treated surgically with palmaris tendon grafting, followed by 6 to 9 weeks of physiotherapy. The mean follow up was 4.3 years and hand function improved in all cases. The authors subsequently recommended that experienced surgeons should use this technique for the treatment of young and motivated patients. (Level IV evidence)

Masaki F, Tasaki I, Aya Y, et al: Spontaneous flexor tendon rupture of the flexor digitorum profundus secondary to an anatomic variant. *J Hand Surg Am* 32A(8):1195–1199, 2007.

This is a case report of flexor digitorum profundus tendon rupture of the little finger, which was predisposed by an anatomic variation of the tendon. Intraoperative findings and magnetic resonance imaging of the opposite hand suggested that the flexor digitorum profundus tendons of the ring and the little finger bifurcated. The patient had tendon reconstruction and regained function. (Level of evidence: Case report)

Sawaya ET, Choughri H, Pelissier P: One-stage treatment of delayed 'jersey finger' by z-step lengthening of the flexor digitorum profundus tendon at the wrist. *J Plast Reconstr Aesthet Surg* 65(2):264–266, 2012.

This is one of a few case reports on FDP tendon avulsions in females. The authors presented a case of a 19 year old female who had acquired a Type 2 injury 6 weeks prior to presentation. She was successfully treated surgically by z-step lengthening of the FDP at the wrist. (Level of evidence: Case report).

Tuttle HG, Olvey SP, Stern PJ: Tendon avulsion injuries of the distal phalanx. *Clin Orthop Relat Res* 445:157–168, 2006.

This is one of the latest review articles about jersey finger. The authors concisely summarized the current FDP tendon avulsion classification system (Types 1 to 5). (Review)

Wenger DR: Avulsion of the profundus tendon insertion in football players. *Arch Surg* 106:145–149, 1973.

This case series looked at four teenage American football players that acquired FDP avulsion injuries to the ring finger; three of the four injuries were in defensive players. One of the players did not experience any pain. The author warned that the diagnosis may be delayed if physicians that deal with athletes are not aware of FDP avulsion injuries. (Level IV evidence)

Rugby Injuries

Collins CL, Micheli LJ, Yard EE, et al: Injuries Sustained by high school rugby players in the United States, 2005-2006. *Arch Pediatr Adolesc Med* 162(1):49–54, 2008.

This article describes the incidence and characteristics of injuries among US high school rugby players and identifies possible injury risk factors. (Level 4 evidence)

Quarrie KL, Alsop JC, Waller AE, et al: The New Zeland Rugby injury and performance project. VI. A prospective cohort study of risk factors for injury in rugby union football. *Br J Sports Med* 35(3):157–166, 2001.

This article examines the association between potential risk factors and injury risk. Using a multiple regression model to study a prospective cohort of 258 male rugby players, the authors concluded that previous injury is a predictor of injury incidence and of missing play. (Level 2 evidence)

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Multiple-Choice Questions

Mallet Finger

QUESTION 1. What kind of fingertip injury clinically presents similar to a mallet finger and should be ruled out immediately because of its potential for causing complications?

A. Transverse fracture of the distal phalanx
B. Jersey finger
C. Seymour's fracture
D. Subungual hematoma

QUESTION 2. Most mallet injuries can be treated with

A. open reduction and internal fixation.
B. splinting.
C. percutaneous pinning.
D. observation.

QUESTION 3. A surgeon may perform surgery to treat a mallet injury if

A. the injury occurred 1 month prior to presentation.
B. the injury occurred 6 months prior to presentation.
C. the patient demands surgery because he/she has read that surgery results in better cosmetic outcomes.
D. the injury involves 35% of the articular surface of the distal phalanx and was displaced.

QUESTION 4. Mallet finger injures are characterized by

A. loss of passive DIP joint extension.
B. resting posture of PIP joint hyperextension.
C. loss of active DIP joint extension.
D. inability to flex the DIP joint.

QUESTION 5. Mallet finger injuries are most often treated with

A. 3 weeks of nighttime splinting.
B. DIP joint ROM exercises and taping.
C. 6 to 8 weeks of uninterrupted DIP joint extension splinting.
D. splinting of the DIP and PIP joints for 1 month during the day.

Jersey Finger

QUESTION 6. Acute flexor digitorum profundus avulsion injuries should be treated surgically as early as possible because

A. tendon sheath scarring tends to occur within 7 to 10 days of injury.
B. tendon retraction and myostatic contraction can permanently shorten the tendon.
C. rupture of the vincula disrupts the transport of nutrition to the tendon.
D. All of the above

QUESTION 7. The Ring finger is the most frequently involved digit in jersey finger because

A. the ring finger has the least independent motion.
B. the ring finger has a weaker FDP insertion compared to the long finger.
C. the ring finger absorbs most of the force during grip.
D. All the above

QUESTION 8. What factor is the least important when planning a surgery for jersey finger?

A. Hand dominance
B. The duration since injury
C. The level of tendon retraction
D. The size of the bony fragment

Answer Key

QUESTION 1. Correct answer: **C** (see Differential Diagnosis)

QUESTION 2. Correct answer: **B** (see Treatment)

QUESTION 3. Correct answer: **D** (see Surgical Indications)

QUESTION 4. Correct answer: **C** (see Classic Pathological Findings)

QUESTION 5. Correct answer: **C** (see Treatment.)

QUESTION 6. Correct answer: **D** (see Aspects of History, Demographics, or Exam Findings that Affect Choice of Treatment)

QUESTION 7. Correct answer: **D** (see Pathophysiology: Intrinsic Factors)

QUESTION 8. Correct answer: **A** (see Aspects of History, Demographics, or Exam Findings that Affect Choice of Treatment)

NONOPERATIVE REHABILITATION FOR MALLET FINGER

A. Lee Osterman, MD, Abdo Bachoura MD, Sidney M. Jacoby, MD, Terri M. Skirven, OTR/L, CHT, and Jason A. Suda, MOTR/L

GUIDING PRINCIPLES OF NONOPERATIVE REHABILITATION

JERSEY FINGER

- Surgery is required to restore active DIP joint flexion
- Nonoperative management addresses:
  - Postinjury swelling
  - Limitations in range of motion of the adjacent joints and digits
  - Loss of full grip function

MALLET FINGER

- Late management does not preclude successful outcome of nonoperative management. People treated 4 months after injury did as well as an early-treatment group (2 months out).[1]
- Type of mallet injury (i.e., bony versus soft)
- Doyle's classification of mallet injury
  - Type I: Closed trauma with loss of tendon continuity with or without avulsion fracture
  - Type II: Laceration at distal interphalangeal joint with loss of tendon continuity
  - Type III: Deep abrasion with loss of skin, subcutaneous tissue, and tendon substance
  - Type IVA: Transepiphyseal fracture in children
  - Type IVB: Fracture of articular surface of 20% to 50% hyperflexion injury
  - Type IVC: Hyperextension injury with articular fracture
  - Condition of proximal joints (i.e., hyperextension of PIP joint or secondary swan neck deformity)
  - Patient compliance
  - Open or closed injury
  - Associated injuries

Phase I (weeks 0 to 6 ± 2): Bony Mallet Injuries Will Heal Faster than Soft Tissue Mallet Injuries

Protection

- Custom fabricated DIP joint extension orthosis (Fig. 16-9)
  - Can include a PIP joint hyperextension block when mallet injury is accompanied by a swan neck deformity (Fig. 16-10)
- Additional Coban wrap to secure splint as needed

Management of Pain and Swelling

- Can include if needed 2 to 4 days after injury:
  - Compressive wraps
  - Ice



FIGURE 16-9. Orthosis for mallet finger supports the DIP joint in full extension to mild hyperextension.



FIGURE 16-10. Orthosis for a mallet finger with secondary swan neck deformity. The orthosis blocks the PIP joint from full extension and maintains the DIP joint in full extension to slight hyperextension.

Techniques for Progressive Increase in Range of Motion

- PIP and MP ROM of the involved digit with DIP splint in place
- No DIP ROM during phase I
- ROM of all uninvolved digits
- Isometric extension of DIP joint while in the splint
- Some players return immediately to play; however, they play with the mallet splint taped to secure it to the finger.
  - Players are reminded that if the splint falls off they will have to start the immobilization process all over.
- With splint in place the patient may continue total body strengthening, core stability, total arm/leg strengthening, any cardiovascular activity
- No participation in contact drills
- The patient may resume all practice activities as long as splint stays in place; however, the athlete is encouraged to avoid contact drills in which the hand may be grabbed and the splint pulled off. Because the injury is only at the level of the distal end of the finger a rugby player will find he or she can participate in most noncontact drills and activities the player was involved with prior to their injury.

Milestones for Progression to the Next Phase

- Adherence to continuous splinting program in phase I
- Absence of extensor lag or droop with splint off by week 6 to 8
- Ability to actively extend or maintain DIP extension with the splint off by week 6 to 8

TIMELINE 16-1: Nonoperative Rehabilitation of Mallet Finger

PHASE I (weeks 1 to 6 to 8)	PHASE II	
	(weeks 6 to 8 to 10)	(weeks 10 to 12)
• Use of custom fabricated DIP joint orthosis with DIP joint in full extension to slight hyperextension • Patient education regarding importance of uninterrupted orthosis use/splint use • Patent education regarding skin care and hygiene while maintaining the DIP joint in extension • AROM exercise of the PIP joint and the MCP joint • Stabilization of the MCP joint during PIP joint exercises (blocking) • Isometric extension of the DIP joint within the orthosis/splint • Reinforce splint security using tape or Coban when sleeping and during activities as needed. • Regular follow-up visit to therapist for monitoring of orthosis fit, skin condition, ROM of the uninvolved joints and protocol compliance • Can engage in noncontact sports with additional tapping to secure splint.	• If no extensor lag, begin active DIP joint ROM out of the splint. • Controlled rate of recovery of DIP joint flexion to avoid over stress to the extensor tendon caused by overzealous flexion and fisting • Emphasize DIP joint extension while introducing DIP joint flexion exercises to avoid development of DIP joint extensor lag. • Reduce use of mallet splint/orthosis in increasing increments of time over the next 2 weeks while continuing mallet splint at night. Adjust rate of weaning based on extensor lag: i.e., if lag develops increase use of splint; if no lag is present, increase intervals of no splint use during the day. • While the splint is off kinesiotape can be applied dorsally to provide additional support for DIP extension. • Begin ADL involving finger flexion without resistance. • Avoid repetitive gripping exercises. • Continue with sport activities with splint in place and secured with tape.	• Continue splint use at night based on need (presence of development of extensor lag when splint is not on). • Light strengthening exercise using therapy putty, alternating flexion and extension exercises • Gradually resume ADL and other activities while monitoring for extensor lag. • Engage in sport activities with splint and or taping.

Phase II (weeks 8 to 10)

Protection

- Begin to wean from splint. Splint is worn in public, at night, or during activities in which the finger may be exposed to stress for another 2 to 4 weeks.

Management of Pain and Swelling

- Can continue ice and Coban wraps as needed

Techniques for Progressive Increase in Range of Motion

- If the patient is compliant and the extensor lag is minimal (about 10°) the patient may be weaned from the splint and gentle DIP range of motion can begin (i.e., gentle fisting or tendon glides).
- Emphasis is also placed on DIP active extension. Flexion/extension exercises should be done in the favor of DIP extension to reduce the likelihood of a DIP lag. The athlete is instructed to resume use of the splint if the extensor lag worsens.
- The athlete is weaned from the splint but encouraged to wear the splint in public, when sleeping at night, and in any activities in which a forceful grip may be used
  - When performing light activities the splint can be off but kinesiotape can be used over the dorsal aspect of the finger to offer support for DIP extension.
- At 9 weeks the athlete is progressed to DIP blocking exercises if the lag does not increase with gentle ROM activities. Again active extension of the DIP joint is emphasized over flexion of the DIP joint.
- At 10 weeks the patient can resume strengthening and full contact sports if the lag does not worsen with DIP blocking exercises. However, during these activities the patient can be encouraged to tape or continue to use the splint for DIP extension if a mild lag still persists. A slight lag is not uncommon (about 10 to 15° even after operative treatment)
  - Kinesotaping (Fig. 16-11) can provide flexible support for DIPJ extension. Can be used as the patient resumes sports or resistive activities of daily living (ADLs)

Other Therapeutic Exercises

- The athlete may return to practice and sports activities as long as these activities do not increase or cause an extensor lag of the DIP joint.
  - It is recommended that the athlete first start with weight lifting or plyometrics, progress to tackling and contact drills, and then full contact rugby games, monitoring for extensor lag throughout this time period.
  - If the extensor lag begins to increase the athlete then returns to splint use until extensor lag improves. Once lag improves the athlete may try to progress with activities again.
  - It is possible to have some noncompliant athletes wear the mallet splint for 20 weeks before weaning from a splint.

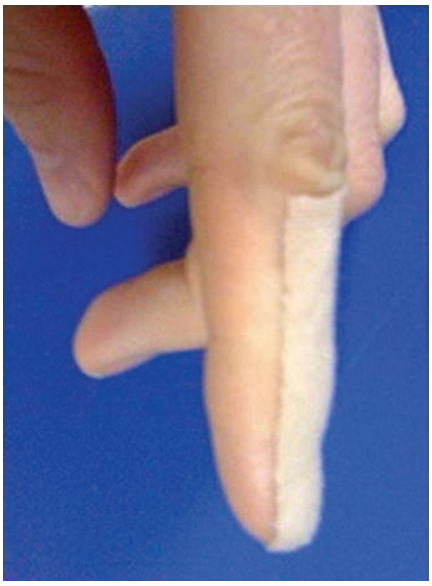

FIGURE 16-11. Kinesiotape used to provide support for DIP joint extension during the phase of weaning from the mallet splint.

  - It is important to note that with a nonoperative or operative treatment, it is possible for an extensor lag to remain (of about 10°) after healing but this lag will not limit function. Only if the extensor lag increases with activity should the patient return to splint use. It is recommended that a therapist follow the athlete while he or she returns to sport activities for the first 1 to 2 weeks in order to monitor for the development of extensor lag.

Milestones for Progression to Advanced Sport-Specific Training and Conditioning

- There are no additional stages of rehabilitation for nonoperative mallet finger treatment.

Evidence

Al-Qattan MM: Extra-articular transverse fractures of the base of the distal phalanx (Seymour's fracture) in children and adults. *J Hand Surg Br* 26(3):201–206, 2001.

This case series looked at 25 adult and pediatric patients who sustained a Seymour open fracture, which presents clinically as a mallet injury and a nail plate injury and must be ruled out. (Level IV evidence)

Handoll HH, Vaghela MV: Interventions for treating mallet finger injuries. *Cochrane Database Syst Rev* (3):CD004574, 2004.

This review looked at randomized or quasi-randomized clinical trials evaluating different interventions, including no intervention for treating mallet finger injuries, and included four trials that involved 283 mallet finger injuries. The authors concluded that there was insufficient evidence to establish the relative effectiveness of different, either custom-made or off-the-shelf, finger splints used for treating mallet finger injury. (Review)

Kalaninov DM, Hoepfner PE, Hartigan BJ, et al: Nonsurgical treatment of closed mallet finger fractures. *J Hand Surg* 30A:580–586, 2005.

In this study 22 closed bony mallet injuries were treated nonsurgically with DIP extension splints. With a mean splinting time of 5.5 weeks patients expressed negligible pain, minimal difficulties with activities of daily living, and showed high satisfaction with finger function but were marginally satisfied with the appearance of the finger. (Level IV evidence)

O'Brien LJ, Bailey MJ: Single blind, prospective, randomized controlled trial comparing dorsal aluminum and custom thermoplastic splints to stack splints for acute mallet finger. *Arch Phys Med Rehabil* 92(2):191–198, 2011.

In this study 64 people were treated with prefabricated stack splints, dorsal padded aluminum splints, or custom-made thermoplastic splints. All were worn for 8 weeks continuously, with a 4 week graduated withdrawal and exercise program. There was no difference in primary outcomes between the groups. The Stack and dorsal splint groups had a significant rate of treatment failure. (Level I evidence)

Okafor B, Mbubaegbu C, Munshi I, et al: Mallet Deformity of the finger: Five-year follow-up of conservative treatment. *J Bone Joint Surg* [Br] 79-B:544–547, 1997.

This article looked at 31 patients that were treated with stack splinting for a mean time of 7.2 weeks. 48% had osteoarthritic changes, 29% had a swan-neck deformity; extensor lag greater than 10° for 35% but patient satisfaction was generally high with little functional impairment. (Level IV evidence)

Pike J, Mulpuri K, Metzger M, et al: Blinded, prospective, randomized clinical trial comparing volar, dorsal, and custom thermoplastic splinting in treatment of acute mallet finger. *J Hand Surg Am* 35(4):580–588, 2010.

This prospective, randomized study of 87people with Type I mallet finger injuries randomized the patients to three conservative treatment groups: volar padded aluminum splint, dorsal padded aluminum splint, and custom thermoplastic. No lag differences were demonstrated radiographically after 12 weeks. (Level II evidence)

Simpson D, Queen MM, Kumar P: Mallet deformity in sport. *J Hand Surg* (British and European Volume). 26B(1):32–33, 2001.

This article describes cases of acute sporting injuries that were treated at an orthopedic trauma unit in a 4-month time period. Mallet finger made up a small amount of cases seen in did have excellent functional outcomes.

Wehbe MA, Schneider LH: Mallet fractures. *J Bone Joint Surg Am* 66(5):658–669, 1984.

In this retrospective study, 21 patients who had bone-involved mallet finger injuries were treated either conservatively or surgically. Mean follow up was 3.25 years. Radiographic assessment revealed bone remodeling and reconstitution of the articular surface and preservation of the joint space in all digits. In addition, there was a near-normal range of painless motion in all but one finger. Surgical treatment offered no advantage over splinting and introduced more morbidity. The authors subsequently concluded that "most mallet fractures can be treated conservatively, ignoring joint subluxation and the size and amount of displacement of the bone fragment." (Level IV evidence)

REFERENCES

1. Gaberman SF, Diao E, Peimer CA: Mallet finger: Results of early vs. delayed closed treatment. *J Hand Surg* 19:850–852, 1994.

Multiple-Choice Questions

QUESTION 1. What is a potential problem that may occur during Phase I of mallet finger rehabilitation?

A. Skin breakdown
B. Loss of PIP ROM
C. Inadequate position of DIP within splint
D. All of the above

QUESTION 2. What indications are used to determine when to initiate DIP ROM after six weeks in the non-operative treatment of mallet finger?

A. DIP joint extensor lag
B. PIP joint hyperextension
C. Inability to flex the DIP joint
D. Skin breakdown

QUESTION 3. The most significant risk of nonoperative management of jersey finger is

A. loss of grip strength.
B. loss of tenodesis activity of the involved finger.
C. hyperextension of the PIP joint.
D. DIP joint flexion contracture.

QUESTION 4. When a mallet finger injury is accompanied by a swan neck deformity, what modification should be made to the orthosis/splint?

A. DIP joint should be positioned in slight flexion.
B. PIP joint should be blocked from full extension with DIP joint supported in slight hyperextension.
C. PIP joint should be blocked from full extension but the DIP should be allowed to flex.
D. None of the above

QUESTION 5. A rugby player with a mallet finger injury can return to play

A. immediately as long as the finger is taped.
B. with the mallet splint on and taped to secure it.
C. after 3 months of splinting.
D. as soon as the pain and swelling subside.

Answer Key

QUESTION 1. Correct answer: **D** (see Phase I)

QUESTION 2. Correct answer: **A** (see Phase II)

QUESTION 3. Correct answer: **A** (see Guiding Principles of Nonoperative Rehabilitation box)

QUESTION 4. Correct answer: **B** (see Phase I)

QUESTION 5. Correct answer: **B** (see Phase I)

POSTOPERATIVE REHABILITATION FOR MALLET FINGER AND JERSEY FINGER

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Indications for Surgical Treatment

- Failure or noncompliance of non-operative treatment for mallet finger
- If the patient finds the lack of active DIP flexion with Jersey finger, or DIP joint extension with mallet finger prohibitive of work tasks, participation in sport activities, or other activities of daily living

Brief Summary of Surgical Treatment

Major Surgical Steps

Jersey Finger

- Under either regional, general, or local anesthesia a well-padded pneumatic tourniquet is placed about the affected limb and set to 250 mm Hg.
- Preoperative antibiotics are typically delivered.
- Either a volar-based Bruner incision or a midlateral incision is utilized to visualize the flexor tendon sheath; hemostasis is achieved with bipolar cautery.
- Critical pulleys, including A2 and A4, are preserved during surgical dissection.
- Proximal and distal stumps of the avulsed tendon are identified (Fig. 16-12*A*); frequently a "milking maneuver" is performed to reveal the proximal stump of the avulsed flexor tendon.
- If the proximal stump has retracted far proximal, either a Swanson suture passer or other thin device such as a pediatric feeding tube or red rubber catheter may be placed retrograde through the flexor tendon sheath; the proximal stump is then provisionally fixed to this device and passed through the flexor tendon tunnel with great care to avoid injury to the intact FDS attachments and critical A2 and A4 pulleys, as well as neurovascular structures nearby (Fig. 16-12*B*).

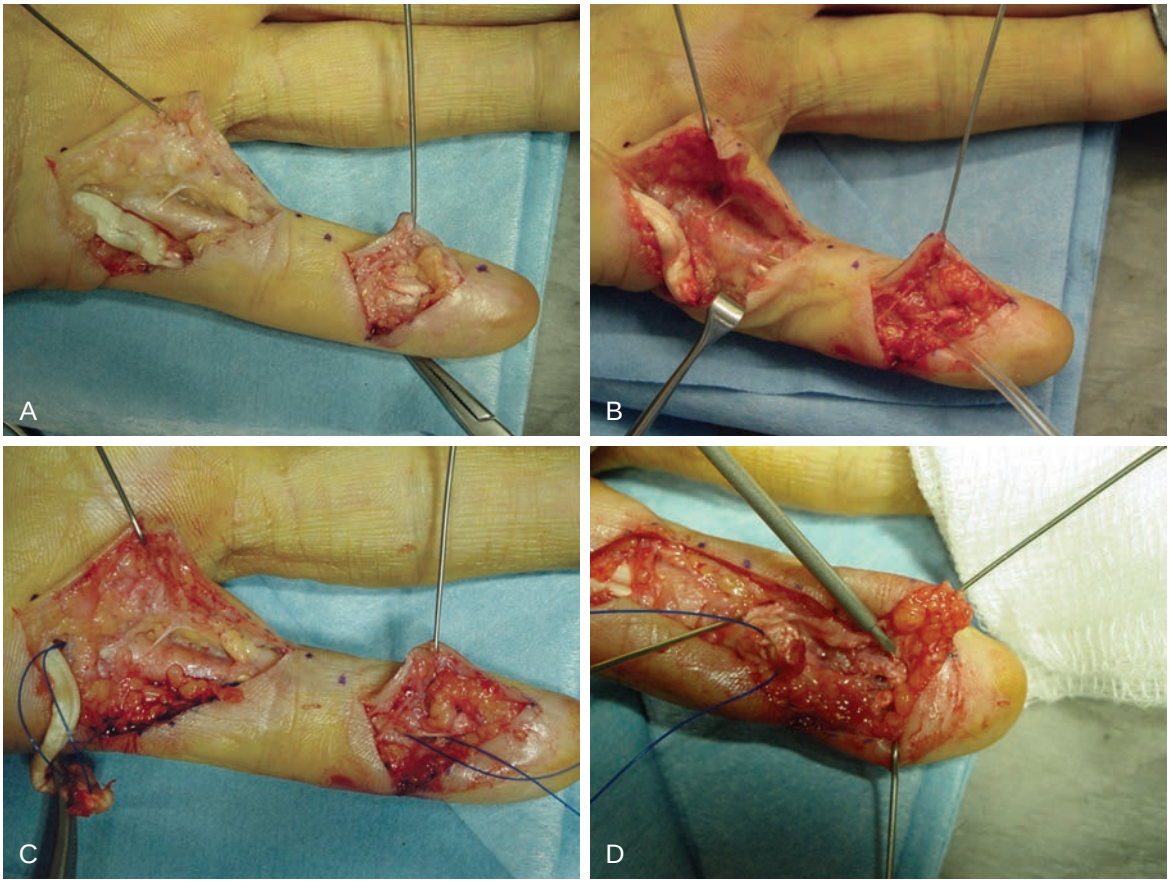

FIGURE 16-12. A, The ruptured flexor digitorum profundus tendon of the small finger is identified at the level of carpometacarpal joint level. **B,** Drain tubing has been passed through the A2 and A4 pulleys to ensure their preservation. **C,** A Prolene stitch is used to pull the proximal stump of the tendon through the annular pulleys to the distal phalanx. **D,** A suture anchor is used to fix the stump to the anatomic footprint of the FDP insertion. *(Courtesy of Mr. Michael Hayton, MB.ChB, FRCS.)*

- Tendon repair is performed either with direct suture repair to the residual stump (if there is enough tendon substance to suture) or via a pull-through technique in which the proximal stump is sutured with a 3-0 Prolene stitch that is passed through Keith needles and ultimately drilled through the distal phalanx and fixed to a dorsal button (Fig. 16-12*C,D*). Some authors utilize either a mini or micro suture anchor placed in the distal phalanx at the anatomic footprint of FDP insertion. Finally, some authors propose passing Keith needles containing the limbs of the 3-0 Prolene around the distal phalanx and tied down to the nail plate without a button.

Mallet Finger

- Affected finger is placed in a neutral to slightly extended posture and either a 0.035 or 0.042 inch K-wire is driven retrograde through the DIP joint to the base of the middle phalanx. Wire is often cut just beneath the skin surface.
- For bony mallet injuries, a dorsal block pin (0.045 inch K-wire) may be placed at the distal aspect of the middle phalanx in a retrograde fashion to help maintain reduction and prevent subluxation of the fracture fragment. A second pin is then driven retrograde as indicated above.

Factors that May Affect Rehabilitation

- Nonsurgical treatment is reserved for chronic injuries or for those individuals who are either unwilling or unable to comply with an intensive postoperative therapy protocol. Otherwise, surgical patients are rehabilitated as will be discussed below.

GUIDING PRINCIPLES OF POSTOPERATIVE REHABILITATION

MALLET FINGER

- Understanding the type of surgical repair performed
- Understanding of the anatomic structures and their rate of healing
- Understanding positions and activities that stress the healing structure
- Proper selection of manual therapy intervention applied at the appropriate phase of healing
- Surgery for mallet finger involves pinning the DIP joint in full extension for 6 to 8 weeks.
  - The patient is instructed to clean the pin with a 50:50 mixture of hydrogen peroxide and sterile water if a crust begins to develop at the pin area.
  - The patient is warned about the signs of infection and is given pain medicine and antibiotics based on surgeon's preference.
- After 6 to 8 weeks the pin can be removed and therapy follows the same guidelines outlined in the nonoperative rehabilitation section (see Nonoperative Rehabilitation for Mallet Finger).

JERSEY FINGER

- Understand the type of surgical repair performed
- Understanding of the anatomic structures and their rate of healing
- Understand positions and activities that stress the healing structure
- Proper selection of manual therapy intervention applied at the appropriate phase of healing
- Postoperative flexor tendon therapy includes early active, passive, and initial immobilization protocols. Selection of the specific protocol depends on the specific tendon repair technique, any associated injuries and the capacity of the patient to be compliant with a detailed home program and to observe strict precautions regarding splint use and avoidance of unguarded hand use.
- Too much motion early on during healing is indicative of a tendon that is gliding without much restriction from scar tissue. Although this may seem good, it is actually problematic: scar formation around the repair site provides the strength to the repair as it heals.

Phase I (days 0 to 5 postoperatively): Immediate Postoperative Period[1]

Goals

- Protect the repaired FDP tendon from rupture.
- Promote early gliding of the repaired tendon and minimize adhesion formation.
- Decrease pain and edema.
- Maintain motion of uninvolved joints.

Protection

- Dorsal block splint positioning the wrist in 30 to 40° of flexion, the MCP joints at 30° flexion, PIP joints at 0, and the rest of the uninvolved digits in extension. This splint extends proximally two thirds the length of the forearm and distally to the tips of the fingers (Fig. 16-13).
- Dorsal finger splint: Evans[1] recommends a separate dorsal splint for the involved DIP joint to position the DIP joint in 40 to 45° of flexion. This splint should extend from the distal portion of the PIP joint to the distal tip of the involved finger.
- Custom fabricated splints are recommended because precise fit of the splint is critical to prevent rupture of the tendon and for patient comfort
- The splint is worn 24 hours a day. If the patient is believed to be compliant with postoperative restrictions, the splint may be removed for hygiene and wound/skin checks at home
  - If the patient's compliance is in question, then hygiene and wound/skin care will be managed by the therapist.

[1]*Prehabilitation, if appropriate, is described in the Nonoperative Rehabilitation section of this chapter.*

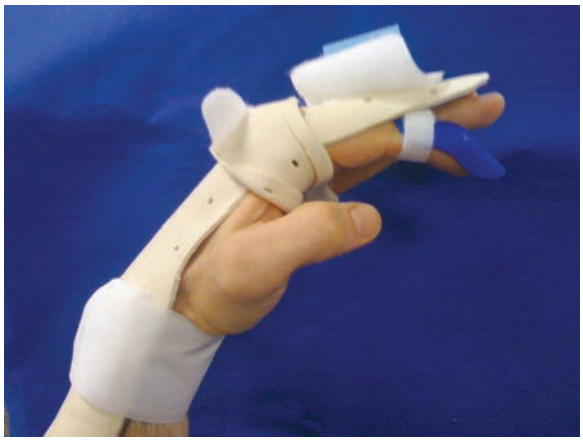

FIGURE 16-13. Dorsal block protective splint/orthosis with separate dorsal DIP joint block with the DIP joint positioned at 40 to 45° of flexion.

Management of Pain and Swelling

- Oral pain medications as recommended by the surgeon
- Heat and ice: If swelling is not significant, heat can be used prior to therapy or performing exercises. Ice can be used after an exercise session.
- Elevation of the affected limb above the heart between exercises
- The use of self-adhesive wraps around fingers to apply gentle compression
- The use of compression garments if edema engulfs hand and forearm
- Patient education
  - Perform exercises gently
  - Some discomfort is anticipated but if pain is increasing, the patient needs to perform the exercises at a lesser intensity.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Precautions
  - All exercises are performed gently within the limits of the dorsal block splints.
  - No passive composite finger extension (simultaneous extension of MCP, PIP, and DIP joints); no blocking exercises for DIP joint active flexion
  - No use of the involved hand for ADL
- Passive motion protocol
  - The DIP, PIP, and MP joints are all flexed passively individually to the full available range of motion, but not permitted to extend beyond the confines of the splints.
  - Modified hook fist: PIP and MP joints are flexed simultaneously within the confines of the splints.
  - Composite fist: MP, PIP, and DIP joints are simultaneously flexed at the same time.
- Active motion protocol
  - Begin with passive motion exercises as above to overcome any resistance to motion and reduce swelling.
  - Active motion exercises are permitted as follows:
    - Active extension of the digits is allowed within the confines of the splints.
    - Assisted active flexion of the fingers in a partial fist position (Fig. 16-14)
    - Place-and-hold technique: The uninvolved hand places the injured fingers into a gentle fist (MP joints at 75 to 80° flexion, the PIP joints at 70 to 75° flexion, and the DIP joints at 40° flexion. The uninvolved hand then lets go and the patient is asked to gently contract the muscles of the involved hand to hold this position for a five count (Fig. 16-15*A*,*B*).

TIMELINE 16-2: **Postoperative Rehabilitation after Zone 1 Flexor Tendon Repair or Mallet Finger**

PHASE I (days 0 to 5)

- Use of two custom-fabricated splints
  - Forearm-based dorsal block orthosis positioning the wrist in 30 to 40° of flexion, the MCP joints at 30° flexion, PIP joints at 0, and the uninvolved digits in extension
  - Finger-based dorsal orthosis to maintain the DIP joint in 40 to 45° of flexion
- Patient education regarding importance of uninterrupted orthosis/splint use
- Cryotherapy, edema management as needed
- Exercises will depend on surgeon's choice of protocol.
  - Passive motion protocol
    - The DIP, PIP, and MP joints are all flexed passively individually.
    - Passive modified hook fist
    - Passive composite fist
  - Active motion protocol
    - In addition to the PROM exercise previously described, the patient is allowed to perform:
      - Active extension to the limit of the dorsal block splint
      - Place-and-hold finger flexion
      - Active assisted range of motion into a partial fist
- Two to three therapy visits per week depending on limits in ROM
- No sports or resistive activities performed with injured hand

PHASE II (day 5 to week 4)

- Continue use of both splints.
- Cryotherapy, edema management as needed
- At 21 to 25 days DIP splint can be discharged and DIP extension is allowed.
- At 4 weeks the dorsal block splint is remolded with the wrist positioned in neutral and the MCP joints are placed in slight flexion, with IP joints gently extended.
- The patient continues with the above exercises.
- If excessive motion is noted the patient is not progressed any further with the exercises.
- Tenodesis exercises are added between 1 and 2 weeks.
- FDS gliding exercises are added between 3 and 4 weeks.
- Once the wound is closed, scar management strategies are started.
- If tendon glide is limited, modalities can be used as needed.
- No sports or resistive activities performed with injured hand



FIGURE 16-14. Active assisted flexion of the fingers within the confines of the dorsal block splint/orthosis performed during early phases of rehabilitation. *(Courtesy of Ross Evans.)*

Clinical Pearl

It is critical that the patient understands that this force is gentle. Excessive force will rupture the repair site. (Patients are often told: "pretend you are holding an egg".) A Haldex pinch meter can be used to measure force by tying a string to the patient's finger and around the Haldex meter. A force of 15 to 20° is recommended.

Active extension of the digits is allowed within the confines of the splints.

Other Therapeutic Exercises

- Athletes are encouraged to refrain from physical activity; excessive activity will promote swelling in a thermoplastic splint and create an unsanitary environment healing.

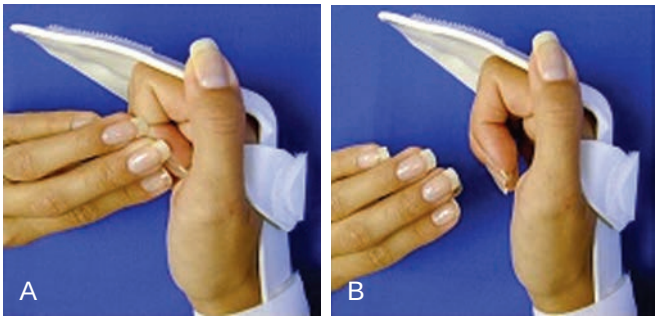

FIGURE 16-15. Place and hold exercise involves (a) the fingers placed in a flexed position and (b) the patient attempts to actively hold the flexed position without passive assistance.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- No activation of primary muscles is recommended beyond the scope of what has previously been discussed because this could potentially rupture the repair site.

Phase II (day 5 to week 4 postoperatively)

Goals

- Protect the repaired FDP.
  - Promote protected gliding of the repaired FDP.
  - Prevent restrictive adhesion formation.
  - Maintain ROM of uninvolved joints.

TIMELINE 16-2: **Postoperative Rehabilitation after Zone 1 Flexor Tendon Repair or Mallet Finger** (Continued)

PHASE III (weeks 4 to 8)

- Dorsal block splint is discharged at 7 to 9 weeks.
- Extension splint fabricated as needed to correct MP or PIP contractures
- No sustained passive stretching of the finger is permitted before 8 weeks postoperatively.
- Cryotherapy, scar and edema management continue.
- Static progressive splints may be issued to correct DIP contractures beginning at 8 weeks after surgery.
- The patient can progress to gentle tendon gliding exercises and blocking exercises after the dorsal splint is discharged.
- Blocking exercises can begin if active DIP joint flexion is limited indicating passive tendon adherence.
- Passive ROM exercises discussed in the previous section may continue.
- Ultrasound or iontophoresis with saline may be used if scar adhesions are believed to be present.
- The athlete may return to cardiovascular and lower body exercises but is encouraged to avoid resistive gripping activities.

PHASE IV (weeks 8 to 12)

- All ROM and soft tissue techniques previously described are continued.
- All modalities are continued on an as-needed basis.
- Light putty exercises may be issued.
- The use of electrical stimulation can be initiated to increase tendon glide.
- After discharge from therapy, the patient may return to light weight lifting activities and progress gradually in the absence of pain.
- May return to sports but can use buddy tape as needed

- Limit excessive motion.
- Minimize pain and edema.

Protection

- Continue use of both splints; however, between 21 and 25 days use of the dorsal digital splint can be discontinued, but no passive extension of the DIP joint is allowed. At 4 weeks the dorsal block splint is remolded with the wrist positioned in neutral and the MCP joints are placed in slight flexion, with IP joints gently extended

Management of Pain and Swelling

- Oral pain medications as recommended by the surgeon
- Heat and ice: If swelling is not significant, heat can be used prior to therapy or performing exercises. Ice can be used after an exercise session.
- Elevation of the affected limb above the heart between exercises
- The use of self-adhesive wraps around fingers to apply gentle compression
- The use of compression garments if edema engulfs hand and forearm
- Patient education
  - Perform exercises gently.
  - Some discomfort is anticipated but if pain is increasing the patient needs to perform the exercises more gently and adjust the frequency and duration of the exercises.
  - The patient is instructed to avoid attempts to use the involved hand.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Precautions
  - Are the same as previously discussed, but if the patient begins to show excessive motion (i.e., full or almost-full composite fist) he or she will not be progressed any further until 4 to 5 weeks.
- Passive and active motion protocols
  - Are the same as previously discussed, with the addition of FDS tendon gliding exercises: the uninvolved digits are held in extension to the limit of the splint (Fig. 16-16). The involved finger is allowed to gently flex and extend at the PIP joint.
  - Synergistic wrist motion (tenodesis) can be added with both protocols (Fig. 16-17 *A*,*B*) added between 1 and 2 weeks.
  - These exercises are first performed under therapist supervision. If the patient shows good understanding of exercises and compliance with postoperative protocols the patient may be instructed to add this exercise to the home exercise program.
  - If tendon excursion is limited, the exercise program may be upgraded by increasing frequency, adding physical agents, and carefully modifying the exercises to promote increased FDP tendon function.



FIGURE 16-16. Gliding exercise of the flexor digitorum superficialis: Within the confines of the splint/orthosis, the digits adjacent to the involved digit are held in extension to the limit of the splint and the patient attempts to actively flex the PIP joint of the involved digit.

  - PROM exercises will remain the same as previously discussed.

Soft Tissue Techniques

- Gentle scar massage once wound is closed.
- Scar pad fabricated from Elastomere or Otoform. The patient may also purchase name-brand silicon scar pads found in most pharmacies.
- Edema massage as needed

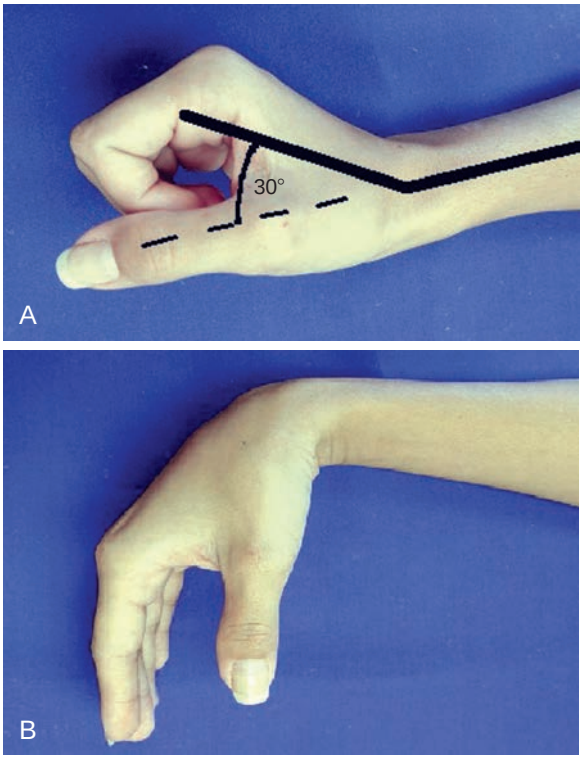

FIGURE 16-17. Tenodesis exercise/synergistic motion involves (a) wrist extension to 30° which results in passive flexion of the digits; this is followed by (b) active flexion of the wrist resulting in passive extension of the digits.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Not permitted during this phase; stretching of the FDP musculotendinous unit puts it in danger of rupture or gapping at the repair site.

Other Therapeutic Exercises

- Once the wound is closed and the patient shows good compliance, they light aerobic activities (such as seated stationary bike) may be allowed. It is important that these activities do not allow the patient to bear weight or grasp using the injured hand. The patient must understand the importance of cleaning the hand/splint after the activity while maintaining the postoperative restrictions.
- Activities such as running (outside or on a treadmill) are not recommended because if the patient falls on a hard surface, even with the splint, the repair site may rupture.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- AROM of the elbow and shoulder is still encouraged but the patient is restricted from resistive activities.

Sensorimotor Exercises

- Not appropriate for this diagnosis. Both mallet finger and jersey finger involve the distal joint of a finger. Because only a small portion of the finger is involved, balance, overall strength, and endurance are not adversely affected.

Phase III (weeks 4 to 8 postoperatively)

Goals

- Protect the repaired FDP.
- Promote gliding of the repaired FDP tendon.
- Maintain ROM of uninvolved joints.
- Limit excessive motion.
- Minimize pain and edema.
- Progress patient to a full composite fist and full DIP extension.

Protection

- Use of the dorsal block splint is discontinued at 7 to 9 weeks.
- Once the dorsal block splint is discontinued, if a flexion contracture is present at the MP or PIP joint an extension splint can be made that positions the involved joint and digit at the end range of comfortable active extension. The splint also can be worn at night and for intervals during the day to achieve greater extension. This splint can be brought in once a week to be gradually adjusted into more extension by the therapist.
- No sustained passive stretching of the finger is permitted before 8 weeks postoperatively.
- Static progressive splints may be issued to correct DIP contractures beginning at 8 weeks after surgery.

Clinical Pearl

> Do not allow the patient to throw away any of the splints. Part or all of any thermoplastic splint can be used to fabricate another splint. This can save a therapist time in a clinical setting and reduce cost for the patient.

Management of Pain and Swelling

- Pain medications as prescribed by the surgeon.
- Heat and ice: If swelling is not significant, heat can be used prior to therapy or performing exercises. Ice can be used after an exercise session.
- Elevation of the affected limb above the heart between exercises
- The use of self-adhesive compressive wraps around fingers to apply gentle compression
  - The use of compression garments if edema engulfs hand and forearm
- Patient education
  - Perform exercises gently.
  - Some discomfort is anticipated but if pain is increasing, the patient needs to perform the exercises more gently and adjust the frequency and duration to lessen discomfort.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- AROM: The patient can progress to gentle tendon gliding exercises and blocking exercises after the dorsal splint is discharged. It is recommended that exercises start out gently and progress depending on the patient's reports of pain and the amount of tendon glide.
- Blocking exercises can begin if DIP joint flexion is limited indicating scar adherence of the repaired FDP tendon. Blocking involves stabilization of the PIP joint in neutral as the patient attempts to actively flex the DIP joint (Fig. 16-18).

Clinical Pearl

> If the patient has difficulty performing isolated DIP blocking exercises a blocking splint can be fabricated to hold the PIP in extension.

- PROM: Continue as discussed in prior section.
- Joint mobilization is indicated if joint stiffness is noted prior to treatment.
- If the tendon seems to be adherent, ultrasound or iontophoresis with saline can be administered.

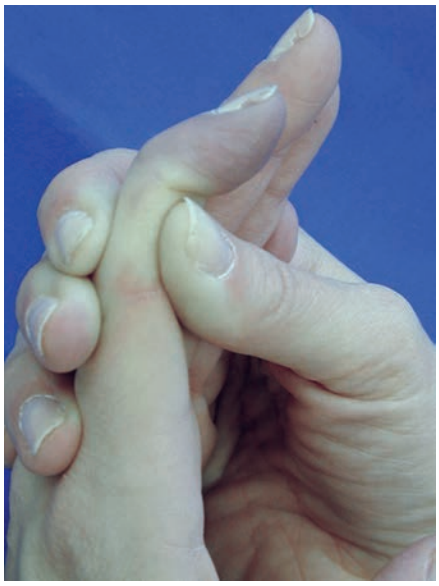

FIGURE 16-18. Blocking exercises are performed in the later phases of rehabilitation following surgery for Jersey finger. The proximal PIP joint is held in neutral extension and the patient attempts to actively flex the involved DIP joint.

Soft Tissue Techniques

- Continue as discussed in the prior section.

Other Therapeutic Exercises

- Cardiovascular: Once the splint is discharged the patient may participate in light aerobic activities. However, the patient is encouraged to refrain from strenuous gripping activities.
- Lower body strengthening may begin in the form of squats, lunges, leg press, etc., as long as the patient is aware he is not to perform strenuous gripping activities. As such upper body strengthening is omitted.
- Core activities that do not require excessive force of the involved hand may be started.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- The same as discussed in prior section

Sensorimotor Exercises

- The same as discussed in prior section

Phase IV (weeks 8 to 12 postoperatively)

Goals

- Protect the repaired FDP.
- Promote gliding of the repaired FDP tendon.
- Maintain good ROM of uninvolved joints.
- Minimize pain and edema.
- Progress patient to a full composite fist and full DIP extension.
- Strengthening may begin at 10 weeks.

Management of Pain and Swelling

- Pain medications prescribed by the surgeon depending on the surgeon preference
- Heat and ice: If swelling is not significant, heat can be used prior to therapy or performing exercises. Ice can be used after an exercise session.
- The use of self-adhesive wraps around fingers to apply gentle compression
  - The use of compression garments if edema engulfs hand and forearm
- Patient education
  - Perform exercises gently.
  - Some discomfort is to be anticipated but if pain is increasing, the patient needs to perform the exercises more gently and adjust the frequency and duration of the exercise sessions to lessen discomfort at a lesser intensity.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Passive and active range of motion protocols: the same as discussed in prior section
- If tendon gliding is still limited, the use of neuromuscular electrical stimulation can be used to enhance the contraction of the FDP muscle.
- Strengthening with light putty
- Assist with contractions of the FDP of the involved finger.

Soft Tissue Techniques

- The same as in prior section

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Not indicated or appropriate for this diagnosis

Sport-Specific Exercises

- Once the patients/athletes are discharged/cleared from a therapy program they can then gradually return to their sports without difficulty. In most instances after therapy patients are instructed to return to weight lifting and sport activities at about 50% of the resistance and progress under their own supervision as their tolerance and symptoms permit pending their pain.

Outcome Measures

- Patient-reported outcome scales should be completed on the initial therapy evaluation and followed up at weeks 4, 8, and 12 and at the final day of therapy.
- Disabilities of the Arm, Shoulder, and Hand (DASH), Quick Dash, The Patient Rated Wrist Evaluation

(PRWE), and the Patient Rated Wrist and Hand Evaluation (PRWHE) are recommended.
- All have all been shown to be effective.

Criteria for Return to Sport

General

- Functional AROM
- Minimal to no pain or edema
- Minimum of 80% (side-to-side) symmetry of grip strength

Sport-Specific

- Implementation of return to sport criteria must include a demand/needs analysis of the chosen sport. The rehabilitation specialist should be able to analyze the demands on the hand and finger through a series of tests and exercises to ensure readiness for return to preinjury levels of activity.

After Return to Sport

Continuing Fitness or Rehabilitation Exercises

- Total arm and total body strengthening exercises

Exercises and Other Techniques for Prevention of Recurrent Injury

- There are no exercises to prevent jersey or mallet finger. However, once a patient returns to her or his sport they may wish to buddy tape the rehabilitated finger for protection.

Evidence

Evans RB: A study of the zone 1 flexor tendon injury and implications for the treatment. *J Hand Ther* 24:275–280, 1990.

This article describes early motion protocol for patients who have had surgical repair of Zone 1 Flexor tendon injuries then reviews the clinical results. (Level IV evidence)

Evans RB: Zone 1 flexor tendon rehabilitation with limited extension and active flexion. *J Hand Ther* 18(2):128–140, 2005.

This study looks at the outcomes for 41 patients who had surgical repairs of Zone 1 FDP tendon injuries. Surgery was followed by therapy in which the patient performed an early active flexion protocol with limited extension. These patients were followed for 10 years and showed a mean total active range of motion that was 81% of their normal motion. (Level IV evidence)

Groth NG: Pyramid of progressive force exercise to the injured flexor tendon. *J Hand Ther* 17:31–42, 2004.

This article is a literature review and case study. It describes the application and rational for using exercises in a systematic and progressive way to reduce the risk of rupture and adhesion formation. (Case study)

Handoll HH, Vaghela MV: Interventions for treating mallet finger injuries. *Cochrane Database Syst Rev* (3):CD004574, 2004.

This review looked at randomized or quasi-randomized clinical trials evaluating different interventions, including no intervention for treating mallet finger injuries, and included four trials that involved 283 mallet finger injuries. The authors concluded that there was insufficient evidence to establish the relative effectiveness of different, either custom-made or off-the-shelf, finger splints used for treating mallet finger injury. (Review)

Lunn PG, Lamb DW: "Ruby Finger"—avulsion of profundus of ring finger. *J Hand Surg BR* 9:69–77, 1984.

This is a study of nine patients who sustained an isolated avulsion injury of the FDP tendon, all to the ring finger while playing rugby. The patients all presented later than 4 weeks and were treated surgically with palmaris tendon grafting, followed by 6 to 9 weeks of physiotherapy. The mean follow up was 4.3 years and hand function improved in all cases. The authors subsequently recommended that experienced surgeons should use this technique for the treatment of young and motivated individuals. (Level IV evidence)

Tuttle HG, Olvey SP, Stern PJ: Tendon avulsion injuries of the distal phalanx. *Clin Orthop Relat Res* 445:157–168, 2006.

This is one of the latest review articles about jersey finger. The authors concisely summarized the current FDP tendon avulsion classification system (Types 1 to 5). (Review)

REFERENCES

1. Evans RB: A study of the zone 1 flexor tendon injury and implications for the treatment. *J Hand Ther* 24:275–280, 1990.

Multiple-Choice Questions

QUESTION 1. When can place and hold exercises be started?

A. When the surgical repair supports the use of active motion as determined by the referring surgeon
B. When the patient shows the capacity to follow and be compliant with instructions and precautions
C. Within the first 3 to 5 days after surgery
D. All of the above

QUESTION 2. Which of the following is an appropriate exercise for jersey finger in the first 3 weeks postop?

A. Forceful flexion to a full composite fist
B. A dorsal block splint to maintain wrist/MPs flexed while DIP/PIPs are held at 0° extension
C. PROM into full fist and full extension
D. Gentle wrist tenodesis under therapist supervision

QUESTION 3. When is it safe to discharge the dorsal finger splint (with continued use of the wrist and hand dorsal splint)?

A. 21 to 28 days
B. 28 to 38 days
C. 5 weeks
D. 6 weeks

QUESTION 4. According to Evans, at what angle should the DIP joint be positioned when the initial dorsal DIPJ splint is fabricated?

A. 0 to 10
B. 10 to 25
C. 20 to 35
D. 40 to 45

QUESTION 5. What is considered when upgrading a patient's therapy program to include light strengthening?

A. Timeframe from surgery
B. The degree of gliding of the repaired FDP
C. The patient's functional requirements
D. All of the above

Answer Key

QUESTION 1. Correct answer: **D** (see Techniques for Progressive Increase in Range of Motion)

QUESTION 2. Correct answer: **D** (see Phase II)

QUESTION 3. Correct answer: **A** (see Phase II)

QUESTION 4. Correct answer: **D** (see Phase I)

QUESTION 5. Correct answer: **D** (see Phase II)

Chapter 17



Thumb Ulnar Collateral Ligament Injuries

INTRODUCTION

Mohamed Khalid, MD, MCh, FRCS

Epidemiology

Age

- 40 years (average)

Sex

- Male : female ratio: 3 : 2

Sports

- Skiing, snowboarding, ball-handling sports, hockey, cycling, wrestling, break dancing
- The incidence is 3% of all skiing injuries. The most common injuries resulting from skiing are knee injuries (medial collateral ligament sprain, anterior cruciate ligament damage, and meniscal injury) 30% to 40%; and shoulder girdle injuries (dislocation of shoulder and acromioclavicular joints, fracture of clavicle, humerus, and wrist) 25% to 30%; followed by ankle sprains 17%; and head injuries 10% to 15%

Position

- Sudden forced radial deviation (abduction)

Pathophysiology

Intrinsic Factors

- Anatomical: The shallow articulating surfaces of the thumb metacarpophalangeal (MCP) joint provide very little inherent stability.
- For its stability the MCP joint relies on muscles (adductor pollicis), static ligaments such as the ulnar collateral ligament, accessory collateral ligament, and volar plate (Figures 17-1 and 17-2). The proper ulnar collateral ligament runs from the head of metacarpal to volar surface of the base of proximal phalanx. It is the primary restraint to an abduction force to the MCP joint and tightens in flexion and relaxes in extension. The accessory ulnar collateral ligament also provides stability to the ulnar aspect of the MCP joint and tightens in extension and relaxes in extension.
- The ulnar collateral ligament is the key stabilizer of the thumb MCP joint.

Extrinsic Factors

- Improper use of ski pole straps (Figure 17-3*A*,*B*)

Traumatic Factors

- The mechanism of the injury is forceful abduction of the thumb associated with striking the ground, striking the ski pole handle, or forced abduction of the thumb, which is caught in the ski pole strap.
- When a skier falls onto the hand the pole handle in the palm can act as a lever across the MCP joint and force it into abduction/radial deviation (Figure 17-4).

Classic Pathological Findings

- Strain, partial tears, or complete rupture of ulnar collateral ligament
- The tear is most often at the distal attachment. Ruptures within the substance of the ligament or avulsion of the ligament from the metacarpal ligament can also occur.

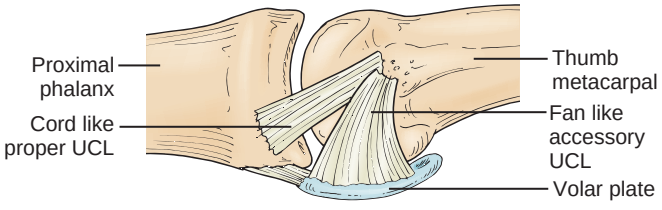

FIGURE 17-1. Stabilizers of the metacarpophalangeal joint of the thumb.

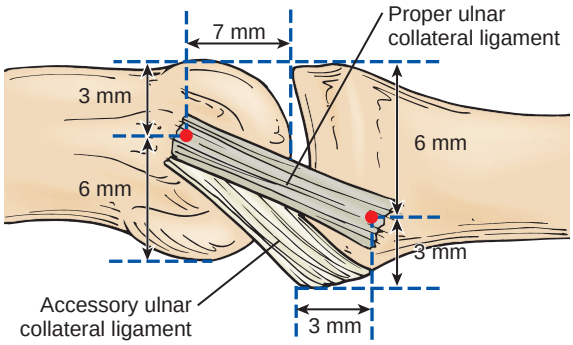

FIGURE 17-2. The proper ulnar collateral ligament runs from the head of metacarpal to volar surface of the base of proximal phalanx. It is the primary restraint to an abduction force to the MCPJ and tightens in flexion and relaxes in extension. The accessory ulnar collateral ligament also provides stability to the ulnar aspect of the MCPJ and tightens in extension and relaxes in extension. *(Redrawn from Hand Clinics 25(3):437–442, 2009.)*

- Associated lesions might include injury to dorsal capsule, a rent in adductor aponeurosis, extensor expansion, volar plate or avulsion fracture.

Clinical Presentation

History

- History of combined hyperextension and forced abduction to the thumb
- Acutely painful MCP joint and swelling

Physical Examination

Abnormal Findings

- Tenderness, ecchymosis, and swelling along the ulnar border of MCP joint
- Laxity in excess of 35° and/or 15° greater than the contralateral thumb on valgus stress testing (Figure 17-5)
- A weak pincer grip

Pertinent Normal Findings

- No tenderness over the radial border of the thumb (vs. radial collateral ligament injury, MCP joint dislocation)
- No increased warmth (vs. septic or crystal arthropathy)

Imaging

- Plain radiographs, including stress views
- Ultrasonography
- Magnetic resonance imaging

Differential Diagnosis

- MCP joint dislocation
- Peri-articular fractures around the MCP joint

Treatment

Nonoperative Management

- Rest, ice, compression, and elevation (RICE)
- Splinting, functional versus rigid
- Casting in a thumb spica

Guidelines for Choosing Among Nonoperative Treatments

- Presence of an end point to valgus stress
- Absence of a Stener lesion. A Stener lesion is avulsion of the distal attachment of the ulnar collateral ligament with interposition of the adductor aponeurosis between



FIGURE 17-3. Proper **(A)** and improper **(B)** use of ski pole straps.



FIGURE 17-4. Mechanism of injury resulting in ulnar collateral ligament damage.

the avulsed ligament and its site of original attachment to the base of the proximal phalanx (Figure 17-6).
- Absence of displaced fractures

Surgical Indications

Absolute Indications

- Complete avulsion with interposition of adductor aponeurosis (Stener lesion)
- Displaced (greater than 2 mm) avulsion fractures (ulnar base of the proximal phalanx, metacarpal head, and shearing fractures of the volar surface of the radial condyle of the metacarpal head) (Figure 17-7)

Relative Indication

- Minimally displaced intraarticular avulsion fracture

Aspects of History, Demographics, or Exam Findings That Affect Choice of Treatment

- Weak pincer grip
- Lack of end point on abduction stressing

Aspects of Clinical Decision Making When Surgery Is Indicated

- Complete versus incomplete rupture/strain (definite end point or not on abduction stressing



FIGURE 17-5. Unstable thumb following an ulnar collateral ligament injury.

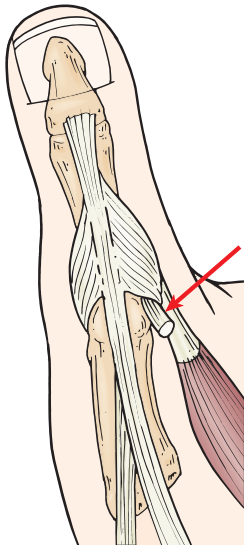

FIGURE 17-6. Stener lesion.

- 30° laxity of the ulnar side of the joint when stressed radially in extension and 40° of flexion (the latter is more reliable)
- 15° more laxity compared with contralateral thumb
- Presence of a Stener lesion
- Presence of a palpable "tumor" (mass) at the level of UCL just proximal to the MCP joint
- Retracted ligament on ultrasonography or MRI
- Greater than 2 mm displacement of fracture
- Joint incongruity
- Rotated fragment

Evidence

Abrahamsson SO, Sollerman C, Lundborg G, et al: Diagnosis of displaced ulnar collateral ligament of the metacarpophalangeal joint of the thumb. Preoperative diagnosis. *J Bone Joint Surg* 68-A:1320–1326, 1986.



FIGURE 17-7. Displaced avulsion fracture.

In this study the authors prospectively studied 24 consecutive patients with posttraumatic instability of the metacarpophalangeal joint of the thumb. Clinical examination including instability tests and palpation of displaced ulnar collateral ligaments was used to separate the patients into two groups, nondisplaced and displaced ruptures. Palpable displaced ruptures were treated surgically, whereas nonpalpable ruptures were interpreted as nondisplaced and were treated with plaster, irrespective of the instability. At follow-up 1 year later both groups showed similar results with respect to stability, strength, and function. They concluded that it was possible to determine the surgical candidates reliably with clinical examination alone. (Level II evidence)

Bowers WH, Hurst LC: Gamekeeper's thumb. Evaluation by arthrography and stress Roentgenography. *J Bone Joint Surg* 59A:519–524, 1977.

This study correlated stress radiographs, arthrography, and findings at surgical exploration and found that valgus angulation of greater than 30° was predictive of a complete UCL rupture, but that arthrography was needed to diagnose Stener lesion accurately. (Level III evidence)

Hergan K, Mittler C, Olser W: Ulnar collateral ligament: Differentiation of displaced and nondisplaced tears with ultrasound and MR imaging. *Radiology* 194(1):65–71, 1995.

The comparative usefulness of ultrasound versus MRI in UCL ruptures was studied in 17 patients and 21 normal volunteers. Ultrasound had a sensitivity of 88% and a specificity of 83% for displaced, and 91% for nondisplaced UCL tears. MRI had a sensitivity and specificity were both 100%. The authors concluded that MRI was superior to ultrasound, but both were useful diagnostic modalities. (Level II evidence)

Heyman P, Gelberman RH, Duncan K, et al: Injuries of the ulnar collateral ligament of the thumb metacarpophalangeal joint. Biomechanical and prospective clinical studies on the usefulness of valgus stress testing. *Clin Orthop Relat Res* 292:165–171, 1993.

This evidence study reported that the presence of valgus angulation of more than 35° with the joint in extension and 30° with the joint in flexion was predictive of a complete tear with a Stener lesion in 15 of 17 cases (sensitivity, 94%; specificity, 57%; accuracy, 83%; positive predictive value, 83%; negative predictive value, 80%). (Level II evidence)

Stener B: Displacement of the ruptured ulnar collateral ligament of the metacarpophalangeal joint of the thumb: A clinical and anatomical study. *J Bone Joint Surg Br* 44:869–879, 1962.

In this classical study, the author prospectively studied 40 clinical cases of complete rupture of UCL supplemented with 42 cadaveric dissections. He demonstrated that in a displaced complete rupture of the UCL the adductor aponeurosis interposed between the ruptured end of the ligament and the phalangeal attachment of the ligament.

Multiple Choice Questions

QUESTION 1. Thumb ulnar collateral ligament injury is common in all the following injuries except

A. skiing.
B. break dancing.
C. netball.
D. table tennis.

QUESTION 2. Ulnar collateral ligament injuries constitute what percentage of all skiing injuries?

A. 5%
B. 3%
C. 40%
D. 8%

QUESTION 3. Stabilizers of thumb MCP joint include all of the following except

A. adductor pollicis.
B. abductor pollicis.
C. ulnar collateral ligament.
D. volar plate.

QUESTION 4. The ulnar collateral ligament commonly avulses off of what attachment?

A. Distal
B. Midsubstance
C. Proximal
D. b+c

QUESTION 5. The most sensitive and specific modality of diagnosing an unstable UCL injury is

A. history.
B. clinical examination.
C. ultrasonography.
D. MRI.

Answer Key

QUESTION 1. Correct answer: **D** (see Epidemiology)

QUESTION 2. Correct answer: **B** (see Epidemiology)

QUESTION 3. Correct answer: **B** (see Anatomy)

QUESTION 4. Correct answer: **A** (see Pathological findings)

QUESTION 5. Correct answer: **D** (see Evidence)

NONOPERATIVE REHABILITATION OF THUMB ULNAR COLLATERAL LIGAMENT INJURIES

Mohamed Khalid, MD, MCh, FRCS, Bradley Kent Earnest, OTR/L, CHT, and Mark Simenson, OTR/L, CHT

GUIDING PRINCIPLES OF NONOPERATIVE REHABILITATION

- Protect
- Monitor pain, edema, and range of motion
- Maximizing strength and activities of daily living (ADLs) independence

Phase I (weeks 0 to 4)

Protection

- Hand-based IP free thumb spica splint with no more than 30° of abduction (Figure 17-8).

Management of Pain and Swelling

- Compression
- Ice
- Elevation

Techniques for Progressive Increase in Range of Motion

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Allow active flexion/extension of thumb MP joint (10 reps, three times per day) but no opposition movements at this time.

Functional Exercises

- Gentle/light hygiene (avoid radial MP joint stress)



FIGURE 17-8. Static hand-based splint.

Milestones for Progression to the Next Phase

- Decreased pain per patient report
- Decreased tenderness to palpation and edema
- Increased stability (within 15 degrees radial deviation (MP joint) of noninjured thumb
- If not progressing continue phase I for 2 more weeks and if criteria is still not met refer back to MD for further evaluation

Phase II (weeks 4 to 6)

Protection

- Continue splinting with heavy use and while sleeping.
- Splint may be removed for light ADL (2 lb or less).

Management of Pain and Swelling

- Continue as for Phase I.
- Retrograde massage may be added if needed for edema.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Technique

- Retrograde massage

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Continue with active MP joint flexion and extension exercises as in Phase I.
- Active opposition added to treatment and home program

Other Therapeutic Exercises

- ADL (2 lb or less) with splint removed

Activation of Primary Muscles Involved

- Same as for Phase I

Functional Exercises

- ADL (2 lb or less) with splint removed

Milestones for Progression to the Next Phase

- Pain at rest 0/10. Pain/tenderness 2/10 or less with palpation over UCL and with gentle use.
- MP joint stable with flexion, extension, and active opposition

Phase III (weeks 6 to 10)

Protection

- Wean from splint for ADL and nighttime use. Continue splinting with heavy use.

Management of Pain and Swelling

- Continue with ice, retrograde massage, and compression.
- Modalities such as ultrasound and neuromuscular electrical stimulation (NMES) may be added.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Joint mobilization and passive range of motion initiated to MP joint

Soft Tissue Techniques

- Scar massage initiated over UCL for internal scarring management

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Initiate place and hold exercises in MP flexion, extension and opposition.

Other Therapeutic Exercises

- If UCL is stable and pain free outside of splint with ADL then extra-soft (yellow) Theraputty exercises are initiated for flexion, extension and opposition.

Activation of Primary Muscles Involved

- Same as for Phase I

Techniques to Increase Muscle Strength, Power, and Endurance

- Yellow Theraputty activities of pinch and grip initiated three times per day for 5-minute sessions.

Functional Exercises

- Resisted three-jaw chuck, palmar, and tip pinch initiated under therapist supervision.

Milestones for Progression to the Next Phase

- No tenderness to palpation over UCL ligament
- Minimal pain with activities outside of splint

Phase IV (weeks 10 to 12)

Protection

- Continue splinting with heavy use.
- Taping may be initiated for protection with sport related activities (Figure 17-9*A-D*).

Management of Pain and Swelling

- Same as for Phase III

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Increase aggressiveness of joint mobilization and active/passive range of motion.

Soft Tissue Techniques

- Manual and vibration scar massage.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Dynamic splinting to increase MP joint flexion and thumb opposition (Figure 17-10) as needed

Other Therapeutic Exercises

- Increase resistance grade of Theraputty
- Power web, upper body exerciser, and graded clothes pins
- NMES

Activation of Primary Muscles Involved

- Same as for Phase I

Techniques to Increase Muscle Strength, Power, and Endurance

- Same as above

Functional Exercises

- Use for all ADL outside of splint.

TIMELINE 17-1: **Nonoperative Rehabilitation of Thumb Ulnar Collateral Ligament Injuries**

PHASE I (weeks 1 to 4)	PHASE II (weeks 4 to 6)
• Hand-based IP free thumb spica splint • Compression/ice/elevation • Active flexion/extension MP joint • Gentle hygiene allowed	• Splinting for protection and nighttime wear • Splint removed for light ADL (2 lb or less) • Add retrograde massage as needed to decrease edema • Add active opposition

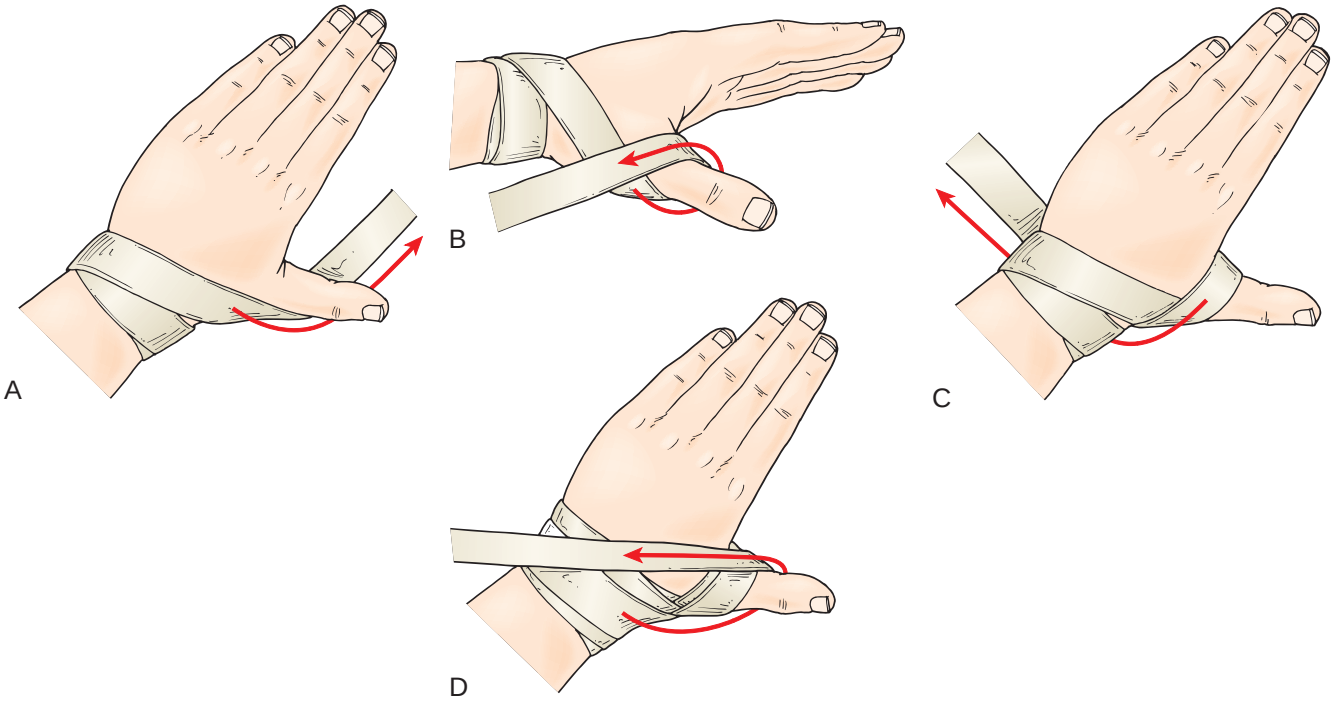

FIGURE 17-9. A–D, Taping for protection during sporting activity.



FIGURE 17-10. Dynamic splinting.

Sport-Specific Exercises

- Trainer input

Milestones for Progression to Advanced Sport-Specific Training and Conditioning

- No reported pain (rest/general use)
- UCL stability
- Functional pinch/grip strength

Criteria for Abandoning Nonoperative Treatment and Proceeding to Surgery or More Intensive Intervention

- Significant pain outside of splint
- Instability of UCL
- Stener lesion

Tips and Guidelines for Transitioning to Performance Enhancement

- Trainer input

Performance Enhancement and Beyond Rehabilitation: Training/ Trainer and

- Trainer input

TIMELINE 17-1: **Nonoperative Rehabilitation of Thumb Ulnar Collateral Ligament Injuries** (Continued)

PHASE III (weeks 6 to 10)	PHASE IV (weeks 10 to 12)
• Wean from splint for ADL and nighttime • Splint worn with heavy use • Modalities as needed • Joint mobs and passive range of motion • Scar massage • Place and hold exercises • Yellow Theraputty exercises • Resisted pinching in clinic	• Splint only with heavy use • Taping with sport-related activities • Apply dynamic or static progressive splinting as needed • Power web/upper body exerciser

Optimization of Athletic Performance

- Trainer input

Evidence

There are no key evidence-based trials.

Multiple Choice Questions

QUESTION 1. What splint would best protect the UCL in the first 4 weeks of injury?

A. Wrist cock-up
B. Hand base thumb spica
C. Neoprene thumb wrap
D. Mallet

QUESTION 2. What degree of thumb abduction is advised in the splint?

A. 0
B. 30
C. 60
D. 90

QUESTION 3. What active thumb motion is introduced in week 5?

A. Flexion
B. Extension
C. Adduction
D. Opposition

QUESTION 4. When are modalities (ultrasound/NMES) added to the treatment plan?

A. Phase I
B. Phase II
C. Phase III
D. Phase IV

QUESTION 5. What type of splint is added in Phase IV?

A. Dynamic
B. Static progressive
C. No splint
D. Silver ring

Answer Key

QUESTION 1. Correct answer: **B** (see Phase I)

QUESTION 2. Correct answer: **B** (see Phase I)

QUESTION 3. Correct answer: **D** (see Phase II)

QUESTION 4. Correct answer: **C** (see Phase III)

QUESTION 5. Correct answer: **A** (see Phase IV)

POSTOPERATIVE REHABILITATION OF THUMB ULNAR COLLATERAL LIGAMENT INJURIES

Mohamed Khalid, MD, MCh, FRCS, Bradley Kent Earnest, OTR/L, CHT, and Mark Simenson, OTR/L, CHT

Indications for Surgical Treatment

- Failure of nonsurgical treatment
- Stener lesion
- Gross instability

Brief Summary of Surgical Treatment

Major Surgical Steps

- General or regional anesthesia
- Patient supine with upper extremity on arm table; tourniquet control
- Lazy S incision with the distal limb volar to the midaxial line to provide sufficient access to the volar plate (Figure 17-11). Identify and protect branches of superficial radial nerve.
- The proximal edge of adductor aponeurosis is identified (Figure 17-12). If a Stener lesion (avulsion of the distal attachment of the ulnar collateral ligament with interposition of the adductor aponeurosis between the avulsed ligament and its site of original attachment to the base of the proximal phalanx) is present, this

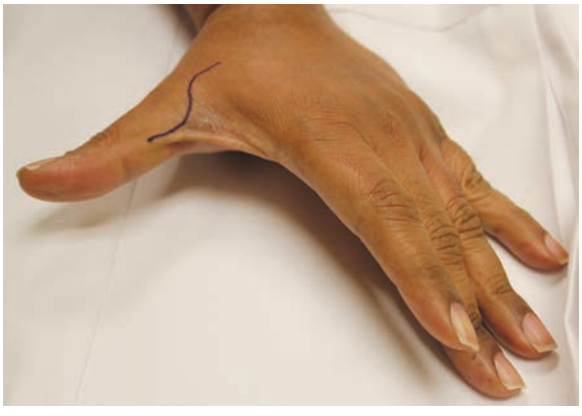

FIGURE 17-11. Dorsoulnar incision for thumb UCL repair.

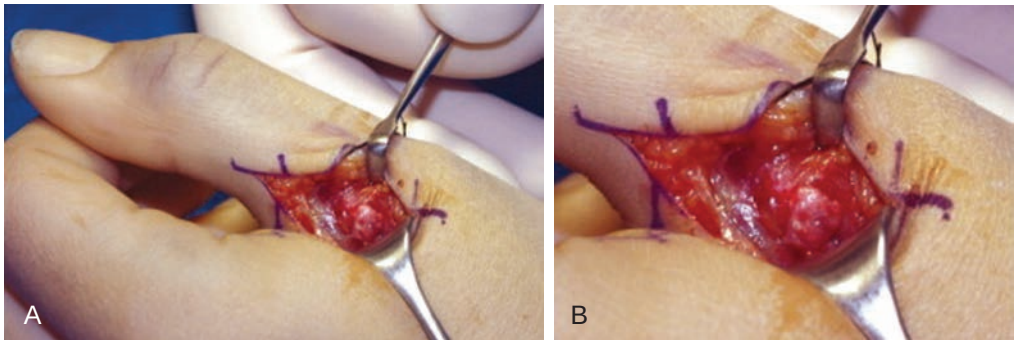

FIGURE 17-12. The adductor aponeurosis is identified. The proximal stump of the torn UCL may be identified at the proximal margin of the adductor aponeurosis if a Stener lesion is present. *(From Glickel SZ, Catalanolli LW: Repair of acute ulnar collateral ligament injury of the thumb. Procedure 7. In Chung KC, editor: Operative techniques. Hand and wrist surgery. Philadelphia, 2008, Elsevier.)*

usually well-defined edge may appear edematous and bulbous and thus less distinct.

- A longitudinal incision is made in the adductor aponeurosis parallel and volar to the ulnar border of the extensor pollicis longus tendon. This exposes the ulnar aspect of the metacarpophalangeal (MCP) joint (Figure 17-13*A*,*B*). The joint is examined to determine the extent of cartilaginous injury and if a cartilaginous shear fragment is identified, the same is removed.
- The ligament is usually avulsed distally. It is re-attached with a small bone anchor or with a suture (pullout after healing in clinic) technique. The repair is tensioned with the MCP joint in 45° of flexion to avoid overtightening. Less commonly, there may be a midsubstance tear, which can be repaired with figure-eight or horizontal mattress sutures using nonabsorbable braided synthetic suture material such as 4/0 fiber wire.
- If a fragment of bone is attached to the avulsed ligament, and it is small (less than 15% of the articular surface), the same is excised. If it is a larger fragment, it should be reduced anatomically and fixed with a K-wire, pullout suture, bone screws, or an interosseous wire.
- The adductor aponeurosis is repaired with as absorbable suture such as 4/0 Vicryl. Skin is re-approximated with a running monofilament subcuticular suture such as Monocryl.
- The thumb is immobilized in a thumb spica cast with the IP joint left free to prevent adhesions of the extensor mechanism, and the distal phalanx of the thumb is allowed to move freely after the case.

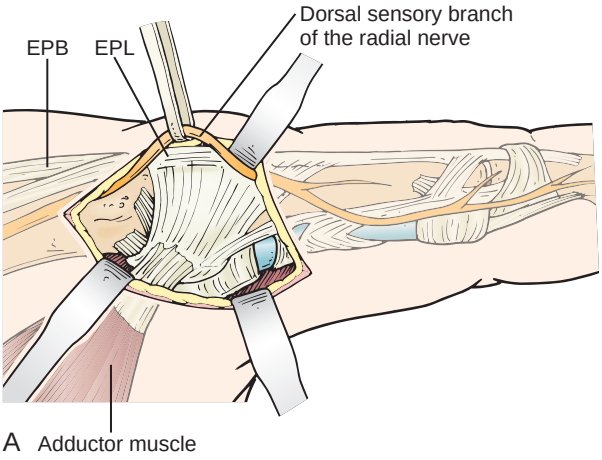

FIGURE 17-13. A, Dorsoulnar approach to the metacarpophalangeal (MCP) joint of the thumb, identifying the structures. **B,** *Dorsoulnar approach to the MCP joint of the thumb. EPB, Extensor pollicis brevis tendon; EPL, extensor pollicis longus tendon. (**A, B,** From Dorsoulnar to MCP Joint. AO Foundation. Available at: https://www2.aofoundation.org/wps/portal/surgery?showPage=approach&contentUrl=srg/76/04-Approaches/12-Dorsoulnar-MCP-JoinThumb.jsp&bone=Hand&segment=Thumb&approach=Dorsoulnar%20to%20MCP%20joint.)*

Other Surgical Techniques and Options

- Arthroscopic assisted percutaneous fixation of avulsed fracture fragment has been described by Ryu and Fagan,[1] Badia,[2] and others. Badia's technique involves using a 1.9-mm arthroscope introduced via a longitudinal portal radial to extensor pollicis longus tendon; the fractured fragmented is de-rotated and reduced and transfixed with a 0.035 K-wire under fluoroscopic guidance. The MP joint is left undisturbed.
- Because the extensor mechanism, adductor aponeurosis, and capsule are undisturbed, the rehabilitation is said to be shorter with a faster fracture healing time.

GUIDING PRINCIPLES OF POSTOPERATIVE REHABILITATION

- Protect surgical repair from lateral force
- Control pain and edema
- Maximize range of motion
- Maximize strength and ADL independence

Phase I (days 0 to 14):[1] Immediate Postoperative Period

Clinical Pearl

It is important that the patient minimize lateral stress on the MCP joint when performing hygiene activities outside of splint.

Goals

- Patient will understand the importance of postoperative splint wear and will be allowed activity to prevent extensor mechanism adhesions.
- Patient will understand ADL limitations such as repetitive and resisted pinch.
- Patient will experience controlled pain and edema.

Protection

- Hand-based IP free thumb spica splint with no more than 30° of abduction.
- Splint removal allowed for hygiene purposes.

Management of Pain and Swelling

- Ice as needed for pain.
- Light compressive wrap such as Coban as needed, ice and elevation for swelling.

Techniques for Progressive Increase in Range of Motion

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Active motion of IP and wrist joints.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Extrinsic/intrinsic thumb musculature

Functional Exercises

- Light ADL use within splint such as eating, grooming, writing, and dressing.

[1]*Prehabilitation, if appropriate, is described in the Nonoperative Rehabilitation section of this chapter.*

Milestones for Progression to the Next Phase

- Minimal pain with light ADL use.

Phase II (postoperative weeks 2 to 6)

Clinical Pearl

It is important that the patient understands the difference between active and passive motions of the MCP joint to protect the UCL from lateral forces while healing.

Goals

- Pain and edema control
- Patient will perform active range of motion to involved joint in therapy and as instructed at home.
- Increasing active range of motion of MCP joint
- Minimize hypertrophy of scar and begin collagen remodeling.
- Minimize scar hypersensitivity.

Protection

- Continue with splint wear except when performing exercises and hygiene.

Management of Pain and Swelling

- Ice as needed for pain.
- Elevation, compression, active motion of involved upper extremity, including MCP, for swelling.

Techniques for Progressive Increase in Range of Motion

Soft Tissue Techniques

- Massage and scar mobilization may be initiated at 4 weeks.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Active extension and flexion are performed in therapy and added to home program. Patient will perform three

TIMELINE 17-2: **Postoperative Rehabilitation After Ulnar Collateral Ligament Repair**

PHASE I (weeks 1 to 2)	PHASE II (weeks 3 to 6)	PHASE III (weeks 6 to 10)
• Hand-based IP free thumb spica splint • Compression/ice/elevation • Active flexion/extension MP joint • Gentle hygiene allowed	• Splinting for protection and nighttime wear • Splint removed for light ADL (2 lb or less) • Add retrograde massage as needed to decrease edema • Add active opposition	• Wean from splint for ADL and nighttime • Splint worn with heavy use • Modalities as needed • Joint mobs and passive range of motion • Scar massage • Place and hold exercises • Yellow Theraputty exercises • Resisted pinching in clinic

sets of 10 repetitions per day. Opposition is added at week 4.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Same as for Phase I

Functional Exercises

- Same as for Phase I

Milestones for Progression to the Next Phase

- Pain at rest 0/10
- Pain/tenderness 2/10 or less with palpation over UCL and during ADL use.

Phase III (postoperative weeks 6 to 10)

Clinical Pearl

It is important that the patient understand the lateral force component of ADL and will wear the splint for protection during heavy use.

Goals

- Patient will understand and begin gentle use of involved hand with splint removed.
- Patient will understand and begin static progressive splinting of MCP joint.
- Control pain and edema.
- Continue protection of UCL.

Protection

- Patient may begin weaning from splint for ADL.
- Continue splinting with heavy use.

Management of Pain and Swelling

- Continue with ice, retrograde massage, and compression.
- Modalities such as ultrasound and neuromuscular electrical stimulation (NMES) may be added.
- For swelling, the guidelines are the same as for Phase II.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Joint mobilization and passive range of motion may be initiated at MCP joint.

Soft Tissue Techniques

- Same as for Phase II.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Initiate place and hold exercises in MP flexion, extension, and opposition.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Same as for Phase I.

Techniques to Increase Muscle Strength, Power, and Endurance

- Extra-soft (yellow) Theraputty activities of pinch and grip initiated three times per day for 5-minute sessions.

Functional Exercises

- Resisted three-jaw chuck, palmar, and tip pinch initiated under therapist supervision

Milestones for Progression to the Next Phase

- No tenderness to palpation over UCL ligament and minimal pain with activities outside of splint.

Phase IV (postoperative weeks 10 to 14)

Clinical Pearl

- Patient education should focus on sport specific protection to prevent future UCL injury.
- Patient can reenter athletic activity with monitoring of pain, edema, instability, and stiffness.

TIMELINE 17-2: **Postoperative Rehabilitation After Ulnar Collateral Ligament Repair** (Continued)

PHASE IV (weeks 10 to14)	PHASE V (weeks 14 to 24)	PHASE VI (weeks 24 to 52)
• Splint only with heavy use • Taping with sport-related activities • Apply dynamic or static progressive splinting as needed • Power web/upper body exerciser/ increase resistance of Theraputty	• Short opponens splint as needed for aggressive sport-specific use • Trainer input for strength, power, endurance, and sport-specific exercises	• Return to sport/Trainer input

Goals

- Patient will regain full functional active motion of involved thumb.
- Scar formation will be limited.
- Pinch and grip strength will be functional.
- Patient will progress to sport-specific training and conditioning.

Protection

- Continue splinting with heavy use. Taping may be initiated for protection with sport-related activities.

Management of Pain and Swelling

- Same as for Phase III.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Increase aggressiveness of joint mobilization and active/passive range of motion.

Soft Tissue Techniques

- Same as for Phase III.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Dynamic splinting to increase MP joint flexion and thumb opposition as needed.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Same as for Phase I.

Techniques to Increase Muscle Strength, Power, and Endurance

- Increase resistance grade of Theraputty.
- Power web, upper body exerciser and graded clothes pins, NMES.

Functional Exercises

- Use for all ADLs outside of splint.

Sport-Specific Exercises

- Use of a power web, flex bar and calibrated hand gripper

Milestones for Progression to the Next Phase

- No reported pain (rest/general use)
- UCL stability
- Functional pinch/grip strength

Phase V (postoperative weeks 14 to 24)

Clinical Pearls

> Focus on the patient's ability to reenter sport-specific training, avoiding reinjury to the UCL. At this phase the patient should be reaching use of the affected thumb at the same level as before the injury.

Goals

- Patient will initiate sustained power pinch.
- Patient may consider wearing the short opponens splint to protect thumb with aggressive sport-specific use.
- Return to unrestricted activity.
- Return to unrestricted sport-specific training under the guidance of a qualified trainer.

Protection

- Short opponens splint as needed for aggressive sport-specific use.

Management of Pain and Swelling

- Same as for Phase III

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Same as for Phase IV

Soft Tissue Techniques

- Same as for Phase III

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Same as for Phase IV

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Same as for Phase I

Functional Exercises

- Unrestricted

Sport-Specific Exercises

- Variety of hand tools with the BTE/bodyblade.

Milestones for Progression to the Next Phase

- Pain, edema, stability, strength, will be near pre-injury levels to allow the final sport- specific abilities under the supervision of a qualified trainer.

Phase VI (postoperative weeks 24 to 52)

Clinical Pearls

The patient will combine the last five stages, allowing strength, stability, pain-free mobility, and full functional use to return to sport.

Goals

- Full range of motion with UCL stability
- Pain free
- Return to sport

Protection

- Splint/tape only as needed

Management of Pain and Swelling

- Same as for Phase III

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Same as for Phase IV

Soft Tissue Techniques

- Same as for Phase III

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Same as for Phase III

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Same as for Phase I

Functional Exercises

- Unrestricted

Sport-Specific Exercises

- Same as for Phase V

Milestones for Progression to the Next Phase

- Full sport participation

Criteria for Return to Sport

General

- Pain free
- Within 10% of total active motion of the nonaffected thumb
- Stable with lateral pinch

Sport-Specific

- Trainer input

After Return to Sport

Continuing Fitness or Rehabilitation Exercises

- Fitness/rehabilitation exercises per direction of sport-specific trainer

Exercises and Other Techniques for Prevention of Recurrent Injury

- Continued patient education
- Continued strengthening of extrinsic/intrinsic thumb musculature
- Consider NMES/biofeedback to the above muscle groups
- Splinting/Taping as needed

Evidence

There are no key evidence-based trials.

REFERENCES

1. Ryu J, Fagan R: Arthroscopic treatment of acute complete thumb metacarpophalangeal ulnar collateral ligament tears. *J Hand Surg Am* 20:1037–1042, 1995.
2. Badia A, Riano F: Arthroscopic reduction and internal fixation for bony gamekeeper's thumb. *Orthopedics* 29(8):1–4, 2006.

Multiple Choice Questions

QUESTION 1. What splint would best protect the UCL in the first 4 weeks of injury?

A. Wrist cock-up
B. Hand base thumb spica
C. Neoprene thumb wrap
D. Mallet

QUESTION 2. Splint may be removed for light activities of daily living 2 lb or less in what phase?

A. Phase I
B. Phase II
C. Phase III
D. Phase IV

QUESTION 3. What type of splint is added in Phase IV?

A. Dynamic
B. Static progressive
C. No splint
D. Silver ring

QUESTION 4. When are modalities (ultrasound/NMES) added to the treatment plan?

A. Phase 1
B. Phase 2
C. Phase 3
D. Phase 4

QUESTION 5. The patient will initiate sustained power pinch in what phase?

A. Phase 3
B. Phase 4
C. Phase 5
D. No phase

Answer Key

QUESTION 1. Correct answer: **B** (see Phase I)

QUESTION 2. Correct answer: **B** (see Phase II)

QUESTION 3. Correct answer: **A** (see phase IV)

QUESTION 4. Correct answer: **C** (see Phase III)

QUESTION 5. Correct answer: **C** (see Phase V)

BEYOND BASIC REHABILITATION: RETURN TO SKIING AFTER NONOPERATIVE OR OPERATIVE TREATMENT OF THUMB ULNAR COLLATERAL LIGAMENT INJURIES

Mohamed Khalid, MD, MCh, FRCS

Introduction

Aspects of Skiing That Require Special Attention In Rehabilitation

- Optimal handling of the ski pole with reference to the technique, grip strength, and flexibility
- Ability to control the body's movement during descent in various positions
- Improved agility and quickness to be able to better handle quick lateral movements
- Good joint mobility and appropriate muscle balance, especially in relation to quadriceps and hamstrings
- Optimal core and back strength in order to control the body's movements, especially in highly variable conditions like glades, steeps, mixed crud, and bumps
- Skiing is the most common upper extremity injury experienced by skiers.
- Return to sports is advised when there is minimal or no pain and swelling, strength has been fully regained, and stability of the MCPJ is fully restored. The specific requirements of the sport are also an important consideration. This usually takes 6 to 8 weeks in partial (grade I and II) tears. According to Lane a risk of re-rupture exists if the patient with a complete (grade III) rupture returns to sport within 3 months following surgical repair.[1] He recommends that the patients be counseled regarding this and with this understanding they can be conditionally allowed to return to sports at 4 to 6 weeks in the orthosis, and the orthosis can be discontinued at 12 weeks postoperative.
- Foye et al.[2] recommend 6 to 8 weeks of immobilization followed by return to sport with a protective splint.

Phase I: Advanced Strength and Conditioning Programs

Periodization

- Undulating
- Macrocycles
- Mesocycles
- Microcycles

TIMELINE 17-3: **Return to Skiing After Nonoperative or Operative Treatment of Thumb Ulnar Collateral Ligament Injuries**

PHASE I (weeks 1 to 2)	PHASE II (weeks 3 to 6)
• Hand-based IP free thumb spica splint • Compression/ice/elevation • Active flexion/extension MP joint • Gentle hygiene allowed	• Splinting for protection and nighttime wear • Splint removed for light ADL (2 lb or less) • Add retrograde massage as needed to decrease edema • Add active opposition

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- Training continuum
- Flexibility/joint mobility for joint stability
- Training with optimum posture
- Sensorimotor and balance training
- Core training
- Cardiorespiratory training
- Multiplanar training activities
- Training for optimum muscle balance
- Training for optimum muscle functional strength
- Training for optimum muscle functional power
- Neuromuscular dynamic stability exercises
- Plyometric training

Olympic Lifts Used in the Training Program

- Not appropriate until full healing and recovery of the thumb has taken place (usually about 12 weeks)

Training Principles Used in the Design of the Program

- Principle of progression
- Principle of overload
- Principle of variation
- Principle of individualization
- Principles of specificity-specific adaptation to imposed demands (SAID)

Application of Acute Training Variables

- Repetitions: as many as possible in 60 seconds
- Sets: 1 to 4
- Rest interval: as short as possible while maintaining proper form
- Intensity: beginning at 60% to 70% of target heart rate (THR) and working toward a 75% to 85% THR (as calculated by the Karvonen formula)
- Repetition tempo: The aim is to develop/maintain basic strength; therefore the appropriate repetition tempo is 2/0/2 (eccentric/isometric/concentric).
- Training frequency: Three per week
- Training duration: 45 to 60 minutes
- Specific exercises used in the training:
  - Exercises that do not involve use of the injured hand
  - Should perform warmup and stretching before performing these exercises
- Lower body circuit:
  - **Ski Jumps:** Aim to stay in a squatted position while jumping first 90° to the left, then back to the center, then 90° to the right, finishing back at the center (Figure 17-14).
  - **Machine Squat:** Avoid locking the legs. Maintain the knee flexion angle at a minimum of 90° (Figure 17-15).
  - **Jump Lunges:** One leg forward in the bottom of a lunge position, with shin vertical. Start by explosively jumping in the air and switch legs so that the opposite leg comes in the forward position (Figure 17-16).
  - **Box Jumps:** The box is set to at least a 15- to 20-inch high. Jump up explosively on to the box and jump back down immediately. Spring right back up for the next jump (Figure 17-17).
  - **Seated Leg Extension:** Performed in a smooth motion avoiding locking of the legs with the back straight. Can be performed double leg or single leg with weights adjusted accordingly (Figure 17-18).
  - **Abductor and Adductor Machine:** Aim to hold the leg abducted for at least 3 seconds before lowering under control and repeating (Figure 17-19).
  - **Pulsing Squat:** Performed in small movements. Stay in a squatted position and pulse three to five times. Add suitable weights for progression (Figure 17-20).
  - **Hamstring Curls:** Making sure that Hamstring stretches are performed before using the machine. Suitable weights selected and performed in a smooth motion. Weights can be increased for progression (Figure 17-21).



FIGURE 17-14. Ski jump.

TIMELINE 17-3: **Return to Skiing After Nonoperative or Operative Treatment of Thumb Ulnar Collateral Ligament Injuries** (Continued)

PHASE III (weeks 6 to 10)	PHASE IV (weeks 10 to 14)	PHASE V (weeks 14 to 24)
• Wean from splint for ADL and nighttime • Splint worn with heavy use • Modalities as needed • Joint mobs and passive range of motion • Scar massage • Place and hold exercises • Yellow Theraputty exercises • Resisted pinching in clinic	• Splint only with heavy use • Taping with sport related activities • Apply dynamic or static progressive splinting as needed • Power web/upper body exerciser/ increase resistance of Theraputty	• Short opponens splint as needed for aggressive sport-specific use • Trainer input for strength, power, endurance, and sport-specific exercises



FIGURE 17-15. Machine squat.



FIGURE 17-16. A–C, Jump lunge.



FIGURE 17-17. Box jump.



FIGURE 17-18. Seated leg extension.



FIGURE 17-19. A,B, Abductor and adductor machine.

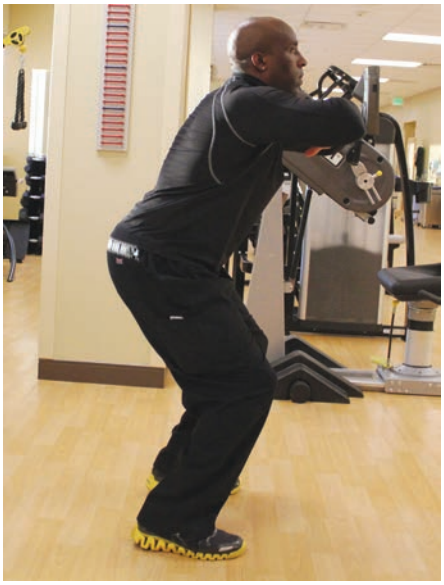

FIGURE 17-20. Pulsing squat.



FIGURE 17-21. Hamstring curl.



FIGURE 17-22. Body weight squat.

- **Body Weight Squats:** Start with arms out straight with the feet slightly wider than the shoulder width, looking straight, and back flat to slightly arched. The squat is initiated from the hips by sitting back and down, keeping the weight on the heels and coming down to a position where the thighs are approximately parallel to the ground. Press back to the starting position following the same movement pattern (Figure 17-22).

- **Abdominal Circuit:**
  - **Normal Sit-Ups:** Keep the chin off the chest (Figure 17-23).
  - **Elbow to Knee Sit-Ups:** Alternate elbows to knees; count reps on one side only (Figure 17-24)
  - **Hand to Foot Sit-Ups:** Alternate hands to feet; count reps on one side only (Figure 17-25)

Application of Chronic Training Variables

- In general, the preparatory phase consists of reviewing the previous season's performance and identifying and addressing the deficiencies.
- The duration of this phase depends upon the phase (early, mid, or late) the injury occurred.

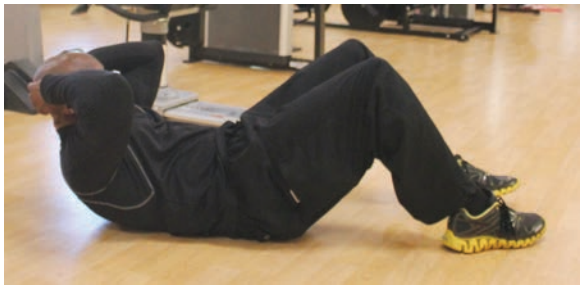

FIGURE 17-23. Normal sit up.

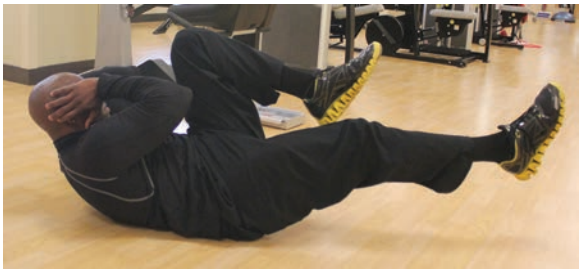

FIGURE 17-24. Elbow to knee sit up.

Phase II: Performance Enhancement Training Techniques

Periodization

- Undulating
- Macrocycles
- Mesocycles
- Microcycles

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- In this period the emphasis is on high-intensity weight lifting and anaerobic exercises.
- By the start of this phase the injured hand should have recovered sufficiently for it to be used; therefore it would be appropriate to use the hand for performing various exercises.
- The following concepts are used:
  - Training continuum
  - Flexibility/joint mobility for joint stability
  - Training with optimum posture
  - Sensorimotor and balance training
  - Core training
  - Cardiorespiratory training



FIGURE 17-25. Hand to foot sit up.

- Multiplanar training activities
- Training for optimum muscle balance
- Training for optimum muscle functional strength
- Training for optimum muscle functional power
- Neuromuscular dynamic stability exercises
- Training for speed, agility, quickness (SAQ)
- Plyometric training
- Functional training

Olympic Lifts Used in the Training Program

- Snatch
- Clean and jerk
- Power clean

Training Principles Used in the Design of the Program

- Principle of progression
- Principle of overload
- Principle of variation
- Principle of individualization
- Principles of SAID

Application of Acute Training Variables

- Repetitions: 6 to 12
- Sets: five
- Rest interval: as short as possible while maintaining proper form
- Intensity: 70% to 80% of THR (as calculated by the Karvonen formula)
- Repetition tempo: maximal strength and hypertrophy is the goal; therefore the appropriate tempo is 4/2/1 to 2/0/2.
- Training frequency: daily except 1 day off per week
- Training duration: 60 to 90 minutes
- Specific exercises used in the training
- **Lower body circuit** (as described in Phase I)
- **Leg circuit**
  - **Two-Footed Squat Thrusts** (Figure 17-26)
    - With the hands flat facing forward under the shoulders, start with your feet together and extended.
    - Staying on the toes, thrust the knees upwards in the direction of the chest.
    - Once the feet have landed up by the chest, thrust them back smoothly to the starting position before repeating.



FIGURE 17-26. Two-footed squat thrust.



FIGURE 17-27. Walking lunge.

    - Aim for a 12-inch jump
  - **Walking Lunge Forward** (Figure 17-27)
    - Stand upright, feet together, holding two light (5- to 8-lb) dumbbells at your sides (palms facing in).
    - Take a controlled step forward with your right leg.
    - Lower hips toward the floor and bend both knees (almost at 90° angles). The back knee should come close but never touch the ground. Your front knee should be directly over the ankle and the back knee should be pointing down toward the floor.
    - Push off with your right foot and bring it forward to starting position. This completes one repetition.
  - **Alternate Leg Squat Thrusts** (Figure 17-28)
    - Place your hands flat on the floor, with fingers facing forward directly under the shoulder joint.
    - Keeping on the toes during the exercise, take one leg from the rear, up toward the chest in a smooth motion. You will find that this exercise will also work your shoulder muscles.
    - Once the foot of this leg reaches the ground, the other leg should then start to come up toward the chest, and at the same time the leading leg should go back to the starting position.
- **Upper body circuit**
  - **Wide Arm Press-Up** (Figure 17-29)**:** With elbows as spread out to the side as possible
  - **Normal Press-Ups** (Figure 17-30)**:** Keeping a straight line through the back
  - **Close Hand Press-Ups** (Figure 17-31)**:** Aiming to keep the thumbs touching each other
- **Abdominal Circuit** (as described in Phase I)



FIGURE 17-28. Alternate leg squat thrust.



FIGURE 17-29. Wide arm press up.

Application of Chronic Training Variables

- **Cardiovascular:** 20 to 60 minutes per session 3 to 6 times a week
- **Muscular Strength:** 30 to 40 minutes per session 2 to 3 times a week
- **Flexibility:** 20 to 30 minutes per session 2 to 3 times a week

Phase III: Sport-Specific Training

Periodization

- Undulating
- Macrocycles
- Mesocycles
- Microcycles

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- In general, body-weight-based exercises and free-weighted exercises, such as squatting, lunging, jumping, stepping, pressing, pulling, and deadlifting, which mimic natural movement patterns are preferred over machine-based exercises, which follow a fixed motion path.
- Plyometric training, especially focused on soft landing with the hips and knees flexed, is very useful.
- Because skiing predominantly involves eccentric movements, exercises such as walking lunges, and jump style lunges that have a major eccentric component are particularly useful.



FIGURE 17-30. Normal press up.



FIGURE 17-31. Close hand press up.

- The ability to make a quick side-to-side movement such as lateral hops across a line are useful in training the body for situations such as skiing the bumps or dicing quickly with ease through the trees in the glades.
- Alpine skiing is predominantly an interval endurance activity and hence is well suited for an interval training workout.
- Training continuum
- Flexibility/joint mobility for joint stability
- Training with optimum posture
- Sensorimotor and balance training
- Core training
- Cardiorespiratory training
- Multiplanar training activities
- Training for optimum muscle balance
- Training for optimum muscle functional strength
- Training for optimum muscle functional power
- Neuromuscular dynamic stability exercises
- Training for SAQ
- Sport-specific training

Olympic Lifts Used in the Training Program

- Snatch
- Clean and jerk
- Power clean

Training Principles Used in the Design of the Program

- Principle of progression
- Principle of overload
- Principle of variation
- Principle of individualization
- Principles of SAID

Application of Acute Training Variables

- Repetitions: 20 to 25
- Sets: four
- Rest interval: 10 seconds
- Repetition tempo: 2/0/2
- Intensity: 70% to 80% of THR (as calculated by the Karvonen formula)
- Training frequency: at least twice a week
- Training duration: 60 to 90 minutes
- Specific exercises used in the training:
  - As in Phase II

- True technique-specific training can take place only on a ski slope, but in most places this is hard to achieve because the snow season may not last long enough. If there is access to simulators such as the ski-power simulator,[3] technique-specific training can be done under controlled conditions.

Application of Chronic Training Variables

- As described in Phase II

Sports Performance Testing

General Information

- General history: demographic information, previous experience in skiing, intensity of perceived exertion (Borg's scale, 4 = very light, 20 = very intense)
- Medical history: diabetes, cardiovascular conditions, and neurological conditions
- Sports injury history: hand injuries, knee injuries, hip injuries, and spinal/head injuries
- Surgical history: repair of ligament injuries and fractures
- Chronic conditions/medications: beta blockers, insulin, oral antidiabetics

Objective Tests

- Physiological assessments: muscular strength, anaerobic power, aerobic power, flexibility
- Body composition tests: height, weight and percentage of body fat. Body fat is calculated by measuring skin fold thickness using a Harpenden skin fold calipers, with values taken from multiple sites.
- Anaerobic power is assessed by measuring squat jump power and percent height loss during 45 seconds of repeated counter movement jumps using a Quattro jump force plate.
- Aerobic power: continuous incremental cycling test on an electromagnetically braked cycle ergometer. During these incremental exercises, oxygen uptake is continually measured using a calibrated spirometry system.
- Static/dynamic postural assessments: 20 meter shuttle run, double leg jumps, 60-second or 90-second repeated box jumps

Specific Criteria for Progression to the Next Stage to Determine Readiness for Skiing

- While the athlete is recovering from the thumb injury he or she should continue with exercises designed to maintain muscle strength, anaerobic/aerobic power, and flexibility even while the thumb is in a protective cast/splint.
- Depending on whether the UCL injury was partial (grade 1/2) or complete (grade 3/4) the athlete can start using the previously injured hand for actual skiing practice in 6 to 12 weeks, respectively.
- A clinical assessment evaluating tenderness, stability, and range of motion is performed and forms the basis for progression to performing exercises involving the hand and finally to actual practice on the ski slopes.

Criteria for Release to Unsupervised Complete Participation in Skiing

- Absence of thumb/hand pain
- Range of motion (ROM) of the metacarpophalangeal joint of 80% to 90% of the uninjured thumb and nearly full ROM of the interphalangeal joint
- Pinch and grip strength within 5% to 10% of the contralateral uninjured side

Recommended Ongoing Exercises

- Stretching
- Flexibility training
- Cardiovascular fitness exercises
- Aerobic and anaerobic exercises

Evidence

Breil FA, et al: Block training periodization in alpine skiing: effects of 11 day HIT on VO_{2max} and Performance. *Eur J Appl Physiol* 109:1077–1086, 2010.

In this prospective study the authors investigated the effect of block training periodization on maximal oxygen consumption and parameters of exercise performance in elite junior alpine skiers. They concluded that in for competitive alpine skiers, block periodization of HIT offers a promising way to efficiently improve VO_{2max} and performance. (Level XX evidence)

Malliou P, et al: Proprioceptive training for learning downhill Skiing. *Percept Motor Skills* 99(1):149–154, 2004.

The aim of this prospective study was to assess whether balance training would improve downhill skiing for 30 physical education students who had no previous skiing experience and were randomly assigned to two groups. The control group attended only ski lessons for two weeks, 2 to 4 hours daily. The experimental group attended downhill ski lessons and indoor balance training on a balance board, wearing ski boots, for 20 minutes every second day in the afternoon. All participants before training completed a balance assessment (stability indices). After the completion of the ski classes, all repeated the balance assessment and two downhill ski tests of agility, slalom and snow-ploughing techniques. Analysis of variance with repeated measures showed both groups improved balance similarly, but the experimental group performed significantly better on the downhill-slalom agility test, so the specific indoor balance training was helpful. (Level XX evidence)

Muller E, et al: Specific fitness training and testing in competitive sports. *Med Sci Sports Exer* 32(1):216–220, 2000.

This prospective study deals, in part, with the kinematic assessment and development of a specific training device for Alpine skiers to enable sport-specific training. (Level XX evidence)

Neumayr G, et al: Physical and physiological factors associated with success in Alpine skiing. *Int J Sports Med* 24(8):571–575, 2003.

In this prospective study the authors describe the physical and physiological characteristics of World Cup (WC) skiers. Twenty female and 28 male members of the Austrian WC ski team were examined pre- and post-seasonally from 1997 to

2000. Physical parameters such as age, height, body mass, body mass index, percent body fat and thigh circumference were recorded from each athlete. The physiological variables investigated consisted in the aerobic power and in the muscle strength of the lower limbs. Racing performance was defined by the WC ranking position. The athlete's aerobic performance capacity was assessed by maximal exercise testing on a bicycle ergometer, and the isokinetic muscle strength of the knee extensor and flexor muscles by the use of a computer-interfaced dynamometer. The study suggests that success in professional alpine skiing is not related to single physiological variables. Two main factors, however, are crucial, that is, high levels of aerobic power and muscle strength. (Level XX evidence)

Turnbull JR, Kilding AE, Keogh JWL: Physiology of Alpine skiing. *Scand J Med Sci Sports* 19:146–155, 2009.

Excellent review article comprising more than 30 years of research including 29 on snow investigations of specific physiology relating to the various ski racing disciplines, nine off snow investigations of off snow investigations of the physiological capacities of ski racers of varying ability and four review articles. (Level XX evidence)

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3. Muller E, et al: Specific fitness training and testing in competitive sports. *Med Sci Sports Exerc* 32(1):216–220, 2000.

Multiple Choice Questions

QUESTION 1. The most common upper extremity injury in skiers is

A. anterior cruciate ligament rupture.
B. fracture of scaphoid.
C. ulnar collateral ligament damage.
D. radial collateral ligament damage.

QUESTION 2. Return to sport after a skier's thumb injury is dependent upon

A. The age of the athlete.
B. The performance level of the athlete.
C. the motivation of the athlete.
D. the grade of the athlete's injury.

QUESTION 3. A commonly used physiological parameter to assess the intensity of conditioning workout is

A. target heart rate.
B. resting blood pressure.
C. resting heart rate.
D. body core temperature.

QUESTION 4. The optimal repetition program (eccentric-isometric-concentric) for a strength conditioning program is

A. 2-1-2.
B. 1-1-2.
C. 4-2-4.
D. 2-0-2.

QUESTION 5. Skiing predominantly involves _____ muscle contraction.

A. eccentric
B. concentric
C. isometric
D. tetanic

Answer Key

QUESTION 1. Correct answer: **C** (see Introduction)

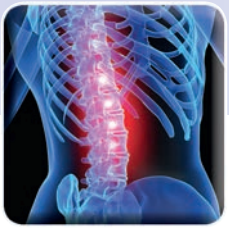
QUESTION 2. Correct answer: **D** (see Introduction)

QUESTION 3. Correct answer: **A** (see Phase I)

QUESTION 4. Correct answer: **D** (see Phase I)

QUESTION 5. Correct answer: **A** (see Phase III)

Chapter 18



Lumbar Spine Strains and Sprains

INTRODUCTION

Christopher J. Durall, PT, DPT, MS, SCS, LAT, CSCS, and Brian K. Allen, DO

Epidemiology

- Lumbar spine injuries in athletes are relatively common and most of these are thought to be strains (partial or complete tears of muscle-tendon units) and/or sprains (partial or complete tears of ligamentous/capsular/discal tissues).[1]
- Among collegiate athletes, men's wrestling, football, and women's gymnastics have the highest rates of low back injury, with an occurrence of 0.36 to 0.49 injuries per 1000 athlete exposures. Approximately 80% of these are thought to be lumbar strains or sprains.[2-4]
- Among high school athletes, 7% to 13% of all sports injuries are lower back injuries, of which muscle strains account for roughly 60%.[5]
- Low back injuries are the most common type of injury in competitive weightlifters, affecting approximately 23% of these individuals. Roughly 82% of these injuries are believed to be strains/tendonitis or sprains.[6]
- Low back pain is the most common musculoskeletal problem reported by both amateur and professional golfers, and most of these injuries are thought to be strains or sprains.[7,8]
- The majority of low back injuries occur during competition, although women's basketball, volleyball, and field hockey have higher rates of low back injury during practice.[2-4]
- Among football players, linemen seem to be more vulnerable to low back injury compared with other positions.

Pathophysiology

Intrinsic Factors

- History of previous back injury or back surgery, obesity, structural deformity (e.g., scoliosis, spondylolysis, hypermobility, leg-length inequality) all appear to elevate risk of future low back sprain/strain.
- Reduced trunk extensor muscle endurance has been found to be a risk factor for nonspecific LBP.[9]
- Lack of adequate trunk muscle endurance, in general, may lead to increased loading of the passive low-back structures (ligaments, capsules, discs), which may increase the risk of future lumbar sprain.[10]
- Contrary to popular belief, a correlation between lumbar mobility/flexibility and low back symptomatology has not been conclusively demonstrated, at least in gymnasts.[11,12]

Extrinsic Factors

- Improper technique/biomechanics leading to excessive tissue loading
- Excessive training/participation resulting in cumulative overload
- Intense training/participation (aggressiveness, "win at all costs" syndrome, etc.).[13]
- Sports-specific demands/biomechanics (e.g., extension loading in gymnasts and football lineman)
- Involvement in impact sports (e.g., football) appears to be a risk factor for lumbar strain/sprain due to loading and repetition demands of these activities.[13]
- Sports that require *repetitive end-range of motion loading (e.g., hyperextension in gymnastics)*, are associated with a greater risk of *lumbar strain/sprain*. Weightlifting, as a sport, or as a performance-enhancing modality for other sports, increases the load on the spine and, thus, the potential for injury.

Traumatic Factors

- Sudden forceful tensile loading (e.g., twisting, bending)

- Muscular overexertion, with either movement or sustained positioning (strains)

Classic Pathological Findings

- Identifiable pathological findings are rare with lumbar strains/sprains.
- Reactive muscle spasm and/or muscular trigger points may be present in some individuals.[14]

Clinical Presentation

History

- The athlete may or may not recall a specific mechanism of injury (e.g., fall).
- Some athletes may report recent increases in training frequency and/or intensity.
- Pain of a lower lumbar sprain or strain generally originates in the lower back and upper buttocks, although it may refer into surrounding areas, including the thighs. The pain is usually movement-related and may be provoked only when the athlete moves in a particular way. Because of this mechanical pain, the athlete may complain of loss of function, such as an inability to turn, twist, or bend normally.
- The athlete may report painful muscle spasms.[15]

Physical Examination

Abnormal Findings

- Trunk active range of motion is typically reduced, presumably due to pain from loading injured tissues (Figure 18-1).
- Gait may be mildly antalgic during the acute phase of injury to avoid loading injured tissues.
- Palpation of the muscles in the lumbar area may reveal local tenderness, trigger points, and/or spasm.



FIGURE 18-1. Trunk active range of motion is typically reduced following a lumbar strain/sprain, presumably because of pain from loading injured tissues.

- Edema, erythema, and elevated skin temperature may be apparent when the injured tissues are superficial.
- With a lumbar sprain, passive posterior-to-anterior "springing" of vertebrae adjacent to affected ligaments/capsule/disc is usually provocative.
- Contraction or palpation of affected muscles is provocative with a lumbar strain, whereas passive posterior-to-anterior "springing" of the lumbar vertebrae is usually not provocative.

Pertinent Normal Findings

- Structural deformities (e.g., sciatic list, "step-off" deformity) should be absent.
- Neurological symptoms (e.g., myotomal weakness, lower extremity reflex aberrations, dermatomal sensory changes) should be absent.
- Pain should not markedly intensify with lumbar extension. (If it does, consider spondylolysis, particularly in young athletes whose sport or position requires repetitive extension, such as gymnasts or football linemen).
- Radicular symptoms (narrow band of pain radiating into legs), particularly those below the knee, should be absent with lumbar sprains/strains.
- The straight-leg raising test may provoke mild low back pain but should not produce leg symptoms below the knee.
- Tests for sacroiliac dysfunction (e.g., posterior thigh thrust, gapping) should be negative.

Imaging

- Imaging is usually not appropriate for lumbar strain/sprain injuries, unless the injury is the result of recent significant trauma.[16]
- Plain radiography may be appropriate to rule out avulsion fractures when pain is localized to tendon-bone interface.
- Imaging should be considered in patients with severe, unremitting pain or neurological findings; pain that developed after an acute traumatic event or pain that persists longer than 6 weeks.
- Imaging should be considered earlier in young athletes because early identification of acute spondylolisthesis can influence outcomes.[17]
- Anteroposterior, lateral, 45° right and left oblique views and collimated lateral views of the lumbar spine should be obtained.
- CT, MR, or scintography may be appropriate for select patients to rule out other potential causes of back pain, such as fracture, infection, tumor, or involvement of spinal nerve roots.

Differential Diagnosis

- Visceral injury/disease (e.g., renal disease, pyelonephritis)
- Vascular disease (e.g., abdominal aortic aneurysm)
- Lumbosacral disc injuries
- Lumbosacral facet syndrome
- Lumbosacral instability
- Lumbosacral radiculopathy
- Lumbosacral spine acute fracture

- Lumbosacral spondylolisthesis
- Lumbosacral spondylolysis
- Piriformis syndrome
- Early discitis before onset of fever
- Rheumatic disease: white blood cell count, erythrocyte sedimentation rate, and human leukocyte antigen assay for HLA-B27 may be used to assess for underlying rheumatic disease.
- Sacroiliac joint injury

Treatment

Nonoperative Management

- Oral, topical, or injectable analgesics
- Oral, topical, or injectable antiinflammatories
- Muscle relaxants
- Pain/symptom modulating modalities (e.g., sensory electrical stimulation, cryotherapy)
- Spinal mobilization (nonthrust) or manipulation (thrust)
- Therapeutic massage/soft tissue mobilization
- Relative rest
- Therapeutic exercise
- Aquatic therapy
- Patient education (e.g., warm-up routines appear to have a positive effect on preventing low back injuries in golfers if they are at least 10 minutes long)[18]

Guidelines for Choosing Among Nonoperative Treatments

- Pain/symptom modulating modalities should be considered during the acute phase of injury. Once the athlete is able to tolerate active treatment, these should be discontinued or used sparingly to minimize iatrogenic effects of exercise or spinal mobilization/manipulation.
- Muscle relaxants: Medication such as Skelaxin and Flexeril has no direct effect on the muscle motor unit. Their mechanism of action is through modifying the central nervous system response to painful stimuli. They do work synergistically with pain medication allowing lower doses of pain medication to have the same pain relieving effect.
- Spinal mobilization (nonthrust) or manipulation (thrust) should be considered in the acute or sub-acute period for athletes with low-to-moderate levels of symptom irritability when the following variables are satisfied: symptom duration less than 16 days, low work-related fear-avoidance belief scores, lumbar hypomobility, hip internal rotation range of motion at least 35° on one or both sides, no symptoms distal to the knee.[19]
- Relative rest: Most athletes who experience a lumbar strain or sprain will require a period of reduced or modified activity, including removal from competition. Symptom-limited alternative activities and exercises should be encouraged to minimize deconditioning.
- Low-level therapeutic exercise should begin as soon as possible after the injury to avoid the deleterious effects of immobilization. The intensity, duration, and complexity of therapeutic exercise should be increased over time in accordance with the athlete's symptomatic and objective improvement.
- Patients who are intolerant of land exercise may tolerate aquatic therapy. Many land exercises can be replicated in a pool, with the benefits of reduced spinal weightbearing (via buoyancy), and increased spinal stabilization (via hydrostatic pressure).
- The majority of lumbar strains/sprains will be self-limiting and resolve within 6 weeks regardless of the type of treatment.[13]
- Most athletes can return to full unrestricted play after sufficient resolution of pain and restoration of range of motion and strength.

Surgical Indications

- There are no absolute indications for surgery with lumbar strain/sprains

Aspects of History, Demographics, or Exam Findings That Affect Choice of Treatment

- See general guidelines in the preceding.

Aspects of Clinical Decision Making When Surgery Is Indicated

- Lumbar strains/sprains are typically benign in nature, transient and self-limiting. Failure to respond to conservative management within 4 to 6 weeks may warrant referral for further specialized testing.

Evidence

Biering-Sorensen F: Physical measurements as risk indicators for low-back trouble over a one-year period. *Spine* 9:106–119, 1984.

In this prospective study of 449 men and 479 women aged 30 to 60, the authors examined the prognostic value of several physical measurements (anthropometric measurements, flexibility measurements of the back and hamstrings, trunk muscle strength, and endurance) for first-time occurrence of low back pain (LBP) and for recurrence or persistence of LBP. The main findings at the 12-month follow-up were that good isometric endurance of the back (extensor) muscles may prevent first-time occurrence of LBP in men and that men with hypermobile backs are more liable to contract LBP. Weak trunk muscles and reduced flexibility of the back and hamstrings were found as residual signs, in particular, among those with recurrent or persistent LBP. (Level IV evidence)

Davis PC, Wippold FJ, 2nd, Brunberg JA, et al: ACR Appropriateness Criteria on low back pain. *J Am Coll Radiol* 6(6):401–407, 2009.

This is an expert-panel consensus document by the American College of Radiology (ACR). Based on a review of the best-available evidence, the authors conclude that uncomplicated acute LBP is a benign, self-limited condition that does not warrant any imaging studies. Radiographs are recommended when any of several red flags are present, including recent significant trauma. Additional guidelines for recognition of patients with more complicated status can be used to identify those who require further evaluation for suspicion of more serious problems and contribute to appropriate imaging utilization. (Level V evidence)

Flynn T, Fritz J, Whitman J, et al: A clinical prediction rule for classifying patients with low back pain who demonstrate short-term improvement with spinal manipulation. *Spine* 27(24):2835–2843, 2002.

This was a prospective, cohort study of 71 patients with nonradicular LBP who were all treated with spinal manipulation. Thirty-two patients had success with the manipulation intervention, determined using change in disability scores. Five pretreatment variables were associated with treatment success: symptom duration less than 16 days, low work-related fear-avoidance belief scores, lumbar hypomobility, hip internal rotation range of motion at least 35° on one or both sides, and no symptoms distal to the knee. The presence of four of five of these variables increased the probability of success with manipulation from 45% to 95% (positive likelihood ratio = 24.38). (Level IV evidence)

Greene HS, Cholewicki J, Galloway MT, et al: A history of low back injury is a risk factor for recurrent back injuries in varsity athletes. *Am J Sports Med* 29(6):795–800, 2001.

In this prospective study, 18.3% (124) of 679 Yale varsity athletes surveyed in 1999 reported that they had sustained a low back injury within the past 5 years, and 6.8% (46) sustained a low back injury in the follow-up season. A history of low back injury was the significant predictor for sustaining low back injury in the following year, and athletes who reported previous low back injury were at three times greater risk. (Level IV evidence)

Lawrence JP, Greene HS, Grauer JN: Back pain in athletes. *J Am Acad Orthop Surg* 14(13):726–735, 2006.

In this review article, the authors provide evidence-based guidance on treating back pain in athletes. The authors suggest that self-limited symptoms must be distinguished from persistent or recurrent symptoms associated with identifiable pathology. Athletes involved in impact sports and those who participate in longer and more intense training appear to have higher incidence rates of back pain. Data suggest that the recreational athlete may be protected from lumbar injury with physical conditioning. Treatment of athletes with back pain usually is nonsurgical, and symptoms generally are self-limited. However, a systematic approach involving a thorough history and physical examination, pertinent imaging, and treatment algorithms designed for specific diagnoses can facilitate symptomatic improvement and return to play. (Level V evidence)

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Multiple Choice Questions

QUESTION 1. Which collegiate sports have the highest rates of low back injury?

A. Golf and competitive weightlifting (i.e., powerlifting)
B. Men's wrestling, football, women's gymnastics
C. Men's rugby and women's field hockey
D. Soccer and tennis

QUESTION 2. Which of the following factors have been shown to increase risk of lumbar spine injury?

A. History of previous back injury
B. Inadequate lumbar flexibility
C. Inadequate stretching before activity
D. Lack of motivation

QUESTION 3. Which of the following is NOT a typical/common finding in patients with lumbar strain/sprain?

A. Ankle dorsiflexor weakness
B. Decreased trunk range of motion
C. Mildly antalgic gait
D. Muscle spasms and/or muscular trigger points

QUESTION 4. Which of the following statements is correct?

A. Imaging is not usually appropriate following a lumbar strain or sprain unless the injury occurred recently.
B. Imaging is not usually appropriate following a lumbar strain or sprain unless the injury occurred during football practice or competition.
C. Imaging is not usually appropriate following a lumbar strain or sprain unless the injury occurred during gymnastics practice or competition.
D. Imaging is not usually appropriate following a lumbar strain or sprain unless the injury is the result of recent significant trauma.

QUESTION 5. Which of the following statements is NOT correct?

A. Most athletes who experience a lumbar strain or sprain will require a period of reduced or modified activity, including removal from competition.
B. Most athletes suffering from a lumbar strain or sprain will require spinal surgery.
C. Some athletes who have sustained a lumbar strain or sprain will benefit from pain modulating modalities.
D. Some athletes who have sustained a lumbar strain or sprain may be appropriate for spinal manipulation treatment.

Answer Key

QUESTION 1. Correct answer: **B** (see Epidemiology)

QUESTION 2. Correct answer: **A** (see Pathophysiology)

QUESTION 3. Correct answer: **A** (see Clinical Presentation)

QUESTION 4. Correct answer: **D** (see Clinical Presentation)

QUESTION 5. Correct answer: **B** (see Treatment)

NONOPERATIVE REHABILITATION OF LUMBAR SPINE STRAINS AND SPRAINS

Christopher J. Durall, PT, DPT, MS, SCS, LAT, CSCS, and Brian K. Allen, DO

GUIDING PRINCIPLES OF NONOPERATIVE REHABILITATION

- Consider the unique requirements of the athlete's sport in addition to the identified deficits when prescribing exercises.
- Maintain or improve sport-specific fitness/conditioning via cross-training.
- Athlete must be able to adequately control lumbar spine and pelvis throughout ranges of motion required by the sport.
- Return to full, unrestricted activity should be predicated on symptom response to activity.

In lieu of trying to identify and treat the injured lumbar spine tissues, an effort should be made to determine the specific treatment approach (manipulation, stabilization exercise, or directionally specific exercise) that is likely to be most beneficial for the injured athlete. Outcomes can be improved when individuals with low back pain receive treatments that are matched to their clinical features.[1] Thus, patients with lumbar hypermobility may be appropriate for stabilization exercise, whereas those with lumbar hypomobility may benefit from manipulation.[2,3] Individuals with a directional preference for movement (e.g., flexion or extension) tend to fare better when the treatment is matched to the directional preference.[4] Guidelines are available to help clinicians match clinical findings with different treatment approaches for LBP.[2–4]

Phase I (weeks 1 to 2)

Protection

- Bracing (e.g., lumbar corset) is not recommended for lumbar sprains or strains because of a lack of proven efficacy and concerns over the deleterious effects of prolonged immobilization on connective tissue integrity. Nonetheless, there are anecdotal reports of patients with severe low back pain benefiting from transient use of bracing with activities of daily living. For this reason, any lumbar bracing should be discontinued as soon as possible.

Management of Pain and Swelling

- Sensory electrical stimulation, moist heat, or cryotherapy may be used to reduce pain and swelling.
- Unlike peripheral joints, anecdotal evidence suggests that superficial heating may be beneficial for treating acute spine pain.
- Fatiguing motor-level electrical stimulation or ultrasound combined with motor-level electrical stimulation may be effective for reducing muscle spasm or for deactivating muscle trigger points.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- The presence of the following variables may increase the likelihood of success with lumbar manipulation or mobilization: symptom duration less than 16 days, low work-related fear-avoidance belief scores, lumbar hypomobility, hip internal rotation range of motion (ROM) at least 35° on one or both sides, and no symptoms distal to the knee.[3]

Soft Tissue Techniques

- Deep massage or ischemic compression may be used for trigger points or muscle spasms.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Gentle lumbar spine self-mobilization exercises should be initiated as soon as possible in a pain-free ROM to



FIGURE 18-2. Weight shifting in quadruped. From a quadruped position, slowly shift weight forward, backward, left, right, or along a diagonal to increase trunk range of motion.

limit the adverse effects of immobilization and to stimulate the synthesis and proper alignment of collagen.[5] These exercises can be performed in supine (e.g., knee to chest, posterior pelvic tilting), prone (e.g., prone press-ups), or quadruped (e.g., weight shifting/rocking in different directions) (Figure 18-2).
  - Athletes who feel better in lumbar extension may tolerate extension activities/exercises, whereas those who feel better in lumbar flexion should be encouraged to try various flexion activities/exercises. Outcomes for LBP tend to be better when treatment is matched to the patient's directional preference, and worse when the patient is given a directionally opposite treatment.[4]
- Stretching exercises should be included for the hip flexors, rotators, adductors, quadriceps, gastrocnemius/soleus, and hamstring muscles (Figure 18-3).
  - Hip/leg stretching exercises should be performed with abdominal bracing (see description that follows) while maintaining a neutral (i.e., mid-ROM) lumbar spine to avoid symptom exacerbation.

Other Therapeutic Exercises

- The presence of the following variables may increase the likelihood of success with a stabilization exercise

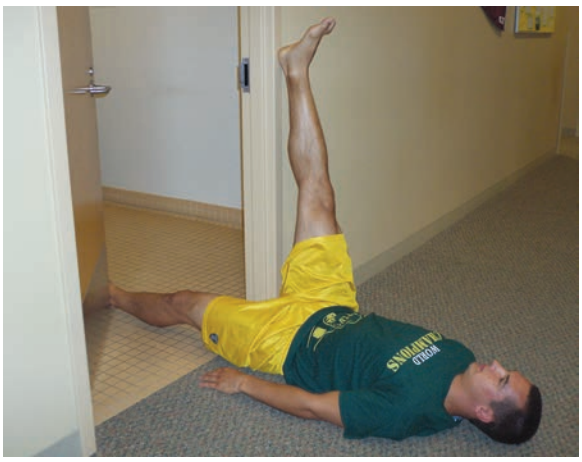

FIGURE 18-3. Hamstring stretch in doorway. Lie on floor with leg to be stretched resting on wall and other leg extended into the open doorway. While maintaining a neutral lumbar spine and an abdominal brace, scoot buttocks toward wall until stretch is felt in hamstrings.

treatment approach: age less than 40, straight-leg raise greater than 91°, positive prone instability test, presence of aberrant motions, lumbar hypermobility with passive testing, and absence of fear-avoidance beliefs.[2]
- Total leg strengthening should be performed, with an emphasis on the gluteus maximus and medius muscles.
  - Gluteal sets/squeezes in prone, supine or hook-lying (i.e., supine with hips and knees flexed and feet on floor)
  - Bridging in hook-lying
- Total arm strengthening should also be performed.
  - Chest press/pushups, rows, shoulder press, latissimus pull-downs, arm curls, elbow extension, wrist extension and flexion
- As with the hip/leg stretching exercises, all leg and arm strengthening exercises should be performed with abdominal bracing while maintaining a neutral (i.e., mid-ROM) lumbar spine to avoid symptom exacerbation.
  - For abdominal bracing, the athlete should tense/tighten his or her entire trunk/core to create a muscular "core-set" (corset), without holding the breath,

TIMELINE 18-1: **Nonoperative Rehabilitation of Lumbar Spine Strains and Sprains**

PHASE I (weeks 1 to 2)	PHASE II (weeks 2 to 4)
• Lumbar bracing prn; discontinue as soon as possible • Modalities prn for pain or swelling • Lumbar manipulation/mobilization if specific factors present • Massage or ischemic compression prn • Pain-free lumbar spine self-mobilization • Lower extremity stretching • Total leg strengthening emphasizing the gluteals • Total arm strengthening as tolerated • Single-leg balancing • Pelvic "clocks" and/or weight-shifting on ball • Single arm or leg unweighting in quadruped • Abdominal bracing in hook-lying ("core-set") • Bent-knee "fallouts" • Marching in hook-lying • Heel slides • Bridging in hook-lying • Walking or sport-specific cardiovascular conditioning on land or in pool	• Modalities prn for pain or swelling • Lumbar manipulation/mobilization if specific factors present • Massage or ischemic compression prn • Progress sport-specific TAS/TLS activities • Progress sport-specific cardiovascular conditioning • Continue lumbar spine stretching/self-mobilization • Exercises from supine bridged position with head and shoulder supported on dome or therapy ball • Exercises while seated on therapy ball • Progress single-leg balance activities • Exercise progression in quadruped • Prone bridging • Supine curlups with greater than or equal to 1 hip in neutral • Emphasize trunk muscle endurance • Lateral walking with cable or elastic band/cord • Oscillations with oscillating blade • Side support on forearm and bent knee • Exercises from supine bridged position with heels on dome • Diagonal chops and lifts in standing

drawing the abdomen in, or pushing the abdomen out.
  - Abdominal bracing has been shown to increase lumbar spine stability to a greater extent than abdominal drawing-in (abdominal hollowing).[6]

NOTE: All of the following exercises should be performed with abdominal bracing while maintaining a neutral lumbar spine

Sensorimotor Exercises

- Single-leg balancing on various surfaces (pillow, dome, foam pad, disc)
- Pelvic "clocks" in hook-lying
- Weight-shifting while seated on therapy ball (anterior-posterior, lateral, circles)

Open and Closed Kinetic Chain Exercises

- Single arm or leg unweighting in quadruped (i.e., from all-fours to three points of contact)

Neuromuscular Dynamic Stability Exercises

- Abdominal bracing in hook-lying ("core-set")
- Bent-knee "fallouts" (Figure 18-4)
- Marching in hook-lying
- Alternating heel slides
- Bridging in hook-lying

Functional Exercises

- Walking on land or in pool

Sport-Specific Exercises

- Sport-specific cardiovascular conditioning should be incorporated to minimize erosion of athletic performance. The athlete should be taught to control lumbopelvic movement during cardiovascular activities.
  - Consider biking for athletes who feel better in slight lumbar flexion versus extension.
  - Consider walking or elliptical trainer for athletes who feel better in lumbar extension versus flexion.
  - Consider sport-specific drills/activities in a pool for athletes who do not tolerate land-based exercise.



FIGURE 18-4. Bent-knee "fallouts." From hook-lying, slowly lower one leg into abduction and external rotation while maintaining a neutral lumbar spine and an abdominal brace.

Milestones for Progression to the Next Phase

- Acute pain, edema and muscle spasms have plateaued or started to subside.
- Activity/exercise tolerance has improved.

Phase II (weeks 2 to 4)

Protection

- Bracing should not be needed by this time.

TIMELINE 18-1: **Nonoperative Rehabilitation of Lumbar Spine Strains and Sprains** (Continued)

PHASE III (weeks 4 to 6)	PHASE IV (weeks 6+)
• Modalities prn for postexercise/activity pain • Lumbar manipulation/mobilization prn • Progress sport-specific TAS/TLS exercises • Progress sport-specific cardiovascular conditioning • Progress lumbar spine stretching/self-mobilization • Diagonal "chops" and "lifts" while seated on therapy ball • Exercise progression from prone bridged position • Single-leg supine bridging • One-arm rows with dumbbell while ½ kneeling on bench • Exercise progression in quadruped • Side support (side bridge) on forearm and feet • Prone bridge with forearms on therapy ball • Exercises from supine bridged position with head and shoulder supported on dome or therapy ball • Sport-specific jumping, hopping, bounding • Depth drop pushups • Single-leg deadlift • Sport-specific, multi-planar activities/exercises	• Modalities prn for postexercise/activity pain • Sport-specific TAS/TLS exercises • Sport-specific cardiovascular conditioning • Progress lumbar spine stretching/self-mobilization • Single-leg deadlift progression • Diagonal "chops" and "lifts" or trunk rotation on one foot • Rotating body bridge • Hanging straight leg raise to 90° hip flexion • Bilateral hip extension over center of plinth • Exercises from supine bridge with heels on therapy ball • Exercises from pushup position with feet on therapy ball • Sport-specific jumping, hopping, bounding • Clapping pushups • Advance intensity, duration, speed and complexity of functional and sport-specific exercises/activities

Management of Pain and Swelling

- Both motor-level electrical stimulation[7] and exercise[8] have been found to be effective for reducing edema during the subacute phase of healing. Exercise is more functional, however, and should be used in lieu of electrical stimulation if tolerated. Sensory-level electrical stimulation and/or cryotherapy may be used to reduce postexercise/activity soreness.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Athletes who responded favorably to spinal mobilization or manipulation during Phase I may benefit from further manual therapy. These interventions may potentiate the effects of therapeutic exercise.

Soft Tissue Techniques

- Deep massage or ischemic compression may be used for trigger points or muscle spasms.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Stretching/self-mobilization exercises for the lumbar spine should be continued within the pain-free ROM.
  - From kneeling, controlled side-to-side and/or forward-backward rolling with forearms on a therapy ball or wheeled stool (Figure 18-5).
  - From hook-lying, both knees are moved side-to-side under control.
- Continue with stretching exercises for the hip flexors, rotators, adductors, hamstrings, quadriceps and gastrocnemius/soleus muscles, with abdominal bracing while maintaining a neutral lumbar spine.

Other Therapeutic Exercises

- See Phase I
- Modify and progress arm and leg strengthening exercises, making them as sport-specific as possible.



FIGURE 18-5. Controlled rolling from kneeling. From kneeling with forearms on a therapy ball or wheeled stool, roll ball side-to-side or forward-backward under control. Maintain an abdominal brace and do not allow excessive lumbar spine flexion, extension, or rotation.



FIGURE 18-6. Starting position for exercises from supine bridged position with head and shoulders supported on dome.

- Single or double leg squats and forward or backward lunges (for developing total leg strength and isometric spinal stabilization simultaneously).
- Pushups and pullups (for developing total arm strength and isometric spinal stabilization simultaneously).
- Progress sport-specific cardiovascular conditioning (e.g., from walking to jogging).

NOTE: All of the following should be performed with abdominal bracing while maintaining a neutral lumbar spine

Sensorimotor Exercises

- Exercises from supine bridged position with head and shoulders supported on dome or therapy ball (Figure 18-6):
  - Alternate heel lifts
  - Hip abduction with elastic band/cord above knees
  - Controlled up/down bridging
- Exercises while seated on therapy ball
  - Side-to-side shifting
  - Pelvic rocking/tilts
  - "Hula-hoops" (circumduction)
  - Unilateral or bilateral shoulder flexion
  - Marching
  - Marching with contralateral shoulder flexion (Figure 18-7)
  - Single arm rowing with cable or elastic band/cord
- Progress single-leg balance activities by using more challenging surfaces, or adding dynamic elements (e.g., playing catch, walking obstacle courses)

Open and Closed Kinetic Chain Exercises

- Exercises in quadruped
  - Single arm flexion
  - Single hip extension
  - Single arm flexion with contralateral hip extension (bird-dog or pointer)
  - Rhythmic stabilization
- Prone bridging on forearms and toes (planks) (Figure 18-8)
- Curl-ups in supine with one or both hips in neutral. Levels of spinal compression and spinal shear and psoas activity were lower during curl-ups with hips in neutral versus flexion.[9]

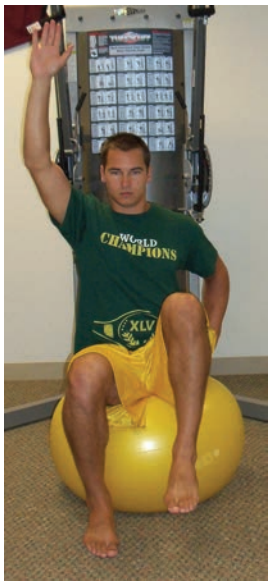

FIGURE 18-7. Marching with contralateral shoulder flexion while seated on a therapy ball. While seated on a therapy ball, flex one hip to lift foot from floor while flexing the opposite shoulder overhead. Maintain an abdominal brace and do not allow excessive lumbar spine flexion, extension, or rotation.

Techniques to Increase Muscle Strength, Power, and Endurance

- Endurance should be emphasized during this phase more than strength.
  - Poor lumbar muscle endurance is a significant risk factor in development of future LBP.[10–12]
  - Trunk muscle endurance training has been shown to be effective in reducing pain and disability in patients with nonspecific low back pain.[13–15]
  - It is particularly important to regain normal bulk and endurance of erector spinae muscles and multifidus.[16]

Neuromuscular Dynamic Stability Exercises

- See sensorimotor exercises in the preceding.
- Lateral walking with cable or elastic band/cord (Figure 18-9)
- Two-handed medial-lateral oscillations of vertically oriented oscillating blade (e.g., Bodyblade) or superior-inferior oscillations of horizontally oriented oscillating blade while standing



FIGURE 18-8. Prone bridging. From a prone position with elbows spaced shoulder-width, arms perpendicular to mat, and hands touching so that the forearms form a V, the pelvis is raised by contracting the trunk flexor muscles.



FIGURE 18-9. Lateral walking with cable or elastic band/cord. Start in an athletic stance with slight hip and knee flexion. Hold handle of cable or elastic band/cord in front of torso at level of lower rib cage. After performing abdominal brace, walk sideways while keeping handle in starting position. Do not rotate torso.

- Side support (side bridge) on forearm and bent knee (Figure 18-10)
- Exercises from supine bridged position with heels on dome (Figure 18-11)
  - Bridging
  - Marching

Functional Exercises

- See sensorimotor exercises in the preceding and sport-specific exercises in the following.

Sport-Specific Exercises

- Diagonal "chops" and/or "lifts" in standing with cable or elastic band/cord, mimicking sport movements as much as possible



FIGURE 18-10. Side support (side bridge) on forearm and bent knee. Start in a side-lying position with both knees bent. Raise the pelvis by contracting the trunk lateral flexor muscles while supporting the upper body on one forearm. A straight line should be maintained from their upper body to the feet (i.e., no trunk or hip flexion or extension). The hand of the non–weight-bearing arm can assist in stabilizing the weight-bearing shoulder.



FIGURE 18-11. Starting position for exercises from supine bridged position with heels on dome.

Milestones for Progression to the Next Phase

- Minimal pain with activity
- Good tolerance for exercises listed in the preceding
- Minimal, transient postexercise/activity pain
- Minimal muscle spasm
- Minimal edema

Phase III (weeks 4 to 6)

Management of Pain and Swelling

- Sensory electrical stimulation and/or cryotherapy may be used to reduce postexercise/activity soreness.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- See Phase II recommendations

Soft Tissue Techniques

- See Phase II recommendations

Stretching and Flexibility Techniques for the Musculotendinous Unit

- See Phase II recommendations

Other Therapeutic Exercises

- See Phase II recommendations

NOTE: All of the following should be performed with abdominal bracing while maintaining the lumbar spine in a symptom-free ROM.

Sensorimotor Exercises

- Exercises while seated on therapy ball
  - Diagonal "chops" and/or "lifts" with cable or elastic band/cord

Open and Closed Kinetic Chain Exercises

- Exercise progression from prone bridged position (see Figure 18-8)
  - Single-leg unweighting (i.e., four-point to three-point)
  - Single-arm unweighting
  - Single-leg circles or diagonals



FIGURE 18-12. One-arm rows with dumbbell while half kneeling on bench (lawn mowers). Maintain an abdominal brace and do not allow excessive lumbar spine flexion, extension, or rotation while lifting and lowering weight.

Techniques to Increase Muscle Strength, Power, and Endurance

- See exercises in the preceding and the following.

Neuromuscular Dynamic Stability Exercises

- Single-leg supine bridging
- One-arm rows with dumbbell while half kneeling on bench (lawn mowers) (Figure 18-12)
- Exercise progression in quadruped
  - Arm and/or opposite leg circles (i.e., circumduction) from bird-dog position (i.e., single arm flexion with contralateral hip extension)
  - Arm and/or opposite leg diagonals from bird-dog position
  - Single knee to opposite elbow
- Side support (side bridge) on forearm and feet (Figure 18-13)



FIGURE 18-13. Side support (side bridge): From a side-lying position, the pelvis is raised by contracting the trunk lateral flexor muscles while supporting the upper body on one forearm. A straight line should be maintained from the upper body to the feet (i.e., no trunk or hip flexion or extension). The hand of the non–weight-bearing arm can assist in stabilizing the weight-bearing shoulder.



FIGURE 18-14. Prone bridge with forearms on therapy ball. From a prone position with forearms resting on a therapy ball, elbows spaced shoulder-width, and hands touching so that the forearms form a V, the pelvis is raised by contracting the trunk flexor muscles.

- Prone bridge with forearms on therapy ball (Figure 18-14)
- Exercises from supine bridged position with head and shoulder supported on therapy ball
  - Marching
  - Single-leg bridging
  - Diagonal "chops" and/or "lifts" with cable or elastic band/cord (Figure 18-15)

Plyometrics

- Sport-specific jumping, hopping, bounding activities/exercises for the lower extremities
- Depth drop pushups for the upper extremities using different size boxes

Functional Exercises

- Single-leg deadlift (Figure 18-16)

Sport-Specific Exercises

- Sport-specific, multiplanar activities/exercises should be incorporated and progressed according to the athlete's ability to maintain lumbopelvic control during the activity.
- Resistance with all sport-specific exercises should be adjusted based on the athlete's ability to perform the exercise with good form/technique while maintaining abdominal bracing.
- The intensity, speed and duration of activities should increase over time until they approximate those of the appropriate sport.
- Examples
  - Football lineman may need to initially use unweighted blocking sleds.
  - Weightlifters should initially focus on technical aspects of a particular lift using a relatively light weight.
  - Golfers should gradually increase swing speed according to symptom response.
  - Gymnasts should practice routines at slower than usual speed.
- Consult with athlete and coaches for other sport-specific exercises/activities.



FIGURE 18-15. Diagonal "chops" or "lifts" from supine bridged position with head and shoulders supported on therapy ball. Maintain an abdominal brace and do not allow excessive lumbar spine flexion, extension, or rotation while "chopping" or "lifting."



FIGURE 18-16. Single-leg deadlift: Start in single-leg stance position with arms at sides, then move trunk forward and contralateral leg into extension by flexing stance leg's hip. Stance knee should remain slightly flexed throughout exercise. Continue leaning trunk forward (via flexing at hip) as far as possible while maintaining spinal alignment and control.

Milestones for Progression to the Next Phase

- No pain with activity
- Intermittent short-duration pain with movement
- Minimal, transient postexercise pain
- No observable swelling
- Active and passive joint ROM within normal limits
- Trunk muscle deficits less than 25% with manual muscle testing, isokinetic testing, and/or functional testing

Phase IV (weeks 6+)

Management of Pain and Swelling

- See Phase II recommendations

Techniques for Progressive Increase in Range of Motion

- Joint or soft tissue mobilization and/or stretching/flexibility exercises should continue if deficits persist.

Other Therapeutic Exercises

- See Phase III recommendations

NOTE: All of the following should be performed with abdominal bracing while maintaining the lumbar spine in a symptom-free ROM

Sensorimotor Exercises

- Single-leg deadlift progression
  - With both shoulders abducted 90°
  - With one shoulder flexed 90° reaching to floor (alternate flexed shoulder with each repetition)
  - On labile surface (e.g., foam pad)

Open and Closed Kinetic Chain Exercises

- See exercises in the preceding and the following.

Techniques to Increase Muscle Strength, Power, and Endurance

- See exercises in the preceding and the following.

Neuromuscular Dynamic Stability Exercises

- Diagonal "chops and/or "lifts" or trunk rotation with cable or elastic band/cord balancing on one foot
- Rotating body bridge: Move from side plank/bridge position on one arm (see Figure 18-13) to prone bridge (see Figure 18-8) then to side bridge on opposite arm while maintaining neutral lumbar spine and abdominal brace throughout. Hold each bridged position for 10 seconds. The foot of the upper leg should be placed on the floor for the side bridge to enable rolling into a prone bridge without changing foot alignment.
- Hanging straight leg raise to 90° hip flexion
- Bilateral hip extension over center of plinth (Figure 18-17)



FIGURE 18-17. Bilateral hip extension over center of plinth. While holding onto plinth, lift legs from floor to horizontal under control. Motion should occur about the hips, not the spine to avoid lumbar sprain/strain exacerbation.



FIGURE 18-18. Starting position for exercises from pushup position with lower legs and/or feet on therapy ball.

- Exercises from supine bridged position with heels on therapy ball
  - Bridging
  - Marching
  - Roll ball side-to-side
- Exercises from pushup position with lower legs and/or feet on therapy ball (Figure 18-18)
  - Roll ball side-to-side
  - Alternate hip extension
  - Pushups
  - Bilateral hip and knee flexion (prone tucks) (Figure 18-19)

Plyometrics

- Sport-specific jumping, hopping, bounding
- Clapping pushups

Functional Exercises

- See Phase III recommendations.
- The complexity and speed of activities should increase over time until they approximate those of the appropriate sport.

Sport-Specific Exercises

- See Phase III recommendations.
- The intensity and duration of activities should increase over time until they approximate those of the appropriate sport.



FIGURE 18-19. Prone tucks. Start in pushup position with legs or feet on therapy ball. Roll ball forward then back to starting position while controlling for excessive lumbar spine motion.

Milestones for Progression to Advanced Sport-Specific Training and Conditioning

- Full, pain-free ROM
- Normal trunk muscle strength (as determined by manual testing or dynamometry)
- Good technique with all Phase IV exercises

Criteria for Abandoning Nonoperative Treatment and Proceeding to Surgery or More Intensive Intervention

- Lumbar strains/sprains are typically benign in nature, transient and self-limiting. Failure to respond to conservative management within 4 to 6 weeks may warrant referral for further specialized testing.
- There are no absolute indications for surgery with lumbar strain/sprains.

Tips and Guidelines for Transitioning to Performance Enhancement

- During the last phase of rehabilitation the athlete should be advanced to his or her maximum functional potential.
- A whole-body warm-up should precede activity/exercise.
- Exercises should be performed at roughly the same time of day as practices or events.
- All three energy systems should be trained, with the most sport-specific system(s) emphasized.
- Activities/exercises that closely approximate the specific movements and skill requirements of the sport should be included.
- The level of resistance used during functional strengthening drills should approximate or slightly exceed the intensity of the sport.
- Agility, plyometric, speed, and strengthening activities/exercises should be included at a progressively higher level of performance, intensity, and complexity.
- If appropriate, elements of changing speed, direction, and center of gravity should be introduced.
- It may be appropriate to have the athlete exercise with control into nonneutral ranges of motion once they have demonstrated excellent lumbar spine control in neutral. The need to exercise into nonneutral ranges should be predicated on the sport's movement requirements and balanced against any untoward symptom aggravation.

Specific Criteria for Return to Sports Participation: Tests and Measurements

- Adequate pain-free trunk ROM for given sport
- Normal trunk muscle strength (as determined by manual testing or dynamometry)
- No obvious deficits in lower or upper extremity strength or flexibility

Evidence

Brennan GP, Fritz JM, Hunter SJ, et al: Identifying subgroups of patients with acute/subacute "nonspecific" low back pain: Results of a randomized clinical trial. *Spine* 31(6):623–631, 2006.

In this prospective, randomized study the authors studied the impact of classifying 123 patients with LBP of less than 90 days' duration into one of three subgroups based on the type of treatment believed most likely to benefit the patient (manipulation, stabilization exercise, or specific exercise). Patients who received matched treatments experienced greater reductions in disability after 4 weeks and after 1 year than those who received unmatched treatments. This suggests that nonspecific LBP should not be viewed as a homogenous condition and that outcomes with nonspecific LBP can be improved when subgrouping is used to guide treatment decision making.

Hicks GE, Fritz JM, Delitto A, et al: Preliminary development of a clinical prediction rule for determining which patients with low back pain will respond to a stabilization exercise program. *Arch Phys Med Rehabil* 86(9):1753–1762, 2005.

This prospective, randomized study of 54 patients with nonradicular LBP examined the variables associated with treatment success following an 8-week standardized stabilization exercise program. Based on treatment response, the most important variables associated with success were age less than 40, straight-leg raise greater than 91°, positive prone instability test, presence of aberrant motions, lumbar hypermobility with passive testing, and absence of fear-avoidance beliefs. (Level IV evidence)

Hides JA, Richardson CA, Jull GA: Multifidus muscle recovery is not automatic after resolution of acute, first-episode low back pain. *Spine* 21:2763–2769, 1996.

In this clinical trial, 39 patients with acute, first-episode LBP were randomly allocated to either a control group or specific exercise group with 1-year and 3-year telephone questionnaire follow-ups. The specific exercise group performed exercises intended to specifically challenge the lumbar multifidus (LM) and transversus abdominis muscles. At the 10-week follow-up examination LM cross-section area was greater in the specific exercise group. The control group had decreased LM size at 10 weeks despite resuming normal levels of activity. This suggests that LM atrophy may persist after cessation of LBP without exercise intervention. (Level I evidence)

Kavcic N, Grenier SP, McGill S: Determining the stabilizing role of individual torso muscles during rehabilitation exercises. *Spine* 29:1254–1265, 2004.

In this study, 10 healthy males performed a series of eight different exercises while electromyography, three-dimensional lumbar motion, and external forces were measured. Based on subsequent calculations of spine stability, the authors determined that larger, more "global" muscles are better able to alter spine stability than "local," intersegmental muscles. They also concluded that focusing on a single muscle, or only a few muscles, appears to be misdirected if the goal is to ensure a stable spine. (Level IV evidence)

Koumantakis GA, Watson PJ, Oldham JA: Trunk muscle stabilization training plus general exercise versus general exercise only: Randomized controlled trial of patients with recurrent low back pain. *Phys Ther* 85:209–225, 2005.

This prospective, randomized study of 55 patients with nonspecific subacute or chronic LBP compared outcomes following 8 weeks of general trunk muscle exercise or 5 weeks of lumbar multifidus and transversus abdominis muscle training plus 3 weeks of general muscle trunk muscle exercise. Disability decreased to a greater extent at 8 weeks in the general trunk muscle exercise only group, although no difference was measured between groups at the 3-month follow-up, suggesting that stabilization exercises focused initially on isolated training of the lumbar multifidus and transversus abdominis do not provide additional benefit. (Level I evidence)

Vera-Garcia FJ, Elvira JL, Brown SH, et al: Effects of abdominal stabilization maneuvers on the control of spine motion and stability against sudden trunk perturbations. *J Electromyogr Kinesiol* 17:556–567, 2007.

In this prospective, single-limb trial, the authors studied the effectiveness of abdominal bracing and abdominal hollowing to control spine motion and stability against rapid perturbations in 11 healthy males in a semiseated position. Based on electromyography and lumbar spine kinematics, the authors reported that the abdominal hollowing maneuver was ineffective for stabilizing the lumbar spine after sudden perturbation. In contrast, the abdominal bracing maneuver fostered torso co-contraction, actively stabilized the trunk and decreased lumbar spine displacement after sudden perturbation. (Level IV evidence)

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Multiple Choice Questions

QUESTION 1. Following a lumbar sprain or strain, gentle lumbar spine stretching/self-mobilization exercises should be initiated as soon as possible in a minimally painful ROM to

A. limit the adverse effects of immobilization.
B. stimulate collagen synthesis.
C. promote proper collagen alignment.
D. All of the above

QUESTION 2. Which of the following statements concerning abdominal bracing is true?

A. Abdominal bracing has been shown to increase lumbar spine stability to a greater extent than abdominal hollowing.
B. Abdominal bracing should be performed immediately after all leg and arm exercises.
C. Abdominal bracing should be performed by drawing-in or hollowing the abdomen.
D. None of the above is true.

QUESTION 3. Which of the following statements concerning abdominal bracing is true?

A. Poor lumbar muscle endurance appears to be a significant risk factor in development of future LBP.
B. Endurance should be emphasized less during the early phases of lumbar sprain/sprain rehabilitation than strength.
C. Trunk muscle endurance training has been shown to be effective in reducing pain and disability in patients with nonspecific low back pain.
D. It is particularly important to regain endurance of the erector spinae and multifidus muscles.

QUESTION 4. Which of the following is a valid reason for abandoning nonoperative treatment of a lumbar sprain or strain and proceeding to surgery?

A. Subnormal trunk muscle endurance
B. Failure of the lumbar multifidus muscle to recover its normal cross-sectional area
C. Lack of full/normal lumbar spine ROM
D. None of the above

Answer Key

QUESTION 1. Correct answer: **D** (see Phase I)

QUESTION 2. Correct answer: **A** (see Phase I)

QUESTION 3. Correct answer: **B** (see Phase II)

QUESTION 4. Correct answer: **D** (see Phase IV)

Chapter 19



Herniated Lumbar Disc

INTRODUCTION

S. Josh Bell, MD, Stephanie Niño, PT, DPT, FAAOMPT, OCS, and Cheryl Kathleen Obregon, PT, DPT, FAAOMPT

Epidemiology

Age

- All ages can be affected.
- Predominance of patients between ages 30 to 50.
- Trials, such as SPORT trial, have mean enrollment of ages between 40 and 43.

Gender

- Predominance of males
- Males twice as likely to have than females

Sport

- Any sport can cause a disc herniation
- Increased risk with improper technique
- Contact sports
- Repetitive twisting of the back

Position

- Can occur in any position
- Bending and twisting with load cause higher load to disc
- Lifting mechanics, especially with load in front of body away from center axis

Pathophysiology

Intrinsic Factors

- Previous disc herniation
- Male gender
  - 2:1 dominance
  - Ages 30 to 50
- Congenital spinal abnormalities

Extrinsic Factors

- Poor mechanics
- Improper technique
  - Lifting
  - Sport-specific
- Smoking
- Sedentary lifestyle

Traumatic Factors

- High levels of force (traumatic collision sports, such as football)
- Repetitive motions
- Loading of the back (twisting with load)
- Improper technique

Classic Pathological Findings

- Numbness in a dermatomal distribution
  - Dermatomal patterns in the lumbar spine
    - L2—Anterior thigh, medial thigh and groin
    - L3—Anterior thigh and medial knee/calf
    - L4—Anterior knee and medial calf/foot
    - L5—Anterior leg and dorsum foot
    - S1—Posterior leg and lateral/sole foot
- Unilateral weakness
- Leg pain is greater than back pain

Clinical Presentation

History

- Leg pain is greater than back pain
  - Greater back pain indicates the possibility of a lumbar sprain/strain
- Weakness or numbness
  - Specific to muscle groups/nerve distributions
- Low back tightness/spasm



FIGURE 19-1. Dermatomal pattern of a patient with right L5 radiculopathy (hash marks represent dermatomal pattern of decreased sensation).



FIGURE 19-2. Knee reflex testing.

Physical Examination

Abnormal Findings

- Straight leg raise
  - When lifting the straight leg from a supine position pain radiates according to the nerve distribution of the involved nerve
- Numbness in a dermatomal distribution (Figure 19-1)
  - L3—Medial knee
  - L4—Medial leg and medial foot/ankle
  - L5—Anterior leg and anterior foot/ankle
  - S1—Lateral foot/sole of foot
- Loss of relevant reflex (Figure 19-2)
  - L3—Knee reflex
  - L4—Knee reflex
  - S1—Achilles reflex

Pertinent Normal Findings

- Normal bowel and bladder function
- Predominance of leg pain and less back pain
  - To differentiate pathology from nerve root compression and lower back pain
- No evidence of hip pathology
  - Normal motion
  - No pain in groin with resisted hip flexion
  - No pain with log roll maneuver of the leg

Imaging

- Radiographs of lumbar spine
  - AP/LAT
  - Possible flexion/extension (to rule out instability)
- MRI of lumbar spine (Figure 19-3*A*,*B*)
  - Evaluate for compression of nerve roots
  - Should correlate to dermatomal pattern on physical examination
- Potential radiograph of hip to rule out hip pathology

Differential Diagnosis

- Infection
  - Fever may be present
- Tumor
  - Weight loss unexplained
  - Pain at night/rest
- Fracture
  - Significant trauma should be evaluated with radiographs of the spine
- Musculoskeletal back pain (without disc herniation)
  - Lumbar sprain/strain
  - No radiation to legs
- Hip pathology
  - Evaluate with range of motion
  - Evaluate with provocative testing
    - Resisted straight leg raise
    - Muscular strength
    - Log roll
  - Potentially evaluate with radiographs
- Cauda equina syndrome
  - Compression of multiple nerve roots from a large or central disc herniation
  - Present with abnormal bowel or bladder function (retention or loss of control)
- Saddle anesthesia (loss of sensation in the groin area)
- Loss of sensation to bilateral lower extremities

Treatment

Nonoperative Management

- Medication (antiinflammatory: NSAIDS vs. oral steroids or pain medication)
- Stretching and early active rehabilitation
- Workplace and activity restrictions
- Physical therapy
- Epidural steroid injection (ESI)

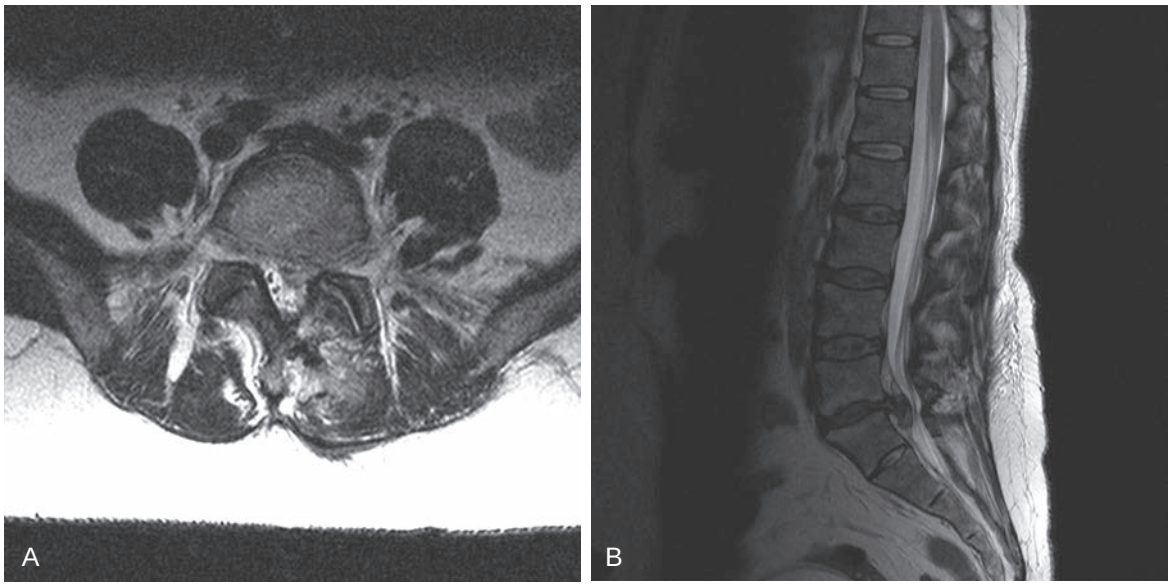

FIGURE 19-3. A, Axial MR image of S1 lumbar disc herniation. **B**, Sagittal MR image of S1 lumbar disc herniation.

Guidelines for Choosing Among Nonoperative Treatments

- No evidence of cauda equina syndrome
- Symptoms managed with medication and activity restrictions
- No progressive weakness or neurological loss

Surgical Indications

- Absolute:
  - Progressive motor and sensory loss
  - Cauda equina syndrome
- Relative:
  - Progressive or persistent symptoms after 6 weeks of nonsurgical care
  - Significant loss of motor strength (e.g., quadriceps)

Aspects of History, Demographics, or Exam Findings that Affect Choice of Treatment

- Progressive neurologic findings affect the decision to proceed to surgery
- Significant weakness in quadriceps or other major motor group
- If patient has persistent or worsening pain that is not relieved with nonoperative treatment

Aspects of Clinical Decision Making When Surgery is Indicated

- Progressive loss of motor function
- Failure of appropriate trial of 6 weeks to 3 months of nonoperative treatment
- Progressive pain not responsive to treatment.

Evidence

Buttermann GR: Treatment of lumbar disc herniation: Epidural steroid injection compared with discectomy. A prospective, randomized study. *J Bone Joint Surg Am* 86:670–679, 2004.

This prospective randomized study of patients with lumbar disc herniation who received discectomy vs. epidural steroid injection. There were 50 patients in each group and a significant amount of crossover between the groups. Patients in the discectomy group had better outcomes. (Level I evidence).

Osterman H, Seitsalo S, Karpinnen J, et al: Effectiveness of microdiscectomy for lumbar disc herniation: A randomized controlled trial with 2 years of follow-up. *Spine* 31:2409–2414, 2006.

This prospective randomized study of patients with lumbar disc herniation who received discectomy vs. isometric physical therapy. There were 28 patients in each group with no statistical difference between groups. (Level I evidence).

Peul WC, van Houwelingen HC, van den Hout WB, et al: Surgery versus prolonged conservative treatment for sciatica. *N Engl J Med* 356:2245–2256, 2007.

A randomized prospective study of patients with surgical and nonsurgical treatment for lumbar disc herniation. This study showed improved outcomes in the surgical group early with no statistical difference at 1 year. (Level I evidence).

Ostelo RW, de Vet HC, Waddell G, et al: Rehabilitation following first-time lumbar disc surgery: A Systematic review within the framework of the Cochrane collaboration. *Spine* 28:209–218, 2003.

This systematic review of randomized controlled trials evaluated the protocol for postoperative rehabilitation after first-time lumbar surgery. No evidence for restriction of activities immediately after surgery was found and strong evidence for intensive exercise. (Level I evidence).

Ostelo RW, Costa LO, Maher CG, et al: Rehabilitation after lumbar disc surgery: An update Cochrane review. *Spine* 34:1839–1848, 2009.

This systematic review of randomized controlled trials evaluated postoperative protocol after lumbar surgery. Exercise

programs after surgery seem to lead to faster decrease in pain postoperatively. (Level I evidence).

Weber H: Lumbar disc herniation: A controlled, prospective study with ten years of observation. *Spine* 8:131–140, 1983.

This prospective study of patients with surgical and nonsurgical treatment for lumbar disc herniation showed improved outcomes in the surgical group at 1 year and no statistical difference at 4- and 10-year follow up. (Level II evidence).

Weinstein JN, Tosteson TD, Lurie JD, et al: Surgical vs. nonoperative treatment for lumbar disk herniation: The Spine Patient Outcomes Research Trial (SPORT), A randomized trial. *JAMA* 296:2441–2450, 2006.

This prospective, randomized study of operative and nonoperative treatment for lumbar disk herniation found better outcomes in surgical patients but the primary differences in the study were not statistically significant. There were large crossovers in the study confounding some conclusions. (Level I evidence).

Multiple-Choice Questions

QUESTION 1. A patient has a disc herniation causing decreased sensation to the area of the right medial malleolus and a decreased knee reflex on the right side. The most likely nerve root effected by this herniation is:

A. Right L2
B. Left S1
C. Right L4
D. Left L4

QUESTION 2. Based on demographics, the most likely patient to get a symptomatic lumbar disc herniation is:

A. 20-year-old female
B. 40-year-old male
C. 65-year-old female
D. 10-year-old male

QUESTION 3. Signs of cauda equina syndrome may include all of the following except:

A. Shortness of breath
B. Loss of normal bowel or bladder function/control
C. Saddle anesthesia
D. Weakness

QUESTION 4. Risk factors for lumbar disc herniation include the following except:

A. Smoking
B. Previous lumbar disc herniation
C. Male
D. Physically fit

QUESTION 5. Appropriate nonoperative treatment for lumbar disc herniation includes the following except:

A. Physical therapy
B. Medication management
C. Work/activity restrictions
D. Trigger point injections

Answer Key

QUESTION 1. Correct answer: **C** (see Pathophysiology)

QUESTION 2. Correct answer: **B** (see Pathophysiology)

QUESTION 3. Correct answer: **A** (see Treatment)

QUESTION 4. Correct answer: **D** (see Pathophysiology)

QUESTION 5. Correct answer: **D** (see Treatment)

NONOPERATIVE REHABILITATION OF HERNIATED LUMBAR DISC

S. Josh Bell, MD, Stephanie Niño, PT, OCS, FAAOMPT, and Cheryl Kathleen Obregon, PT, DPT, FAAOMPT

GUIDING PRINCIPLES OF NONOPERATIVE REHABILITATION

- Pain control
- Pain free mobilization of the spine
- Lower extremity and core strengthening
- Patient specific progression of activities, modalities

Phase I (Weeks 0 to 2, Postinjury)

Goals

- Pain control, decrease of inflammation
- Mobilization, unloading as necessary
- Education

Protection

- Protect with walker as needed
- Use of lumbar support, such as lumbosacral orthosis (LSO), as necessary

Management of Pain and Swelling

- Pharmacologic treatment
  - NSAIDs
  - Oral steroid
  - Pain medication
- Ice or cryotherapy
- Avoidance of painful spinal motions (rest)
- Taping and therapeutic modalities (electrical stimulation)
- Education on log rolling, proper bed mobility, sit to stand transition, hip-hinging exercise for sit to stand and squatting

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Manipulation of thoracolumbar (T/L) junction for lower extremity pain modulation
- Side-lying manual distraction
- Grade I, II mobilization (pain control)
- Neural mobilizations
- Correction of standing lateral shift, if present (Figure 19-4)
- Exercises
  - Pelvic neutral and transverse abdominal bracing, progression with LE movement with brace (start with 5 min then progress to 15 min total time with LE movements)
  - If patient has an extension bias, begin with prone lying (start 5 min base time on patient's symptoms decreasing)
  - Body weight support unloaded walking on treadmill (Figure 19-5)
  - Supine mechanical traction or inversion table for symptom relief (start with 25% of body weight for 20 to 30 min intermittent holds)
  - Lumbar spine pain-free ROM
  - Unloaded squats (using functional gym) (i.e. Total Gym)

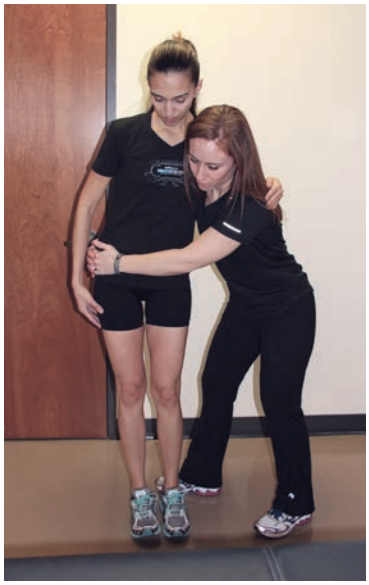

FIGURE 19-4. Correction of lateral shift; pain-free manual correction (by therapist) of pelvis to correct left lateral shift in this patient.



FIGURE 19-5. Body weight support walking on treadmill.

Soft Tissue Techniques

- Paraspinals myofascial release (MFR)
- Soft tissue mobilization (STM) to paraspinals (Figure 19-6)
- Nerve gliding (patient directed) (Figure 19-7)



FIGURE 19-6. Soft tissue paraspinal mobilization (STPM).

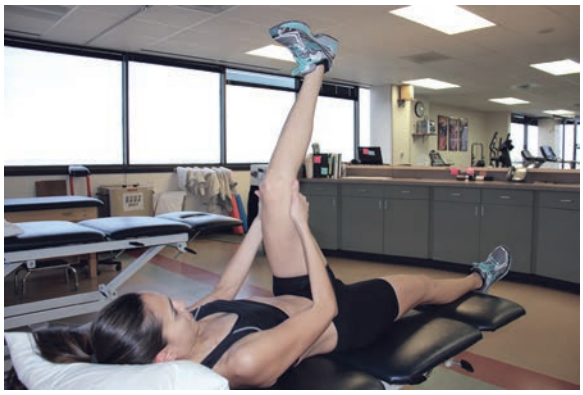

FIGURE 19-7. Patient-directed sciatic nerve gliding.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Stretching to limit of pain allowable
- Gentle hamstring and/or hip flexor stretching with protected spine position, being cautious of radicular symptoms

Other Therapeutic Exercises

- Encourage functional walking to tolerance
- Lower extremity strengthening to pain tolerance
- Education on wearing and removing LSO brace (as needed)
- Avoid sitting greater than 20 minutes

Activation of Primary Muscles Involved

- Lower extremity strength exercises are encouraged, as tolerated by pain level
- Proper activation of transverse abdominal, external obliques, multifidus, and gluteals

Milestones for Progression to the Next Phase

- Oswestry disability index (ODI), between 20% and 40%
- Able to sit and stand with spinal neutral mechanics
- Pain-free transitional movements (i.e., sit to stand, supine to sit)
- No lateral shift or acute lumbar kyphosis can be present (correct spinal position)

Phase II (weeks 2 to 6, Postinjury, variable progression dependent on herniation and patient factors)

Protection

- Retrain protective movement patterns (i.e., using lumbar roll with sitting, avoiding truck flexion with squatting and sit to stand)
- Wean from LSO brace (if used)

Management of Pain and Swelling

- Use of modalities (heat, electrical stimulation, taping)
- Decrease use of walking aids

TIMELINE 19-1: **Rehabilitation of Herniated Lumbar Disc**

PHASE I (weeks 0 to 2)	PHASE II (weeks 2 to -6)
• Rest • PT modalities • Functional unloading • Stretching/ROM to tolerance • Manipulation of T/L junction • Myofascial release (MFR) paraspinals • Soft tissue mobilization (STM) neural tissue	• Retrain protective movement patterns • PT modalities • Functional unloading • Mechanical traction • Paraspinal MFR Soft tissue mobilization (STM) functional movement patterns • Supine hamstring, hip flexor, piriformis stretches • Progression to quadruped exercise • Hip strengthening exercises • Body mechanics training and education • Pelvic neutral stability ball with progressing to LE movement • Supine and prone lumbar stabilization exercises • Walking program, swimming • Body weight squats and lunges • ADLs retraining



FIGURE 19-8. Side-lying manual mobilization of lumbar facet joints (gapping).

- Pharmacological treatment
  - NSAIDs
  - Decrease use of narcotics

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Mobilization and manipulation of thoracic spine, lumbar spine (opening, closing, and gapping techniques) (Figure 19-8)
- Mobilization of SI joint (supine, side lying, prone techniques), hips to correct hypomobility, and for pain modulation
- Muscle energy techniques (METs) for muscular recruitment or inhibition
- Side-lying lumbar distraction

Soft Tissue Techniques

- Paraspinals myofascial release (MFR), soft tissue mobilization (STM) surrounding neural tissue
- STM with movement to restore functional movement patterns

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Supine hamstring, hip flexor
- Figure four piriformis stretches
- Repeat Phase I with progressing to sitting, standing, and quadruped exercise
- Hip/back dissociation exercise (using biofeedback for proper spine alignment while moving at the hips) (Figure 19-9)

Other Therapeutic Exercises

- Hip strengthening exercises
- Continue functional unloading on body weight support treadmill
- Body mechanics training and education

Activation of Primary Muscles Involved

- Lower extremity strength exercises are encouraged, as tolerated by pain level
- Proper activation of transverse abdominus, external obliques, multifidus, and gluteals

TIMELINE 19-1: **Rehabilitation of Herniated Lumbar Disc** (Continued)

PHASE III (weeks 6 to 12)	Phase IV (weeks 10 to 18)	Phase V (weeks 18 to 52)
• Proper protective spine mechanics • PT modalities as needed • Mobilization and manipulation of thoracic spine, lumbar spine, SI joints • Side-lying lumbar distraction • Paraspinal MFR • STM surrounding neural tissue • Supine hamstring, hip flexor, piriformis stretches • Use of resistance with LE strengthening exercise • Increase resistance of long lever challenge on dynamic spine control • Abdominal exercise (plank) • SLS static and dynamic activities • Use of unstable surfaces • Use of resistance bands with UE and LE	• PT modalities as needed • Mobilization and manipulation of thoracic spine, lumbar spine, SI joints • Side-lying lumbar distraction • Paraspinal MFR • STM surrounding neural tissue • Supine hamstring, hip flexor, piriformis stretches • Use of resistance with LE strengthening exercise • Increase resistance of long lever challenge on dynamic spine control • Abdominal exercise (plank) • SLS static and dynamic activities • Use of unstable surfaces • Use of resistance bands with UE and LE • Unloading jumping on reformer progressing to squat jumps, broad jumps	• PT modalities as needed • Mobilization and manipulation of thoracic spine, lumbar spine, SI joints • Side-lying lumbar distraction • Paraspinal MFR • STM surrounding neural tissue • Supine hamstring, hip flexor, piriformis stretches • Use of resistance with LE strengthening exercise • Increase resistance of long lever challenge on dynamic spine control • Abdominal exercise (plank) • SLS static and dynamic activities • Use of unstable surfaces • Use of resistance bands with UE and LE • Unloading jumping on reformer progressing to squat jumps, broad jumps • Progressive resistive exercises (PRE) Lumbar and core • Hip/LE PRE • Upper extremity PRE • Sports-specific drills with protective pivoting • Carioca drills • Slide board • Plyometrics • Agility ladder



FIGURE 19-9. Hip/back dissociation using a stick to give biofeedback for proper spine alignment to allow hip to hinge in normal pattern and allow for proper spine mechanics.

Sensorimotor Exercises

- Balance on unstable surfaces (rocker board, foam with neutral spine)
- Single leg balance (SLB) with resistive bands or pulleys four-way directions (Figure 19-10*A,B*)

Open and Closed Kinetic Chain Exercises

- Pelvic neutral using blood pressure cuff for biofeedback, advancing with lower extremity movements
- Quadruped neutral (Figure 19-11)
- Pelvic neutral on the door with mini squats progressing to upper extremity movements with resistive bands

Techniques to Increase Muscle Strength, Power, and Endurance

- Mini squat in pelvic neutral
- Total or Vigor Gym in pelvic neutral
- Standing lat pulldown with pelvic neutral

Neuromuscular Dynamic Stability Exercises

- Refer to OKC and CKC exercise

Functional Exercises

- Hip hinging series: sit, stand, squat, and stagger squat (keeping spine in position and movement comes from hinging at the hips as opposed to motion through spine)
- Proper log rolling for bed mobility
- Gait training
- Education on getting on/off floor

Milestones for Progression to the Next Phase

- Minimal daily symptoms
- Reduce ODI score <20%
- Able to perform ADLs

Phase III (weeks 6 to 12, Postinjury)

The majority of patients treated in a nonoperative treatment protocol will be advanced to return to sport after this phase. If they require additional treatment/cannot progress, they may require further evaluation and consideration for other treatment modalities (i.e., epidural steroid injection, surgery).

Protection

- Proper protective spine mechanics for high functional activities, return to work, and sport



FIGURE 19-10. **A, B,** Single leg balance with resistive bands.

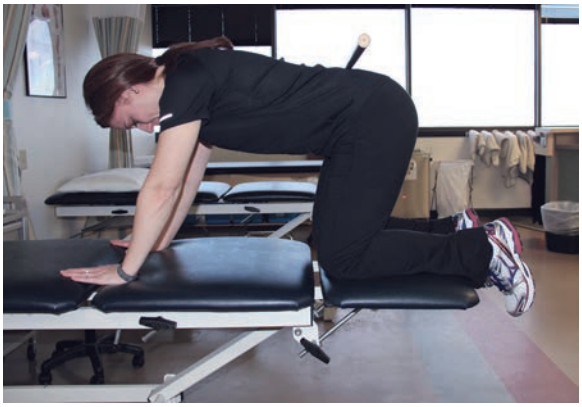

FIGURE 19-11. Quadruped neutral position.



FIGURE 19-12. Pelvic neutral (feedback by therapist) standing upper extremity cable exercises.

Management of Pain and Swelling

- NSAIDs as needed
- Ice or cryotherapy prn
- E-stim/TENS, as necessary

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Mobilization and manipulation of thoracic spine, lumbar spine, SI joint, hips to correct hypomobility and for pain modulation
- Side-lying lumbar distraction
- Muscle energy techniques (METs) for muscular recruitment or inhibition

Soft Tissue Techniques

- Neural tissue mobilization
- Paraspinal MFR
- STM functional movement patterns

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Supine hamstring, hip flexor and piriformis stretches

Other Therapeutic Exercises

- Standing upper extremity exercises with cable with pelvic neutral (Figure 19-12)
- Total Gym
- Treadmill

Activation of Primary Muscles Involved

- Use of resistance bands of upper and lower extremities
- Use of unstable surfaces
- Advance of abdominal exercise (plank, etc.) (Figure 19-13)
- Focus on transverse abdominals, external obliques, latissmus dorsi, gluteus maximus, gluteus medius, hamstrings, multifidus, psoas, quadratus lumborum

Sensorimotor Exercises

- Sitting stability ball
- Advance to standing on unstable disc
- Single leg stance (SLS) static and dynamic activities

Open and Closed Kinetic Chain Exercises

- Prone pelvic neutral with blood pressure cuff with lower and upper extremity progression
- Dynamic movements using a stick for biofeedback on neutral spine
- Use of bands and cables in varies directions/resistance in functional hip hinge position

Techniques to Increase Muscle Strength, Power, and Endurance

- Advance abdominal exercise
  - Plank
  - Lateral plank
  - Resisted proprioceptive neuromuscular facilitation (PNF)



FIGURE 19-13. Plank.

- Emphasis on the following muscle groups: gluteals, abdominals, deep back extensors

Neuromuscular Dynamic Stability Exercises

- BOSU ball
- Single leg stance dynamic and static activities
- Improving body sense awareness in cutting, pivoting, and agility work

Plyometrics

- Unloading jumping on reformer to progressing to squat jumps, broad jumps, SL hops

Functional Exercises

- Education and technique for proper spine mechanics
- Increased resistance of long lever challenge on dynamic spine control
- Hip hinging with upper extremity weighted challenge
- Use of resistive bands in functional positions (i.e., lunge)
- Overhead squatting

Sport-Specific Exercises

- Squat jumps, single leg hips
- Agility ladder
- Resisted golf swings

Milestones for Progression to Advanced Sport-Specific Training and Conditioning

- Able to demonstrate neutral spine in all functional positions (using observation and monitoring patients symptoms)
- Pain free and progressive improvement with standing balance activities (measure by patient pain report and time on single leg stance)
- LE strength returned to within 10% of preinjury level (or 10% of expected strength at normal) (measured with manual muscle testing of all myotomes)
- Able to demonstrate proper form in sports-specific skills

Criteria for Abandoning Nonoperative Treatment and Proceeding to Surgery or More Intensive intervention

- Continued pain on activities
- Inability to advance to sport specific drills
- Continued setbacks with rehabilitation caused by pain, weakness or failure to progress
- Progressive neurological decline
- Persistent or worsening pain

Tips and Guidelines for Transitioning to Performance Enhancement

- Proper body mechanics observed and trained
- Proper nutrition and hydration during training
- Advance per progression to prevent a setback or recurrence of symptoms

Performance Enhancement And Beyond Rehabilitation: Training/Trainer and Optimization of Athletic Performance

- Progression of core strength including abdominals and paraspinals are key to injury prevention in the future (i.e., plants, side plants, bridging, lat pulldown, hip hinging with cable resistance)
- Proper technique (sports-specific) can be the keys to progress and continued improved performance

Specific Criteria for Return to Sports Participation: Tests and Measurements

- Pain-free activities
- Core strength and LE strength within 10% of preinjury or "normal" level (measured by manual muscle testing)
- Single leg balance equal side to side (measured by time)
- Any functional tests?

Evidence

Danielson JM, Johnsen R, Kibsgaard SK, et al: Early aggressive exercise for postoperative rehabilitation after discectomy. *Spine* 25:1015–1020, 2000.

This is a randomized controlled trial comparing a training group and a mild exercise group postoperatively. Vigorous medical exercise started 4 weeks after surgery reduced disability and pain after surgery. (Level I evidence).

McGregor AH, Dore CJ, Morris TP, et al: Function after spinal treatment, exercise, and rehabilitation (FASTER). *Spine* 36:1711–1720, 2011.

This multicenter, factorial, randomized controlled trial on the postoperative management of spinal surgery patients. Found no difference at 12 months ODI for usual care versus rehabilitation versus rehabilitation with educational booklet and booklet only. (Level I evidence).

Ostelo RW, Costa LO, Maher CG, et al: Rehabilitation after lumbar disc surgery: An update Cochrane review. *Spine* 34:1839–1848, 2009.

This systematic review of randomized, controlled trials evaluated postoperative protocol after lumbar surgery. Exercise programs after surgery seem to lead to faster decrease in pain postoperatively. (Level I evidence).

Ostelo RW, de Vet HC, Waddell G, et al: Rehabilitation following first-time lumbar disc surgery: A systematic review within the framework of the Cochrane collaboration. *Spine* 28:209–218, 2003.

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This prospective study of patients with surgical and nonsurgical treatment for lumbar disc herniation showed improved

outcomes in the surgical group at 1 year and no statistical difference at 4- and 10-year follow up. (Level II evidence).

Weinstein JN, Tosteson TD, Lurie JD, et al: Surgical versus nonoperative treatment for lumbar disk herniation: The spine patient outcomes research trial (SPORT), A randomized trial. *JAMA* 296:2441–2450, 2006.

This prospective, randomized study of operative and nonoperative treatment for lumbar disk herniation found better outcomes in surgical patients, but the primary differences in the study were not statistically significant. There were large crossovers in the study confounding some conclusions. (Level I evidence).

Multiple-Choice Questions

QUESTION 1. Plyometric training should start in what phase of rehabilitation after lumbar disc injury?

A. Phase I (1 to 2 weeks)
B. Phase II (3 to 6 weeks)
C. Phase III (6 to 18 weeks)
D. Any time

QUESTION 2. A key to future injury prevention after lumbar herniation:

A. Lower extremity strength
B. Upper extremity strength
C. Proper technique in sport
D. Level of disc herniation

QUESTION 3. A sign that indicates the possible need for more medical intervention for lumbar disc herniation includes:

A. Increasing pain
B. Inability to progress in rehabilitation protocol
C. Progressive neurological signs and symptoms
D. All of the above

QUESTION 4. Goals for successful nonoperative treatment of lumbar disc herniation include all of the following except:

A. Running endurance
B. Core and lower extremity strength
C. Mobilization of the spine
D. Pain control

QUESTION 5. Manipulation of the thoracolumbar spine is an example of:

A. An exercise in rehabilitation
B. A manual therapy technique
C. A soft tissue technique
D. A strengthening technique

Answer Key

QUESTION 1. Correct answer: **D** (See Phase III)

QUESTION 2. Correct answer: **C** (See Phase III)

QUESTION 3. Correct answer: **D** (See Phase III)

QUESTION 4. Correct answer: **A** (See Phase I)

QUESTION 5. Correct answer: **B** (See Phase I)

POSTOPERATIVE REHABILITATION AFTER LUMBAR DISC HERNIATION SURGERY

S. Josh Bell, MD, Stephanie Niño, PT, OCS, FAAOMPT, and Cheryl Kathleen Obregon, PT, DPT, FAAOMPT

Indications for Surgical Treatment

- Progressive neurological symptoms
- Correlation of symptoms with MRI imaging
- Symptoms that persist after reasonable nonoperative management

Brief Summary of Surgical Treatment

Major Surgical Steps

- General anesthesia prone position, abdomen free fluoroscopy positioned (Figure 19-14)
- Techniques vary from open to microdiscectomy with positioning of tubes for access and instrument passing (Figure 19-15)
- Place needle localization under lateral fluoroscopy to confirm level (Figure 19-16)
- Dissect subperiosteal down spinous process to the lamina on the affected side (Figure 19-17)
- Protect the facet joint capsule
- Place lamina spreader between spinous processes
- Expose ligamentum flavum and incise
- Use minimal resection of lamina (based on level of disc) (Figure 19-18)
- Gently protect dura
- Remove disc fragments (Figure 19-19)



FIGURE 19-14. Patient in prone position with fluoroscopy positioned for lumbar discectomy. *(From Angevine PD, Gigante PR, McCormick PC: Patient positioning for spinal surgery. In: Winn HR:* Youmans Neurological Surgery, *ed 4. Philadelphia: Saunders (Elsevier), 2011, pp. 447–452.)*

- Ensure no remnant fragments are present and that nerve root is free (Figure 19-20)
- No postoperative anticoagulation
- Early mobilization

Factors that May Affect Rehabilitation

Anesthetic

- Local long-acting anesthetics may improve early pain control

Surgical

- Multilevel disc herniation require longer early phases to allow for additional surgical trauma

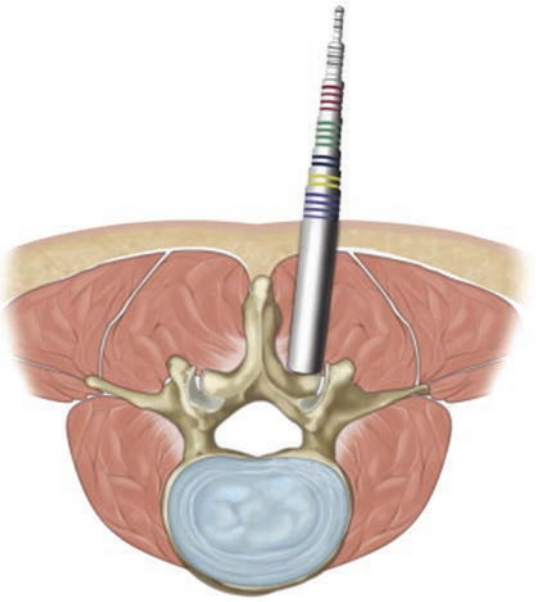

FIGURE 19-15. Use of microdiscectomy dilating tubes to minimize incision. *(From Lee P, Wong AP, Ganju A: Surgical Anatomy and Techniques to the Spine. In* Surgical anatomy and operative techniques of lumbar stenosis. *Philadelphia: Saunders (Elsevier), 2013,* Ch 43.*)*

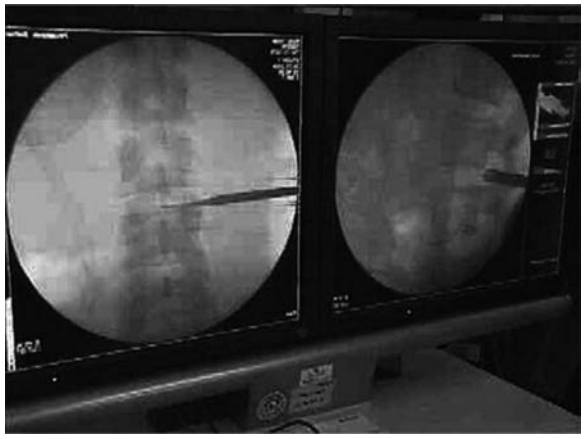

FIGURE 19-16. Intraoperatively fluoroscopically confirmed level for surgical discectomy. *(From Leu HF: Posterior foraminal lumbar decompression. In: Kim DH, Kim Y-C, Kim K-H editors:* Minimally Invasive Percutaneous Spinal Techniques. *Philadelphia: Saunders (Elsevier), 2011, pp 360–366.)*

Before Surgery: Overview of Goals, Milestones, and Guidelines[1]

GUIDING PRINCIPLES OF POSTOPERATIVE REHABILITATION

- Understand the level of disc herniation treated (nerves and levels affected)
- Understand the importance of core muscle groups to support the rehabilitation
- Understand the importance of pain control for advance of therapy
- Proper selection of manual therapy intervention applied at the appropriate phase of healing
- Recognize the importance of reintegration of proper techniques to prevent future injury

Phase I: Immediate Postoperative Period (days 0 to 14)

Clinical Pearls

- Pain control to get the patient to have confidence in the postoperative period is of paramount importance.
- Early mobility with proper pain management to build and restore patient's confidence towards pain-free mobility and progression.

Goals

- Pain control
- Early mobility

[1]*Prehabilitation, if appropriate, is described in the Nonoperative Rehabilitation section of this chapter. For a timeline for postoperative rehabilitation, refer to the Nonoperative Rehabilitation part.*

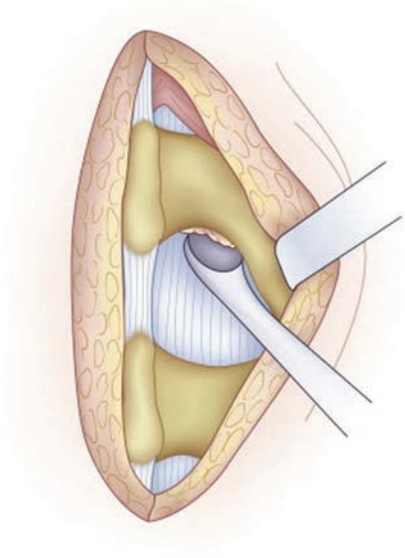

FIGURE 19-17. Dissection down spinous process to expose lamina. *(From Bono CM, Schoenfeld A, Garfin SR: Lumbar disc herniations. In: Herkowitz HN, Garfin SR, Eismont FJ, et al, editors:* Rothman-Simeone The Spine, *ed 6. Philadelphia: Saunders (Elsevier), 2011, pp 887–914.)*

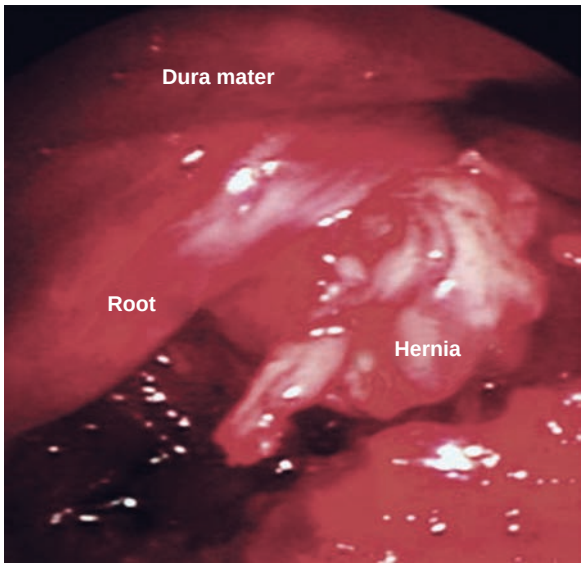

FIGURE 19-19. Herniated material removed with protection of nerve root. *(From Blamoutier A: Surgical discectomy for lumbar disc herniation: Surgical techniques.* Orthop Traumatol Surg Res *99:S187–96, 2013)*

- Support of weight bearing (walking aids, back brace as needed)
- Edema control (medication, ice, and protection from injury)

Protection

- Use of walker for unloading as necessary postoperatively
- Possible use of supportive lumbar brace (LSO)

Management of Pain and Swelling

- In immediate postoperative period, patient will have local anesthetic long-acting for localized pain relief
- Oral pain management with medication
- TENS unit to control pain
- Ice therapy to reduce inflammation and pain
- Patient education regarding avoidance of painful motions
- PT modalities

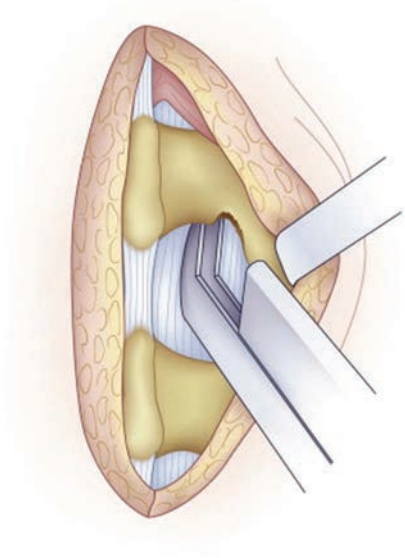

FIGURE 19-18. Minimal resection of lamina to expose herniated disc beneath. *(From Bono CM, Schoenfeld A, Garfin SR: Lumbar disc herniations.. In: Herkowitz HN, Garfin SR, Eismont FJ, et al, editors: Rothman-Simeone The Spine, ed 6. Philadelphia: Saunders (Elsevier), 2011, pp 887–914.)*

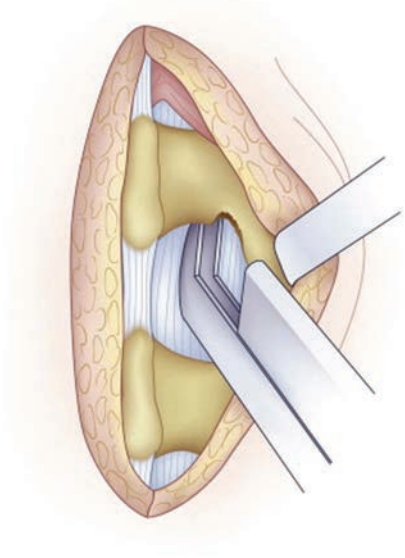

FIGURE 19-20. Ensure area free of disc material and nerve root is not impinged. *(From Bono CM, Schoenfeld A, Garfin SR: Lumbar disc herniations. In: Herkowitz HN, Garfin SR, Eismont FJ, et al, editors: Rothman-Simeone The Spine, ed 6. Philadelphia: Saunders (Elsevier), 2011, pp 887–914.)*

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Limited in first several weeks secondary to incision (gentle soft tissue techniques for early treatment)

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Lumbar spine pain-free ROM
- Functional unloading (unloading the spine/soft tissue to eliminate pain in functional activities, i.e., walking/transitional movements, can use functional unloader—weight supported walking)
- Education of log rolling, proper bed mobility, sit-to-stand transitions

Other Therapeutic Exercises

- Walking low intensity level for cardiovascular fitness
- Body-weight support treadmill for walking with additional offloading (Figure 19-21) (Parameters are 65% of body weight ambulating 0.1 to 0.5 mph up to 40 to 50 minutes)

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Unloaded squatting using Total Gym

Open and Closed Kinetic Chain Exercises

- Walking program
- Body weight support walking on treadmill if available

Functional Exercises

- ADLs training
- Sit-to-stand transitions
- Log rolling
- Don/doff LSO brace if used



FIGURE 19-21. Body weight support treadmill walking.

Milestones for Progression to the Next Phase

- Healing of the surgical incision
- Pain control to allow sitting and standing
- ODI (Oswestry disability index 20% to 40%)

Phase II: (weeks 2 to 6, Postoperative)

Clinical Pearls

- Closely monitor the athlete's progression as it will vary
- Pay attention to movement patterns and guarding in the patient's movements
- Slow progress early with attention to any adjustments as necessary for any adverse neurological symptoms

Goals

- Protect surgical wound
- Increase core strength
- Improve mobility
- Improve flexibility

Protection

- Discontinue ambulatory aids as tolerated
- Retrain protective movement patterns

Management of Pain and Swelling

- PT modalities (heat, electrical stimulation, taping—Kinesio tape for pain reduction/muscle spasm relief)
- Oral pain medication
- Ice or cryotherapy as necessary to decrease inflammation and swelling

Techniques for Progressive Increase in Range of Motion

- Stretching/flexibility techniques for the musculotendinous unit
- Supine hamstring, hip flexor, piriformis stretches, gluteal stretch (Figures 19-22, 19-23)

Manual Therapy Techniques

- Mobilization and manipulation of thoracic spine, lumbar spine (opening, closing and gapping techniques) (Figure 19-24)
- SI joint (supine, side-lying, and prone techniques), hips to correct hypomobility, and for pain modulation
- Muscle energy techniques (METs) for muscular recruitment or inhibition
- Side-lying lumbar distraction

Soft Tissue Techniques

- Paraspinals myofascial release (MFR)
- Soft tissue manipulation (STM) surrounding neural tissue



FIGURE 19-22. Piriformis figure-of-4 stretch.



FIGURE 19-23. Single knee to chest.

- STM functional movement patterns
- Incisional scar massage

Other Therapeutic Exercises

- Body weight support walking on treadmill (unload 65% of total body weight at 0.1 to 0.5 mph on treadmill for up to 40 to 50 minutes)
- Repeat Phase I with progressing to sitting, standing, and quadruped exercise

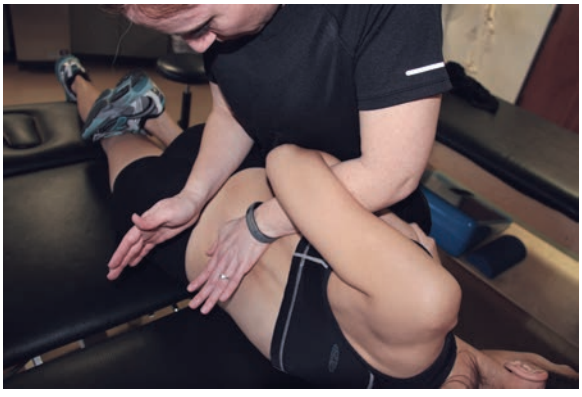

FIGURE 19-24. Side-lying manual lumbar mobilization (gapping).



FIGURE 19-25. Pelvic neutral position with progressive lower extremity mobility challenge (bent knee fallout).

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Lower extremity strength exercises are encouraged as tolerated by pain level, proper activation of transverse abdominal, external obliques, multifidus, and gluteals (Figures 19-25 to 19-26). (Begin with 5 minutes at 10 seconds hold for pelvic neutral or abdominal bracing. Then progress to lower extremity movement with neutral spine for 3 to 5 minutes each leg. Total stabilization time is 10 to 15 minutes. All movement should not be painful and repetitious until proper mechanics/muscle activation is done with ease.)
- Hip/back dissociation exercise (biofeedback on spine to allow hips and back to function independently (Figure 19-27) (2 to 3 minutes total: hip hinge exercise)
- Hip strengthening/neuromuscular recruitment exercises (10 seconds hold × 10 reps; progress to 2 to 3 sets)
- Supine hamstring (Figure 19-28), hip flexor, piriformis stretches (1 minutes hold, 3 to 5 reps)

Sensorimotor Exercises

- Pelvic neutral on stability ball with progressing to LE movement (reps to fatigue: when a patient can no longer maintain neutral spine)



FIGURE 19-26. Pelvic neutral position with progressive lower extremity mobility challenge(marching).



FIGURE 19-27. Hip/back dissociation with biofeedback (with stick) on spine to allow for proper alignment and motion through the hip (hinging at the hip) while keeping a pelvic neutral position of the spine.



FIGURE 19-29. Single leg balance with lower extremity resistance bands.

- Sitting on stability ball, static and dynamic movements on unstable surface (reps to fatigue)
- Balance on unstable surfaces (rocker board, foam with neutral spine)
  - Single leg balance (SLB) with resistive bands or pulleys four-way directions (Figure 19-29) (begin with 10 reps in each direction if patient is able to maintain form, progress to up to 20 reps)

Open and Closed Kinetic Chain Exercises

- Lunges (2 to 3 sets, 10 to 15 reps)
- Body weight squats (unloading as necessary) (5 minutes)
- Pelvic neutral using blood pressure cuff for biofeedback, advancing with lower extremity movements (begin with 5 minutes and progress to 15 minutes total time)
  - Quadruped neutral (Figure 19-30)
  - Pelvic neutral on the door with mini squats progressing to upper extremity movements with resistive bands (3 sets to fatigue)

Techniques to Increase Muscle Strength, Power, and Endurance

- Mini squat with pelvic neutral (3 sets to fatigue)
- Total Gym or Vigor Gym in pelvic neutral (5 to 10 minutes)
- Standing lat pulldown with pelvic neutral (10 to 15 reps, 2 to 3 sets)

Neuromuscular Dynamic Stability Exercises

- Refer to OCK and CKC exercise

Functional Exercises

- Proper sitting mechanics, sit-to-stand transitions, squatting, lifting, getting on/off floor, ADLs retraining
- Hip hinging series: sit, stand, squat, and stagger squat
  - Proper log rolling for bed mobility
  - Gait training
  - Education on getting on/off floor



FIGURE 19-28. Supine hamstring stretch.

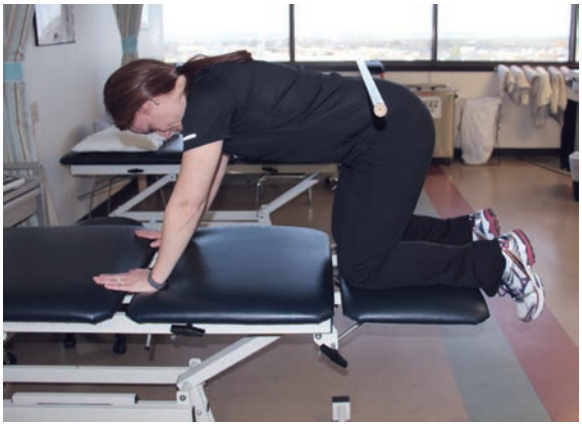

FIGURE 19-30. Quadruped neutral position.

Milestones for Progression to the Next Phase

- Minimal daily symptoms
- Reduce ODI score <20%
- Perform ADLs

Phase III: (weeks 6 to 10, Postoperative)

Clinical Pearls

- Progress of activities with a focus on core strengthening
- Advanced based on ability to perform activities with proper mechanics and technique
- Continue with lifting precautions and protection from injury as any setback or return or neurological symptoms should be avoided.

Goals

- Pain-free transitions
- Demonstrate proper body mechanics with exercises
- Walk 1 mile without pain (trying to approximate up to 20 minutes of loaded activity)

Protection

- Proper protective spine mechanics for high functional activities, return to work, and sport

Management of Pain and Swelling

- NSAIDs as needed

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Mobilization and manipulation of thoracic spine, lumbar spine, SI joint, hips to correct hypomobility and for pain modulation
- Side-lying lumbar distraction
- Muscle energy techniques (METs) for muscular recruitment or inhibition

Soft Tissue Techniques

- Neural tissue mobilization
- Paraspinal MFR
- STM functional movement patterns

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Supine hamstring, hip flexor, and piriformis stretches



FIGURE 19-31. Standing cable exercises of upper extremities with pelvic neutral position.

Other Therapeutic Exercises

- Standing cable exercises of the upper extremities with pelvic neutral (Figure 19-31)
- Total Gym
- Body weight support treadmill with progression to regular treadmill

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Use of resistance bands of upper and lower extremities
- Use of unstable surfaces
- Advance of abdominal exercise (plank, etc.)
- Focus on transverse abdominals, external obliques, latissmus dorsi, gluteus maximus, gluteus medius, hamstrings, multifidus, psoas, quadratus lumborum

Sensorimotor Exercises

- Sitting on stability ball
- Advance to standing on unstable disc
- Single leg stance (SLS) static and dynamic activities

Open and Closed Kinetic Chain Exercises

- Prone pelvic neutral with blood pressure cuff with lower and upper extremity progression
- Dynamic movements using a stick for biofeedback on neutral spine
- Use of bands and cables in varies directions/resistance in functional hip hinge position

Techniques to Increase Muscle Strength, Power, and Endurance

- Advance abdominal exercise
  - Plank
  - Lateral plank
  - Resisted proprioceptive neuromuscular facilitation (PNF)
- Emphasis on the following muscle groups: gluteals, abdominals, deep back extensors

Neuromuscular Dynamic Stability Exercises

- BOSU ball
  - Single leg stance dynamic and static activities
  - Improving body sense awareness in cutting, pivoting, and agility work

Functional Exercises

- Education and technique for proper spine mechanics
  - Increased resistance of long lever challenge on dynamic spine control
  - Hip hinging with upper extremity weighted challenge
  - Use of resistive bands in functional positions, i.e. lunge
  - Overhead squatting (use of bar overhead during squat maneuver; no weight)

Milestones for Progression to the Next Phase

- Complete resolution of pain
- Able to demonstrate neutral spine in all functional positions (both subjective feedback and also qualitative from the therapist observing the motions and positions)

Phase IV: (weeks 10 to 14, Postoperative)

Clinical Pearls

- Use core strengthening exercises as a foundation for total fitness.
- Use exercises focusing on sport specific routine is important at this stage of rehabilitation.
- Ensure proper technique throughout the exercises is important to reinforce spine mechanics and build the foundation for future return to sports.

Goals

- Fluid motion in normal spine activities
- Elimination of abnormal spinal mechanics
- Walking program progression (greater than 1 mile)
- Light lifting program
- ADLs without pain

Protection

- Reinforce proper spine mechanics throughout all activities

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Muscle energy techniques (METs) for muscular recruitment or inhibition (any setbacks with small resurgence of symptoms may require treatment)

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Supine hamstring, hip flexor, and piriformis stretches

Other Therapeutic Exercises

- Total Gym workout
- Swimming
- Treadmill
- Elliptical

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Use of resistance bands of upper and lower extremities
- Use of unstable surfaces
- Advance of abdominal exercise (plank, etc.)
- Focus on transverse abdominals, external obliques, latissmus dorsi, gluteus maximus, gluteus medius, hamstrings, multifidus, psoas, quadratus lumborum

Sensorimotor Exercises

- Single leg stance (SLS) dynamic activities
- Unstable disc

Open and Closed Kinetic Chain Exercises

- Use of bands and cables in varies directions/resistance in functional hip hinge position (therapist to assist to ensure hip is the hinge for motion allowing for stable spine in exercises) (Figure 19-32)

Techniques to Increase Muscle Strength, Power, and Endurance

- Advance abdominal exercise
  - Plank
  - Lateral plank
  - Resisted proprioceptive neuromuscular facilitation (PNF)



FIGURE 19-32. Therapist providing feedback to keep proper hip position during standing upper extremity cable exercises.

- Emphasis on the following muscle groups: gluteals, abdominals, deep back extensors
- Treadmill and swimming for cardiovascular fitness

Neuromuscular Dynamic Stability Exercises

- BOSU ball
  - Single leg stance dynamic and static activities
  - Improving body sense awareness in cutting, pivoting, and agility work

Plyometrics

- Squat jumps, broad jumps, single leg hops

Functional Exercises

- Education and technique for proper spine mechanics
  - Increased resistance (using upper extremity cables) of long lever challenge on dynamic spine control
  - Hip hinging with upper extremity weighted challenge
- Use of resistive bands in functional positions, i.e., lunge
- Overhead squatting

Sport-Specific Exercises

- Squat jumps, single leg hips
  - Agility ladder
  - Resisted golf swings
- Carioca

Milestones for Progression to the Next Phase

- Proper spinal mechanics (both subjective feedback and qualitative assessment from the therapist observing all positions)
- Complete resolution of pain
- Able to demonstrate neutral spine in all functional positions, using both subjective feedback from the patient and qualitative assessment from the therapist observing the positions

Phase V: (weeks 14 to 24, Postoperative)

Clinical Pearls

- Progress at this point can focus towards sport-specific type of exercises.
- It is important that as progress improves with cardiovascular fitness and strength to ensure proper spine mechanics to prevent further injury.
- Therapist to evaluate overall body mechanics to correct deficiency in kinetic chain.

Goals

- Improve cardiovascular fitness
- Incorporate sport-specific protocols
- Encourage proper spine mechanics throughout kinetic chain (from foot to head)

Protection

- Continue to monitor for proper form during activities

Management of Pain and Swelling

- NSAIDs as needed

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Muscle energy techniques (METs) for muscular recruitment or inhibition (as necessary)

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Supine hamstring, hip flexor and piriformis stretches
- Stretching of gastroc-soleus complex

Other Therapeutic Exercises

- Standing cable upper extremity exercises with pelvic neutral
- Total Gym
- Swimming
- Treadmill or elliptical

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Use of resistance bands of upper and lower extremities
- Use of unstable surfaces
- Advance of abdominal exercise (plank, etc.)
- Focus on transverse abdominals, external obliques, latissmus dorsi, gluteus maximus, gluteus medius, hamstrings, multifidus, psoas, quadratus lumborum

Sensorimotor Exercises

- Standing on unstable disc
- Single leg stance (SLS) static and dynamic activities
- BOSU ball

Open and Closed Kinetic Chain Exercises

- Use of bands and cables in variable directions/resistance in functional hip hinge position

Techniques to Increase Muscle Strength, Power, and Endurance

- Plank
- Lateral plank
- Resisted proprioceptive neuromuscular facilitation (PNF)
- Progress from previous phases to include hip flexors, quads, gastroc soleous, hip abductors and external obliques

Neuromuscular Dynamic Stability Exercises

- Single leg stance dynamic and static activities
- Improving body sense awareness in cutting, pivoting, and agility work
- Rocker-board activities
- Single leg stance (SLS) with lower body resistance bands

Plyometrics

- Squat jumps, broad jumps, single leg hops

Functional Exercises

- Education and technique for proper spine mechanics
- Increased resistance of long lever challenge on dynamic spine control
- Hip hinging with upper extremity weighted challenge
- Use of resistive bands in functional positions, i.e., lunge
- Overhead squatting

Sport-Specific Exercises

- Squat jumps, single leg hips
- Agility ladder
- Resisted golf swings

Milestones for Progression to the Next Phase

- Pain-free activities
- Core strength and LE strength within 10% of preinjury or "normal" level
- Single leg balance equal side to side

Phase VI: (weeks 24 to 52, Postoperative)

Clinical Pearls

> Transition to sport should emphasize proper technique and spinal mechanics with restoration of sport activity. Proper spinal mechanics should be emphasized over performance until the ability to maintain those mechanics with endurance are achieved.

Goals

- Progress to normal activities and sport
- Regain normal sport velocity
- Establish endurance for sport and core body strength (depends on specific sport technique to be able to determine return to play)

Techniques for Progressive Increase in Range of Motion

- Manual therapy techniques not applicable, except as necessary as per previous phases
- Stretching of parapinals, piriformis, hip flexors

Other Therapeutic Exercises

- Progression to cardiovascular endurance
- Progression of UE and LE resistance exercises with focus on proper form and endurance

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Focus on transverse abdominals, external obliques, latissimus dorsi, gluteus maximus, hip abductors, hamstrings and lower extremity strengthening

Sensorimotor Exercises

- Stability ball
- Rocker board
- Single leg stance dynamic activities

Open and Closed Kinetic Chain Exercises

- Use of bands and cables in varies directions/resistance in functional hip hinge position

Techniques to Increase Muscle Strength, Power, and Endurance

- Cardiovascular fitness to include treadmill, swimming
- Plank exercises
- Resisted PNF

Neuromuscular Dynamic Stability Exercises

- Agility work with cutting and pivoting/weight transfer
- Single leg stance dynamic and static activities

Plyometrics

- Lunges multidirectional
- Squat jumps
- Single leg jumps

Functional Exercises

- Increased resistance of long lever challenge on dynamic spine control
- Hip hinging with upper extremity weighted challenge
- Observation and correction of spine mechanics during exercise

Sport-Specific Exercises

- Agility ladder
- Carioca
- Pivot drills
- Resisted swinging (golf)

Milestones for Progression to the Next Phase

- Proper technique to and through fatigue
- Return to 10% of estimated or previous strength (manual muscle testing from therapist or isokinetic testing)
- LE strength within 10% of each other (manual muscle testing from physical therapist or isokinetic testing)

Criteria for Return to Sport

General

- Within 10% of normal or previous (preinjury) core strength (How measured?)
- Proper mechanics to and through fatigue
- Pain-free mobility with activity and throughout agility drills
- Demonstration of sport skills with proper mechanics and pain free

Sport-Specific

- Golf
  - Pain-free proper mechanics of swing

  - With attention to hip turn, spine position, and shoulder turn
- Football/contact sports
  - Ensure pain-free noncontact full speed prior to return
  - Gradual return to full contact (protected contact (player initiated) prior to open full contact)
  - Monitor closely during practice to ensure that athlete is progressing with proper mechanics/technique

After Return to Sport

Continuing Fitness or Rehabilitation Exercises

- Proper spine mechanics throughout activity (observed)
- Core strengthening exercises: plank, lateral plank
- Lower extremity strength and conditioning

Exercises and Other Techniques for Prevention of Recurrent Injury

- Lower extremity flexibility important for injury prevention
- Proper technique in sport
- Core (lumbar and abdominal) strength and endurance

Evidence

Danielson JM, Johnsen R, Kibsgaard SK, et al: Early aggressive exercise for postoperative rehabilitation after discectomy. *Spine* 25:1015–1020, 2000.

This is a randomized controlled trial comparing a training group and a mild exercise group postoperatively. Vigorous medical exercise started 4 weeks after surgery reduced disability and pain after surgery. (Level I evidence).

McGregor AH, Dore CJ, Morris TP, et al: Function after spinal treatment, exercise, and rehabilitation (FASTER). *Spine* 36: 1711–1720, 2011.

This multicenter, factorial, randomized controlled trial on the postoperative management of spinal surgery patients. Found no difference at 12 months ODI for usual care versus rehabilitation versus rehabilitation with educational booklet and booklet only. (Level I evidence).

Ostelo RW, Costa LO, Maher CG, et al: Rehabilitation after lumbar disc surgery: An update Cochrane review. *Spine* 34:1839–1848, 2009.

This systematic review of randomized controlled trials evaluated postoperative protocol after lumbar surgery. Exercise programs after surgery seem to lead to faster decrease in pain postoperatively. (Level I evidence).

Ostelo RW, de Vet HC, Waddell G, et al: Rehabilitation following first-time lumbar disc surgery; A systematic review within the framework of the Cochrane collaboration. *Spine* 28:209–218, 2003.

This systematic review of randomized controlled trials evaluated the protocol for postoperative rehabilitation after first time lumbar surgery. No evidence for restriction of activities immediately after surgery was found and strong evidence for intensive exercise. (Level I evidence).

Weber H: Lumbar disc herniation: A controlled, prospective study with ten years of observation. *Spine* 8:131–140, 1983.

This prospective study of patients with surgical and nonsurgical treatment for lumbar disc herniation showed improved outcomes in the surgical group at 1 year and no statistical difference at 4- and 10-year follow up. (Level 2 evidence).

Weinstein JN, Tosteson TD, Lurie JD, et al: Surgical versus nonoperative treatment for lumbar disk herniation: The spine patient outcomes research trial (SPORT)—A randomized trial. *JAMA* 296:2441–2450, 2006.

This prospective, randomized study of operative and nonoperative treatment for lumbar disk herniation found better outcomes in surgical patients, but the primary differences in the study were not statistically significant. There were large crossovers in the study confounding some conclusions. (Level I evidence).

Multiple-Choice Questions

QUESTION 1. An important aspect of the surgical technique includes all of the following except:

A. Broad exposure of disc removing lamina for visualization
B. Protection of the dura
C. Fluoroscopic confirmation of level
D. Removal of disc fragments

QUESTION 2. Pain control in Phase I for the patient who had surgical treatment for lumbar disc herniation should include:

A. Narcotic medication
B. Sleep
C. Repeated injection
D. Meditation

QUESTION 3. Squat jumps should first be incorporated into the postop protocol after surgical treatment for lumbar disc herniation in phase:

A. Phase I
B. Phase II
C. Phase III
D. Phase IV

QUESTION 4. Which milestone is important to advance to phase IV?

A. Discontinuation of narcotic pain medication
B. Complete resolution of pain
C. Return to within 10% of preinjury strength
D. The ability to do a plank exercise

QUESTION 5. Which of the following are essential for prevention of injury?

A. Proper spinal mechanics during exercise and sport
B. Return of core strengthening
C. Appropriate lower extremity strength and flexibility
D. All of the above

Answer Key

QUESTION 1. Correct answer: **A** (see Surgical Technique)

QUESTION 2. Correct answer: **A** (see Phase I)

QUESTION 3. Correct answer: **C** (see Phase III)

QUESTION 4. Correct answer: **B** (see Phase III)

QUESTION 5. Correct answer: **D** (see Phase VI)

BEYOND BASIC REHABILITATION: RETURN TO GOLF AFTER LUMBAR DISC HERNIATION

S. Josh Bell, MD, Stephanie Niño, PT, OCS, FAAOMPT, and Cheryl Obregon, PT, DPT, FAAOMPT

Introduction

ASPECTS OF GOLF THAT REQUIRE SPECIAL ATTENTION IN REHABILITATION

- Ensure adequate mobility throughout the kinetic chain (shoulders, hips, thoracic spine, etc.) to reduce load on lumbar spine.
- Hip strength including rotation and abductors.
- Proper spine mechanics throughout the swing.
- Lumbar disc herniation and lumbar strains are very common in golf.
- Surgery is relatively uncommon for golfers when compared to the number of injuries for this condition.
- Lumbar pain after strain, disc herniation, or other injury is very common in the athletic and occasional athletic population.
- Because golf requires trunk rotation to generate the golf swing, these injuries are very problematic for this sport. Appropriate treatment requires evaluation and treatment of the entire kinetic chain.

Advanced Rehabilitation Program

Week 0 to 12

- Follow protocols for postoperative rehabilitation of lumbar disc herniation (see timeline in the Nonoperative Rehabilitation part of this chapter).

Week 12 to 18

- Stretching/flexibility program (all static holds for 1 minute, 3 reps):
  - Half-kneeling hip flexor stretch
  - Child pose (heel to buttocks) to stretch paraspinals
  - Supine hamstring stretches (Figure 19-33)
  - Supine piriformis figure-of-4 stretch (Figure 19-34)
  - Seated torso rotation
  - Seated torso rotation with club (Figure 19-35)
- Strengthening program to include: (10 to 15 reps, 2 to 3 sets)
  - External obliques and transverse abdominals:
    - PNF Standing diagonal, upper extremity with resistive bands or cables (Figure 19-36)
  - Seated resisted torso rotation with golf club
  - Resistive shoulder flies and reverse flies (Figure 19-37)
  - Standard and side planks (begin with 30 seconds, progress to 1 minute)
  - Bird dog (quadruped position with opposite arm and leg off the ground)



FIGURE 19-33. Supine hamstring stretch.



FIGURE 19-34. Piriformis figure-of-4 stretch.



FIGURE 19-35. Seated torso rotation with club.



FIGURE 19-37. Resistive reverse flies, standing.

- Hip abductors:
  - Standing hip abduction with resistive bands
  - Lateral squat stepping with resistive tubing
- Periscapular: (low weight, 3 to 5 minutes)
  - Postural exercise with cervical neutral and scapular retraction (Figure 19-38)
  - Unilateral resisted scapular retraction
- Balance exercise to include:
  - Squats on foam (10 reps, 2 sets)
  - Single-leg stance with and without foam (goal of 1 minute)

Week 18 to 24

- Stretching program to include (all static holds for 1 minute, 3 reps):
  - Half-kneeling hip flexor stretch
  - Child pose (heel to buttocks) to stretch paraspinals
  - Supine hamstring stretches
  - Supine piriformis figure-of-4 stretch
  - Seated torso rotation
  - Seated torso rotation with club
- Strengthening program to include: (10 to 15 reps, 2 to 3 sets)
  - External obliques and transverse abdominals:
    - Seated resisted torso rotation with golf club (Figure 19-39)
    - Resistive shoulder flies and reverse flies on foam
    - Side planks with resisted able pulling
    - Bird dog on foam rolls
  - Hip abductors/rotators:
    - Standing hip rotation on stool with resistance (Figure 19-40)
    - Sideboard in hip hinge position with stick



FIGURE 19-36. Standing diagonal pulley upper extremity resistance with proper spine mechanics.



FIGURE 19-38. Postural exercise with neutral cervical alignment and scapular retraction.



FIGURE 19-39. Seated resisted torso rotation with club.

- Periscapular:
  - Resisted backswings
  - Resisted downswings
  - Resisted through-swings
- Balance exercise to include:
  - Standing on rocker board with golf swing (until patient fatigues)
  - Single-leg stance with resistance bands (Figure 19-41) (start with 10 reps each direction)

Sports Performance Testing

General History

- Previous injury history
- Length of time symptoms have been present

Subjective Questionnaires

- Oswestry disability index (ODI)
- Visual analog scale (VAS)



FIGURE 19-40. Standing hip rotation on stool with resistance.

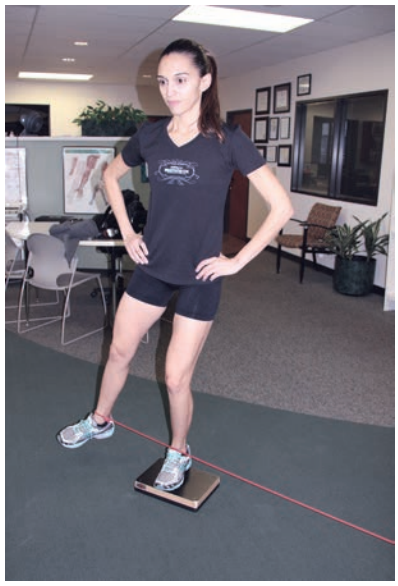

FIGURE 19-41. Single-leg stance exercise with resistance bands.

Medical History

- Other chronic medical conditions
- Previous medical treatment

Sports Injury History

- How has this injury affected performance?
- How long have you trained/performed with this injury?

Surgical History

- Any previous surgery involving the present problem
- Other orthopedic or neurological treatment
- Previous injection history and response to injection

Chronic Conditions/Medication

- Current medications?
- Currently on narcotic medications?
- Do current activities require any medication for function?

Specific Tests

- ODI is used throughout the rehabilitation to assess progress to therapy and ability to advance to the next phase of rehabilitation
- Strength testing (side to side comparison) using manual muscle testing or isokinetic testing
- Single leg activities are used to advance the athlete, such as the Y excursion test
  - Static/dynamic postural assessments
  - Observation of technique during rehabilitation activities to ensure proper form
  - Use of pain-free swings: has athlete progressed back to full swings without pain?

Specific Criteria for Progression to the Next Stage to Determine Readiness for Golf

- Progression and mastery of core and lower extremity strengthening
- Reduction in measured ODI
- Improved performance on stability exercises (e.g., rocker board)

Specific Criteria for Release to Unsupervised Complete Participation in Golf

- Pain-free full swing with proper spine mechanics

Recommended Ongoing Exercises

- Core strengthening including abdominal, lumbar extension, and lower body strengthening should be continued indefinitely.
- Stability and balance exercises, rocker board, and balance ball should be continued.
- Lower extremity and spinal flexibility should be continued indefinitely.

Evidence

Danielson JM, Johnsen R, Kibsgaard SK, et al: Early aggressive exercise for postoperative rehabilitation after discectomy. *Spine* 25:1015–1020, 2000.

This is a randomized controlled trial comparing a training group and a mild exercise group postoperatively. Vigorous medical exercise started 4 weeks after surgery reduced disability and pain after surgery. (Level I evidence).

McGregor AH, Dore CJ, Morris TP, et al: Function after spinal treatment, exercise, and rehabilitation (FASTER). *Spine* 36: 1711–1720, 2011.

This multicenter, factorial, randomized controlled trial on the postoperative management of spinal surgery patients. Found no difference at 12 months ODI for usual care versus rehabilitation versus rehabilitation with educational booklet and booklet only. (Level I evidence).

Ostelo RW, Costa LO, Maher CG, et al: Rehabilitation after lumbar disc surgery: An update Cochrane review. *Spine* 34: 1839–1848, 2009.

This systematic review of randomized controlled trials evaluated postoperative protocol after lumbar surgery. Exercise programs after surgery seem to lead to faster decrease in pain postoperatively. (Level I evidence).

Ostelo RW, de Vet HC, Waddell G, et al: Rehabilitation following first-time lumbar disc surgery; a systematic review within the framework of the Cochrane collaboration. *Spine* 28:209–218, 2003.

This systematic review of randomized controlled trials evaluated the protocol for postoperative rehabilitation after first time lumbar surgery. No evidence for restriction of activities immediately after surgery was found and strong evidence for intensive exercise. (Level I evidence).

Weber H: Lumbar disc herniation: A controlled, prospective study with ten years of observation. *Spine* 8:131–140, 1983.

This prospective study of patients with surgical and nonsurgical treatment for lumbar disc herniation showed improved outcomes in the surgical group at 1 year and no statistical difference at 4- and 10-year follow-up. (Level II evidence).

Weinstein JN, Tosteson TD, Lurie JD, et al: Surgical versus nonoperative treatment for lumbar disk herniation: The spine patient outcomes research trial (SPORT), A randomized trial. *JAMA* 296:2441–2450, 2006.

This prospective, randomized study of operative and nonoperative treatment for lumbar disk herniation found better outcomes in surgical patients but the primary differences in the study were not statistically significant. There were large crossovers in the study confounding some conclusions. (Level I evidence).

Multiple-Choice Questions

QUESTION 1. Specific considerations for return to sport for golf activities after lumbar disc herniations include all of these, except:

A. Ensure adequate mobility throughout the kinetic chain (shoulders, hips, thoracic spine, etc.) to reduce load on lumbar spine
B. Hip strength including rotation and abductors
C. Proper spine mechanics throughout the swing
D. Adequate wrist/grip strength for the swing

QUESTION 2. Sport-specific exercises after lumbar disc herniation begin at what interval after surgery?

A. 8 weeks
B. 4 weeks
C. 12 weeks
D. 16 weeks

QUESTION 3. Criteria to return the golfer to full sports activities without supervision include:

A. Pain-free full golf swing with proper spine mechanics
B. Single-leg jump equivalent on both sides
C. Discontinuation of pain medication
D. Upper body strength returned to preinjury level

QUESTION 4. Sport-specific exercises/rehabilitation protocols can start as early as __ weeks after surgery/injury.

A. 2 weeks
B. 18 weeks
C. 4 weeks
D. 12 weeks

QUESTION 5. The proper interval for static stretches in the progress back to sport is:

A. 3 minute stretch for 2 repetitions
B. 30 second stretch for 5 repetitions
C. 1 minute stretch for 3 repetitions
D. 30 second stretch for 3 repetitions

Answer Key

QUESTION 1. Correct answer: **D** (see Introduction)

QUESTION 2. Correct answer: **C** (see Advanced Rehabilitation)

QUESTION 3. Correct answer: **A** (see Specific Tests)

QUESTION 4. Correct answer: **D** (see Introduction)

QUESTION 5. Correct answer: **C** (see Introduction)

Chapter 20



Spondylolysis

INTRODUCTION

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Epidemiology

Age

- One study reported that children comprise as many as 47% of those who report to a clinic with back pain.
- More common in adolescent athletes, with rates listed from 8% to 15%.
- Age range is from ages 6 to 16, with an increasing incidence that levels off at age 16. Most report it most common during the "school-age years." A child's spine is fully developed at ages 8 to 10 years.
- There is a 2.6% to 4% incidence of spondylolysis in a pediatric population; 5.3% in a population of children with osteogenisis imperfecta (OI).
- Most often in children between 5 and 10 years old.
- Computed tomography is currently considered the most accurate imaging modality for identifying spondylolysis, and it often reveals the presence of nondisplaced spondylolysis.
- Of 855 patients undergoing abdominal computed tomography in Korea, 9% had spondylolysis, males affected more than females.
- The prevalence of a defect in the pars interarticularis is approximately 5% in the general population in the United States.

Gender

- More common in males; some reports indicating a male to female ratio as high as 3:1. In the general population is found to be 3% to 6%.

Sport

- Gymnastics, dance, soccer, football, wrestling, crew, weightlifting, and baseball (batting and weight of bat)

Position

- Football linemen, volleyball servers

Pathophysiology

Intrinsic Factors

- Spondylolysis is an osseous (bone) defect of the pars interarticularis.
- The cause of spondylolysis is not clearly defined. Most specialists believe it is caused by a genetic weakness of the pars interarticularis or results from chronic low-grade trauma, or, less often, acute trauma (Figure 20-1).
- Some list that the developmental process that goes on in the pars predisposes it to stress fracture. Repetitive loading causes fatigue fractures, or a traumatic event may cause a traumatic fracture.
- Increased lumbar lordosis may be a predisposing factor to spondylolysis. One study determined college football players with increased lumbar lordosis were not at increased risk for shortening their career.
- This lesion is most often seen in the adolescent lumbar spine. Adolescents involved in sports have a higher prevalence of spondylolysis than those who are not involved in sports.
- The sports with the highest prevalence of spondylolysis are gymnastics and dance. A common mechanism of injury in these sports is lumbar hyperextension (see Figure 20-23*A* to *D* later in this chapter).
- This condition is often asymptomatic.
- The neural arch is found to increase in strength as we get older. Full ossification is not complete until age 25.
- There may be less cortical bone in the neural arch in general in the adolescent age group, especially in those who have had a fracture.

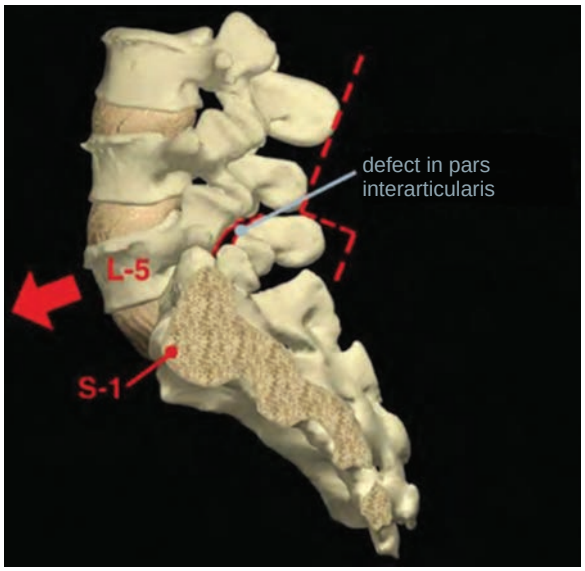

FIGURE 20-1. Spondylolysis. *(From Nau E, Hanney WJ, Kolber MJ: Spinal conditioning for athletes with lumbar spondylolysis and spondylolisthesis. Strength Conditioning J 30:43-52, 2008.)*

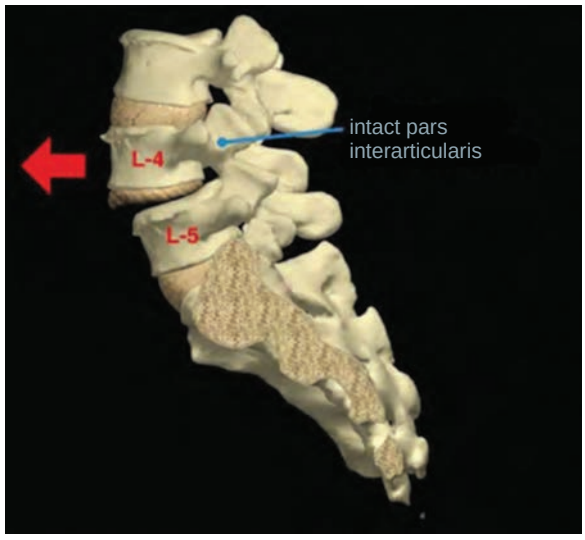

FIGURE 20-2. Spondylolisthesis. *(From Nau E, Hanney WJ, Kolber MJ: Spinal conditioning for athletes with lumbar spondylolysis and spondylolisthesis. Strength Conditioning J 30:43-52, 2008.)*

- Consider the biomechanics of lower lumbar spine; the position of facets is more horizontal, causing forces on the neural arch.
- Most common in forced lumbar extension activity accompanied by lumbar rotation, along with continued flexion to extension.
- May be a relationship between hamstring tightness and amount of lumbar lordosis; spinal active range of motion (AROM).
- Relationship between pars defect and spina bifida occulta.
- May be higher in children with osteogenisis imperfecta.
- May be related to endocrine abnormality.
- Multifidi muscle attaches to the mammillary process and helps to stabilize the vertebral joints. It spans from the sacrum to the cervical spine, endowing stability to each segmental level. The mammillary process is not fully developed until age 25.
- Spondylolisthesis is a forward slippage of one vertebra on another (Figure 20-2), often a result of degenerative changes and/or a vertebral defect.
- Not everyone who has spondylolysis will develop spondylolisthesis; if it does develop, it usually occurs in the 5th lumbar vertebra (85% to 95%) but can involve the 4th vertebra (5% to 15%).
- Initial treatment is always nonsurgical unless traumatic and compromise of the spinal cord is a concern.

Extrinsic Factors

- Cleated sports: traumatic or chronic force
- Baseball: size of bat
- Gymnastics: landing surface
- Football: field conditions
- Wrestling: surface

Traumatic Factors

- Some disagreement, but most seem to agree that spondylolysis is a fatigue/overuse fracture resulting from repetitive motion.
- Most common in forced lumbar extension activity accompanied with lumbar rotation, e.g., gymnastics, dancing and cheerleading.
- Also in football linemen from two- and three-point stance; weightlifting during squatting and supine leg press.
- Volleyball serving
- Wrestling holds

Classic Pathological Findings

- Fracture at pars
- No spondylolisthesis

Clinical Presentation

History

- Pain increases with increased activity; little pain at rest
- Difficult or painful lumbar extension
- May or may not have radiating pain

Physical Examination

Abnormal Findings

- Positive stork test (Figure 20-3)
- Increased lumbar lordosis
- Positive stork test (Figure 20-3)
- Positive stork test (Figure 20-3)
- Tender to palpation at level of pars fracture
- Positive neurological findings generally not found

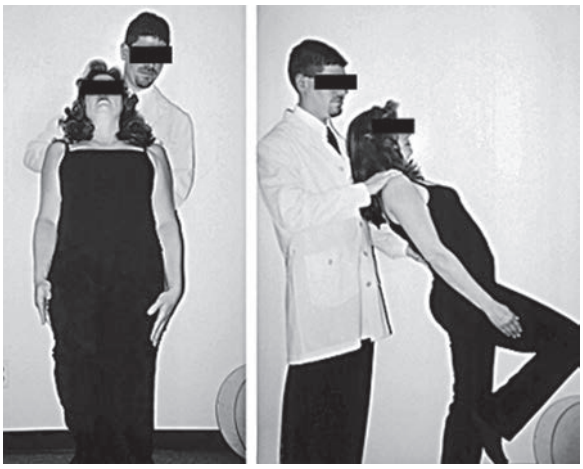

FIGURE 20-3. To assess localized spondylolysis pain, a single-leg hyperextension stork test is performed. The patient stands on one leg and hyperextends and rotates the spine. Reproduction of the patient's pain complaint indicates a diagnosis of spondylolysis until proved otherwise.

Pertinent Normal Findings

- Labs
- Normal neurological exam

Imaging

- Scotty dog on plain radiograph (Figure 20-4*A*). Fracture is demonstrated by a black collar on the Scotty dog (Figure 20-4*B*)
- Computerized Tomography (CT) in a normal spine, intact pars interarticularis (Figure 20-4*C*). CT shows a pars defect (Figure 20-4*D*).
- Bone scan stress reaction at pars interarticularis (Figure 20-4*E*, *F*)

Differential Diagnosis

- Generalized muscular low back pain; duration may help (3 weeks)
- Imaging is key, may need to use algorithm of: plain radiographs/CT/single photon emission tomography (SPECT)/magnetic resonance imaging (MRI).
- Significant neurologic findings

Treatment

Nonoperative Management

- Education
- Core stability
- Aqua/pool therapy
- Bracing (varied opinions here)
- Soft tissue mobilization/manipulation
- Strengthen specific muscle groups (abdominal core, lower extremities); lengthen others (hip flexors)

Guidelines for Choosing Between Nonoperative Treatments

- Primary complaint (pain, AROM)
- Lesion (spondylolysis with no spondylolisthesis)
- Unilateral versus bilateral pars defect
- Radiculopathy versus none
- Availability of pool/soft tissue management
- Type of sport

Surgical Indications

- Abnormal neurologic signs
- Severe and/or progressive neurologic deficits
- Failure of conservative care

Aspects of History, Demographics, or Exam Findings that Affect Choice of Treatment

- Neurologic signs
- Failed treatment over course of one year
- Patients' desires, schedule, and time frame

Aspects of Clinical Decision Making When Surgery is Indicated

- Failed course of conservative care (6 to 12 months)
- Severe and/or progressive neurologic deficits
- Patient's desires

Evidence

Bhatia NN, Chow G, Timon SJ, et al: Diagnostic modalities for the evaluation of pediatric back pain: A prospective study. *J Pediatr Orthop* 28:230, 2008.

This prospective study evaluated and discusses the commonly taught idea that pediatric back pain frequently has an underlying diagnosis. This leads clinicians to order numerous tests. This study examined the rate of diagnosis for pediatric back pain and the value of various diagnostic studies for this problem. (Level II evidence).

Chou R, Qaseem A, Snow V, et al: Diagnosis and treatment of low back pain: A joint clinical practice guideline from the American College of Physicians and the American Pain Society. *Ann Inter Med* 147:478–491, 2007.

This review article discusses and lists seven recommendations to assist with the diagnosis and treatment of patients with low back pain. (Level II evidence).

Hatz D, Espositi PW, Schroeder B, et al: The incidence of spondylolysis and spondylolisthesis in children with osteogenesis imperfecta. *J Pediatric Orthop* 31:655–660, 2011.

Hu SS, Tribus CB, Diab M, et al: Spondylolisthesis and spondylolysis. *J Bone Joint Surg Am* 90:656–671, 2008.

This retrospective review of radiographs found that the incidence of spondylolysis and spondylolisthesis in a group of children with osteogenesis imperfecta was much higher than in the normal pediatric population. (Level IV evidence).

Kim HJ, Green DW: Adolescent back pain. *Curr Opin Pediatr* 20:37, 2008.

This review article discusses previous studies that have suggested a correlation between adolescent back pain and adult-onset back pain. It stresses the importance of a systematic

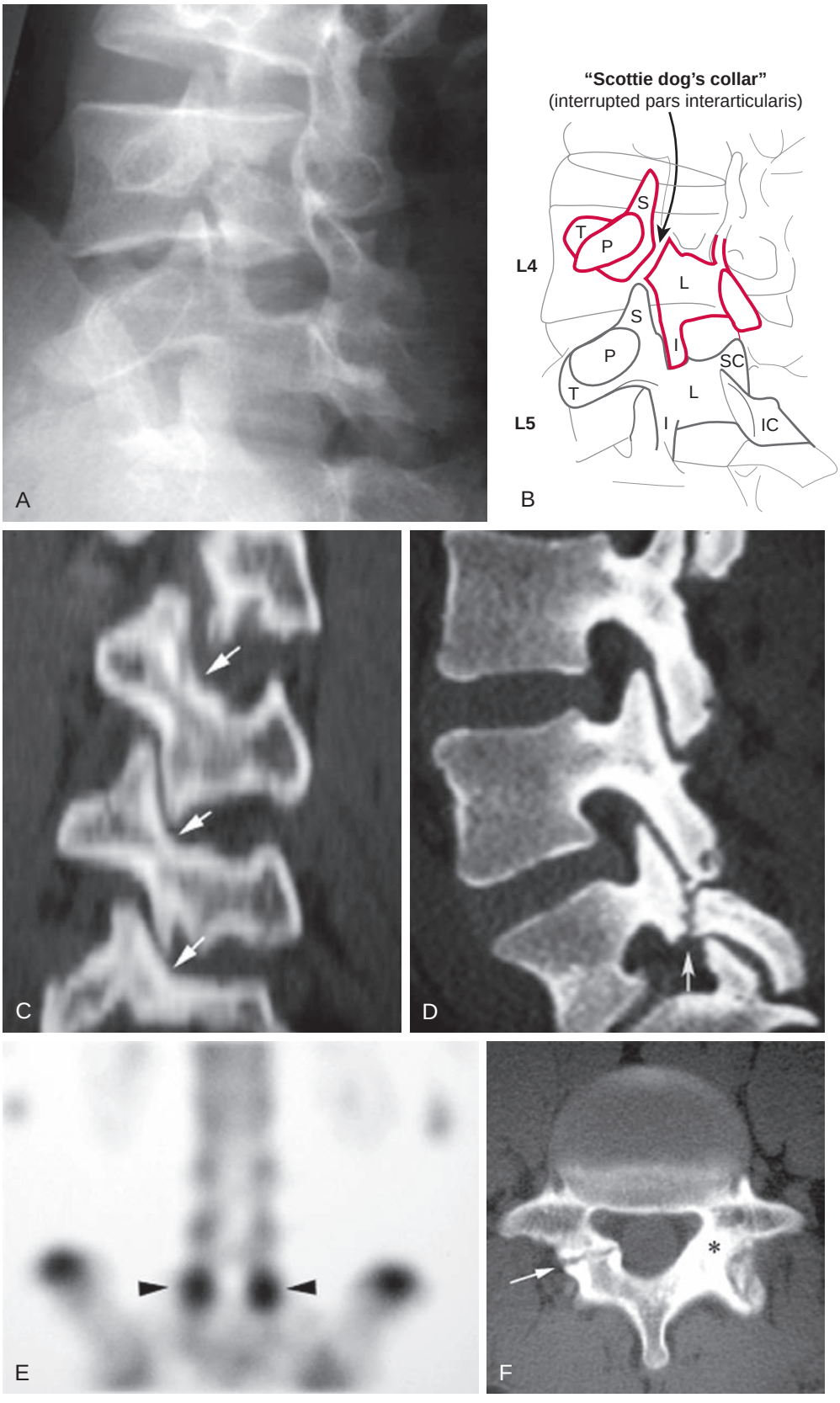

FIGURE 20-4. Spondylolysis. **A** and **B,** Normal and interrupted pars interarticularis. Oblique radiograph (**A**) and corresponding line drawing (**B**) show an intact pars interarticularis at L5 and a pars defect with a collar around the Scottie dog's neck at L4 (arrow in part B). *P*, pedicle (the Scottie dog's eye); *T*, transverse process (nose); *S*, superior articulating facet (ear); *I*, inferior articulating facet (front leg); *L*, lamina (body); *IC*, contralateral inferior articulating facet (rear leg); *SC*, contralateral superior articulating facet (tail). **C,** Oblique sagittal computed tomography (CT) reconstruction in a normal patient. Note the intact pars interarticularis (*arrows*). **D,** Sagittal CT reformat shows a pars defect in L5 (*arrow*). **E,** Radionuclide bone scan of bilateral L5 pars defects. Coronal single-photon emission CT (SPECT) image obtained through the posterior elements shows increased tracer bilaterally at L5 (arrowheads). A CT scan (not shown) was needed to confirm bilateral defects because a unilateral defect with adaptive hypertrophy on the contralateral side could have similar bone scan findings. **F,** Axial CT image of unilateral spondylolysis. Note the spondylolysis on the right (*arrow*). Also note the sclerosis of the contralateral pars interarticularis (*asterisk*). This nonspecific finding may indicate that left-sided adaptive changes caused increased stress because of the right-sided pars defect or an impending left pars stress fracture. *(From Manaster B. Musculoskeletal Imaging: The Requisites. 3rd ed. Philadelphia: Elsevier; 2002.)*

approach to arrive at a clear diagnosis and appropriate treatment for adolescents with low back pain. (Level V evidence).

Ko SB, Lee SW: Prevalence of spondylolysis and its relationship with low back pain in selected population. *Clin Orthop Surg* 3:34–38, 2011.

This retrospective chart review discusses the prevalence of LBP and its association with a patient having a lumbar spondylolysis in a selected population. (Level IIc clinical evidence).

Sairyo K, Sakai T, Yasui N: Conservative treatment of lumbar spondylolysis in childhood and adolescence: The radiological signs which predict healing. *J Bone Joint Surg Br* 91:206, 2009.

This retrospective clinical chart review article suggests a CT /MRI protocol that is a predictor of bony healing of a pars defect in children after conservative treatment. (Level IIIb evidence).

Standaert C, Herring S: Spondylolysis: A critical review. *Br J Sports Med* 34:415–422, 2000.

This review article is from 12 years ago and discusses the natural history, pathophysiology, diagnosis, and treatment of spondylolysis based on the available medical literature at that time. It appears not much has changed. (Level III evidence).

Sys J, Michielsen J, Bracke P, et al: Nonoperative treatment of active spondylolysis in elite athletes with normal X-ray findings: Literature review and results of conservative treatment. *Eur Spine J* 6:498–504, 2001.

This literature review suggests that osseous healing is likely to occur in unilateral spondylolysis although diminishes in bilateral and pseudo-bilateral spondylolysis. Nonunion does not seem to compromise the overall outcome or sports resumption in the short term. (Level III evidence).

Multiple-Choice Questions

QUESTION 1. Spondylolysis is most common in males, with a male/female ratio of:

A. 2:1
B. 3:1
C. 5:1
D. 10:1

QUESTION 2. Spondylolysis occurs most frequently at which spinal level?

A. L2
B. L3
C. L4
D. L5

QUESTION 3. What lumbar motion is predominately painful with a spondylolysis?

A. Flexion
B. Extension
C. Rotation
D. Sidebending

QUESTION 4. A spondylolysis is a fracture demonstrated on a radiograph by what on the Scotty dog?

A. Ears
B. Front legs
C. Rear legs
D. Collar

QUESTION 5. What imaging modality is considered the most accurate for identifying spondylolysis?

A. Radiograph (X-ray)
B. Magnetic resonance imaging (MRI)
C. Computed tomography (CT)
D. Bone scan

Answer Key

QUESTION 1. Correct answer: **B** (see Epidemiology)

QUESTION 2. Correct answer: **D** (see Pathophysiology)

QUESTION 3. Correct answer: **B** (see Clinical Presentation)

QUESTION 4. Correct answer: **D** (see Clinical Presentation)

QUESTION 5. Correct answer: **C** (see Epidemiology)

NONOPERATIVE REHABILITATION OF SPONDYLOLYSIS

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Charles E. Rainey, PT, DSc, DPT, OCS, SCS, CSCS, FAAOMPT, and Stewart M. Kerr, MD

GUIDING PRINCIPLES OF NONOPERATIVE REHABILITATION

- Decrease pain with chosen activity; most important is rest until pain is subsiding
- Increase level of function (without pain) in chosen activity
- Return to sport

Phase I (0 to 3 months)

Goals

- Protect the healing segment.
- Minimize the effect of spinal immobilization.
- No signs or symptoms of instability.
- Rest; avoid sports.

Protection

- For nonoperative care, use of spinal bracing as well as the type of bracing is controversial. Our recommendation is soft bracing (corset) or hard bracing (thoracolumbar sacral orthosis) for at least 3 months.
- After 3 months, pain should be the guide.

Management of Pain and Swelling

- Electrotherapy (TENS) may be used if there is pain, spasm, and muscle guarding
- Oral NSAIDs and analgesic pain medication as needed.
- Cryotherapy as needed

Techniques for Progressive Increase in Range of Motion

- Begins immediately after evaluation by a physician.
- This phase should include evaluation, discussion, and planning. Active physical therapy care will begin once pain is subsiding.

Manual Therapy Techniques

- With the patient in a brace, begin gentle mobilization of extremities and hips to maintain AROM of those structures if needed.
- No manual therapy for lumbar and thoracic spine.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Letting pain be the guide, limit flexibility training to accessory structures of the upper and lower extremities, specifically the shoulders and hips.
- The intent of treatment at this phase is maintenance of accessory structures.

Other Therapeutic Exercises

- Generalized aerobic conditioning may begin if pain-free.
- Continue bracing at all times or as instructed by physician.
- If patient is allowed to remove brace, it is advisable to recommend wearing the brace for exercise for a 3-month period.
- Nonexercise brace wear will coincide with pain level with activity and radiographic evidence of healing.
- Low-level core stability exercises, such as double/single leg bridges, active straight leg raises, and quadruped diagonals (i.e. bird dogs).
- Education; back school

TIMELINE 20-1: **Nonoperative Rehabilitation of Spondylolysis**

PHASE I (0 to 3 months)

- Immobilization for a minimum of 3 months, with up to 12 months being the gold standard
- For the first 3 months, primarily rest and very little formal treatment
- Protect healing segment:
  - Bracing for 3 months
  - After 3 months, pain is guide
- Minimize effect of spinal immobilization using PT modalities: ice, electrotherapy, NSAIDs
- Manual therapy for extremities
- Check for signs or symptoms of instability
- Rest; avoid sports

PHASE II (3 to 6 months)

- Continue as in Phase I
- Discontinue brace
- Minimize effect of spinal immobilization
- Increase spinal AROM
- Manual therapy for spine

Activation of Primary Muscles Involved

- Avoid all high level muscle activation of spinal musculature for at least 3 months.

Sensorimotor Exercises

- These activities are advisable only in the brace and only if they do not cause pain.

Open and Closed Kinetic Chain Exercises

- Avoid open chain activities.
- Closed chain activities to include walking on level surface (no treadmill walking), low-level stationary bike.

Techniques to Increase Muscle Strength, Power, and Endurance

- Maintain upper extremity (UE) and lower extremity (LE) muscle strength, power, and endurance.

Sport-Specific Exercises

- Maintain low-level aerobic fitness.

Milestones for Progression to the Next Phase

- No pain at rest
- Very little to no pain with increased activity
- Outcome measures
  - Patient reported outcome tools should be implemented at the end of each phase. These tools will assist with the decision to advance to the next phase.
  - These outcome measures can also be used more often (monthly) if desired. Tools that have been used in the literature for spinal rehabilitation include the Fear Avoidance Behavior Questionnaire (FABQ) and (modified) Oswestry Disability Questionnaire.

Phase II (3 to 6 months)

Goals

- Protect healing segment.
- Minimize effect of spinal immobilization.
- Discontinue brace.
- Increase spinal AROM.
- Begin with minimal repetitions to assess tolerance for exercise and progress dosage of sets and repetitions as tolerated.

Protection

- Brace wear can be discontinued after 3 months; earlier if cleared by physician. Continue brace with exercise.

Management of Pain and Swelling

- Electrotherapy (TENS) may be used if there is pain, spasm and muscle guarding.
- Oral NSAIDs and analgesic pain medications as needed.
- Cryotherapy as needed.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Precautions: Initially limit AROM only to spinal flexion and extension without rotation. No manual therapy should be applied to healing segment.
- Slowly increase spinal AROM with AP mobilization techniques grades I to II in flexion and extension, with goal of ensuring quality planar motion without rotation in hypomobile segments.
- If no pain with flexion and extension after 1 week of care, begin spinal side-bending and rotation, letting pain be the guide. Mobilization for these motions should also be grades I to II in hypomobile segments.
- Limit increase in motion to 30°/week.
- Grades I to IV segmental mobilization of cervical and thoracic spine may improve overall available spinal AROM and also assist in pain management.
- Initiate spinal mobilization for sacrum/pelvis as indicated by evaluation.

Soft Tissue Techniques

- Begin instrument assisted soft tissue mobilization (IASTM), such as Graston, ASTYM, or other manual soft tissue mobilizations and techniques.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Continue as in Phase I; ensure upper extremity and lower extremity AROM are within normal limits.

TIMELINE 20-1: **Nonoperative Rehabilitation of Spondylolysis** (Continued)

PHASE III (6 to 9 months)	PHASE IV (9 to 12 months)
• Protect healing segment • Maximize spinal mobility/full spinal mobility • No signs or symptoms of instability • Functional spinal movement mechanics • Increased quality of life and function • Begin sport-specific training	• Full function; ready to return to sport • Continue sport-specific training • No signs or symptoms of instability

- Patients may perform supine upper extremity and lower extremity AROM activities/mat activities to include straight leg raise (SLR) and shoulder AROM in spinal flexion/extension plane.
- Cervical spine AROM activities in all planes are encouraged.
- Check for purity of spinal motion and regard compensatory motion as pain and or segmental blocking. Avoidance or lack of motion at individual segments may prevent increase in overall motion and be the cause of pain.

Other Therapeutic Exercises

- Begin gentle mat activities to include pelvic tilts.
- Lower and upper extremity exercise without resistance may also be added during this phase.
- Lower extremity exercises during this phase may include higher level stationary cycling (slowly add resistance) and treadmill walking.

Activation of Primary Muscles Involved

- Stability plank and four-point unilateral leg and arm lifts, no pain.
  - Patients are reminded to avoid high level spine activities, (i.e., plyometric activity, sport-specific activities in this phase.)

Sensorimotor Exercises

Begin active replication exercises, such as yoga and movement patterns for motor control.

Techniques to Increase Muscle Strength, Power, and Endurance

- Overall strengthening exercise may be initiated to include therapeutic ball exercises.

Neuromuscular Dynamic Stability Exercises

- Lower extremity balance activities such as single leg standing, BOSU ball, star excursion

Functional Exercises

- Begin Phase I spinal core stability exercises, which include:
  - Upper body rolling patterns
  - Lower body rolling patterns
  - Dying bug: patient lying on back with lifting alternate arm and legs while maintaining core stability
  - Quadruped diagonals (i.e., bird dogs)
  - Double/single leg bridges
  - Active straight leg raise

Clinical Pearls

The introduction of Phase II activities/exercises coincides with limiting the use of the spinal brace until it is ultimately eliminated.

- A concerted phased approach to maximize effective rehabilitation must be used. The slow introduction of spine specific exercises is key in that the patient has been immobilized for up to 3 months.
- Techniques to increase spinal AROM include stretching and skilled manual therapy techniques. These are important tools to assist with proper spinal rhythm and restoring proper joint arthrokinematics.
- Often, patients are fearful of moving; this is to be expected. However, proper movement patterns play a large role in pain management.

Sport-Specific Exercises

- Patients may begin low level sport-specific exercises.
- If a training program is being used, a careful review should be initiated to decide which activities are appropriate at this time.
- Activities should not include maximum weightlifting.

Milestones for Progression to the Next Phase

- Spinal AROM is improving with no pain
- Able to walk aerobically without pain to patient tolerance for aerobic conditioning
- Begin walk to run program
  - Begin with 5 minutes of walking and 1 minute of running and continue until reaching a duration of 30 minutes (5 cycles).
  - Repeat twice with a day of rest in between workouts.
  - Progress by reducing walking to 4 minutes and increasing running to 2 minutes.
  - Repeat protocol above until running continuously for 30 minutes.
  - If any symptoms occur, digress to previous stage until symptoms resolve.

Phase III (6 to 9 months)

Goals

- Protect healing segment
- Maximize spinal mobility/full spinal mobility
- No signs or symptoms of instability (determined reassessment by a qualified healthcare provider)
- Functional spinal movement mechanics (quality of movement determined by reassessment by a qualified healthcare provider)
- Increased quality of life and function
- Begin with minimal repetitions to assess tolerance for exercise and progress dosage of sets and repetitions as tolerated
- Sensorimotor/proprioceptive activities are performed for 30 to 60 seconds daily. Repeat 2 to 3 times per week or as needed.

Protection

- Patient is out of the brace

Management of Pain and Swelling

- Oral NSAIDS and analgesic pain medicine should be on the decline or discontinued. May be used as needed.
- Cryotherapy is used posttherapy treatment for postexercise inflammation and soreness

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- AROM precautions: None.
- Joint mobilizations: If adhesions are noted in lower spine, joint mobilizations may begin to be more aggressive, no thrust activities. Use oscillatory techniques grades II to IV. Care must be taken when assessing structures.
- Continued evaluation of all joint structures for maintenance and increasing level of function.

Soft Tissue Techniques

- We recommend continuing IASTM treatments over the course of this phase.
- Soft tissue techniques can include Graston, ASTYM, manual soft tissue mobilization or deep tissue massage.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Continue to maintain flexibility of upper extremity and lower extremity structures special attention to hip flexors and hamstrings
- Increase spinal AROM

Other Therapeutic Exercises

- Lower body strengthening is progressed and may include closed kinetic chain exercises (i.e., lunges, tubing resistance hip flex/extension/abduction, wall sits, body weight squats) and open chain resistance exercises.
- Treadmill walking and stationary biking with increased resistance.
- Add upper body ergometer (UBE) within pain free ranges without resistance. Performing the UBE in a standing position, if possible, provides an integrated conditioning exercise involving the trunk and hip girdle musculature.

Activation of Primary Muscles Involved

- Plank exercise with timed activities
- Four-point leg and arm exercises to progress to alternating arm/leg activities, again paying attention to quality versus quantity of motion.
- Stability ball: all activities on mat can advance to stability ball
- Wall squats
- Upper extremity and lower extremity strengthening with light resistance may begin.

Sensorimotor/Proprioceptive Exercises

- The Bodyblade is an effective tool to incorporate at this phase.
- Balance Master, proprioceptive neuromuscular facilitation (PNF) patterns (tall/half kneeling chops and lifts).
- Increase functional movement exercises.
- In addition, purity of motion will flow into sport-specific activities to restore successful movement patterns common to the athlete's sport of choice. This may be as simple as discussing these activities with your athlete.
- Successful movement patterns as this level will prepare the patient for more difficult functional patterns to be performed later as the treatment progresses. PNF patterns may be a way to integrate higher levels of sensory motor activities.

Clinical Pearl

> A key component to successful spinal rehabilitation is patient education for proper positioning during exercise; constant cueing is essential to maintain the purity of the designed activity.

Open and Closed Kinetic Chain Exercises

- Pool or aqua therapy is an effective method to get open chain activity and maximize training.
- Closed chain activities can include seated medicine ball flexion/extension and rotation progressing to standing medicine ball training.

Techniques to Increase Muscle Strength, Power, and Endurance

- Progress to all muscle groups as tolerated first in sitting, then in standing.
- Progress to lower extremity strength training exercises.
- Progress to elliptical and stair stepper for cardiovascular conditioning.

Neuromuscular Dynamic Stability Exercises

- Progress manual rhythmic stabilization drills for spine and advance to varying degrees of spinal motion as pain and ability allows.
- Performing these exercises in sitting first then standing will increase core recruitment.

Sport-Specific Exercises

- Can begin more sports specific training here. All should be performed without pain.

Milestones for Progression to the Next Phase

- No pain with activities
- Increased endurance
- Early participation in chosen sport activity/no competition

Phase IV (9 to 12 months)

Goals

- Full function; ready to return to sport
- Continue sports-specific training

- No signs or symptoms of instability
- Begin with minimal repetitions to assess tolerance for exercise and progress dosage of sets and repetitions as tolerated.

Management of Pain and Swelling

- Should be off all medication at this phase.
- Postexercise cryotherapy if needed.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Should not need any hands-on treatment except for short-term care because patient has an acute condition that will respond to manual therapy/manipulation.

Soft Tissue Techniques

- Should not need any hands-on treatment except for short-term care.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Continue to maintain flexibility of all structures.
- At this phase, stretching is an important part of a sport-specific workout.

Other Therapeutic Exercises

- Continue and increase difficulty of Phase III exercises.

Activation of Primary Muscles Involved

- Continue with Phase III exercises.

Sensorimotor/Proprioceptive Exercises

- Continue Bodyblade
- Balance Master
- Side thrusts high speed crossover training
- Increase functional movement exercises

CLINICAL PEARL

A continuous increase in difficulty should be part of the treatment plan. At some point, it is more of a personal training session than a therapy session. When that becomes the case, the patient should be considered for a home self-paced program.

Open and Closed Kinetic Chain Exercises

- Continue with pool or aqua therapy
- Continue with high level closed chain activities.

Techniques to Increase Muscle Strength, Power, and Endurance

- Continue with increasing intensity

Neuromuscular Dynamic Stability Exercises

- Progress Phase III exercises

Plyometrics

- Continue progression of Phase III exercises

Milestones for Progression to Advanced Sport-Specific Training and Conditioning

- Sport specific training with team/coach
- No contact/competition until cleared by physician

Tips and Guidelines for Transitioning to Performance Enhancement

Once fundamental movement patterns are reestablished with no compensation observed with bodyweight, the athlete can progress to performance enhancement, as evaluated by a qualified rehabilitation heath care provider.

Performance Enhancement and Beyond Rehabilitation: Training/Trainer and Optimization of Athletic Performance

See Beyond Basic Rehabilitation: Return to Gymnastics after Surgical Repair of Spondylolysis later in this book.

Specific Criteria for Return to Sports Participation: Tests and Measurements

- The rehabilitation specialist should be able to analyze the demands on the spinal complex and create a sufficient series of tests and exercises to ensure readiness for return to preinjury levels of activity.
- Meets the demand/need for the chosen sport without symptoms.

After Return to Sport

- Continuing fitness or rehabilitation exercises including total body strengthening and fitness exercises.
- Exercises and other techniques for prevention of recurrent injury.

Evidence

Chou R, Qaseem A, Snow V, et al: Diagnosis and treatment of low back pain: A joint clinical practice guideline from the American College of Physicians and the American Pain Society. *Ann Inter Med* 147:478–491, 2007.

This review article discusses and lists seven recommendations to assist with the diagnosis and treatment of patients with low back pain. (Level II evidence).

Hu SS, Tribus CB, Diab M, et al: Spondylolisthesis and spondylolysis. *J Bone Joint Surg Am* 90:656–671, 2008.

This article reviews surgical and nonsurgical indications of spondylolisthesis and spondylolysis, and states that more than 80% of children treated nonsurgically have resolution of symptoms. The article stated that for patients requiring surgical treatment, fusion in situ may provide adequate treatment for young patients. (Level IV evidence).

Loghmani MT, Warden SJ: Instrument-assisted cross-fiber massage accelerates knee ligament healing. *J Orthop Sports Phys Ther* 39:506–514, 2009.

This article reviews the kinematics and lumbar compressive forces that occur when using the Bodyblade, a popular tool in physical medicine clinics. (Level III evidence).

Looney B, Srokose T, Fernández-de-las-Peñas C, et al: Graston instrument soft tissue mobilization and home stretching for the management of plantar heel pain: a case series. *J Manipulative Physiol Ther* 138–142, 2011.

This article reviews the outcome of a set of patients with plantar fasciitis treated with Graston instrument soft tissue mobilization techniques (GT) and a home stretching program. This article showed a clinically meaningful improvement (Level IV evidence).

Moreside JM, Vera-Garcia FJ, McGill SM: Trunk muscle activation patterns, lumbar compressive forces, and spine stability when using the Bodyblade. *Phys Ther* 87:153–163, 2007.

The article reviews to investigate the effects of instrument-assisted cross-fiber massage (IACFM) on tissue-level healing of knee medial collateral ligament (MCL) injuries. The article states that IACFM-accelerated ligament healing, possibly via favorable effects on collagen formation and organization, but had minimal effect on the final outcome of healing. (Level IV evidence).

Multiple-Choice Questions

QUESTION 1. The goals of Phase I rehabilitation include all but:

A. Protect healing segment.
B. Minimize effect of spinal immobilization
C. No signs or symptoms of instability
D. Return to sports

QUESTION 2. What are appropriate interventions for Phase III rehabilitation?

A. Manual therapy
B. Stretching exercises
C. Begin return to sport activity
D. All the above

QUESTION 3. What is the appropriate phase to discontinue full-time brace wear?

A. Phase I
B. Phase II
C. Phase III
D. Phase IV

QUESTION 4. During which phase is the slow introduction of spine-specific exercise key?

A. Phase I
B. Phase II
C. Phase III
D. Phase IV

QUESTION 5. What is not a criterion for progression of the patient to the next phase?

A. Increased AROM without pain
B. Able to perform sport-specific motion without pain
C. Able to tolerate improved activity without pain
D. Contact sports without physician clearance

Answer Key

QUESTION 1. Correct answer: **D** (see Phase I)

QUESTION 2. Correct answer: **D** (see Phase III)

QUESTION 3. Correct answer: **B** (see Phase II)

QUESTION 4. Correct answer: **B** (see Phase II, Clinical Pearl)

QUESTION 5. Correct answer: **D** (see Phases I to IV)

POSTOPERATIVE REHABILITATION AFTER REPAIR OF SPONDYLOLYSIS

Charles E. Rainey, PT, DSc, DPT, OCS, SCS, CSCS, FAAOMPT, Stewart M. Kerr, MD, Gregg Ziemke, PT, MS, MHA, OCS, and Leslie C. Hair, PT, DSc, OCS, FAAOMPT

Indications for Surgical Treatment

- Severe, refractory lumbosacral pain that has not responded in 6 to 9 months to nonoperative management.
- Imaging (i.e., SPECT and/or MRI) should also be active/positive at the pars defect. The SPECT study is used most commonly and typically is most helpful for localizing a pars defect.

Brief Summary of Surgical Treatment

Major Surgical Steps

- Exposure of defect
- Debridement of sclerotic/fibrous healing response to healthy bleeding bone at the pars
- Use of iliac crest autograft
- Consideration for stabilization/instrumentation for increased bone fusion
- Postoperative lumbosacral bracing
- The single lag screw fixation (Buck) approach has been widely studied in both athletes and nonathletes. Published outcomes have shown that >90% of patients return to their preoperative sports performance.

Factors That May Affect Rehabilitation

Anesthetic

- A general anesthetic is required for any surgical repair.

Presurgical

- Flexion and extension radiographs (A-P and lateral) are taken to observe the degree of vertebrate slippage or abnormal motion (Figure 20-5*A*, *B*)
- An MRI is performed to evaluate the disc, ruling out other various soft tissue causes of pain.

Surgical (Figure 20-6*A* to *F*)

- A lumbar spine standard midline approach is used, preserving the multifidus muscle attachments to the L4-S1 facet joints (keeping the interspinous and supraspinous ligaments intact).
- The pars defect and lamina bilaterally is exposed with the fascial tissue removed.
- Using a 3 cm window, cancellous bone is harvested from the iliac crest.
- The cephalad vertebra's inferior facet joints are resected 3 to 5 mm to decrease the likelihood of impingement occurring in the pars region during spine loading or standing postures (especially hyperextension).
- The lamina's inferior edge is squared off using a bar.
- A drill is used at this edge upward, forward, and slightly outward, passing through the pars and across the pars defect (creating a tunnel within the bone).
- A correct length screw is placed within this bone tunnel.
- The screw is partially withdrawn and the harvested cancellous bone from the iliac crest is placed in the pars defect.
- Screws are readvanced the pars defect stabilizing the bone graft.
- Instrumented arthrodesis alone results in acceptable outcomes for those with spondylolisthesis.

Postsurgical

- Plain radiographs for asymptomatic patients and CT or MR imaging studies only if symptoms persist or new symptoms appear. Surgical outcomes of those achieving bone healing and fibrous union remain similar.
- Lumbosacral bracing. This helps avoid the pathophysiology of spondylolysis which includes repetitive/mechanical flexion, extension and trunk rotation.

Before Surgery: Overview of Goals, Milestones, and Guidelines[1]

GUIDING PRINCIPLES OF POSTOPERATIVE REHABILITATION

- Understand type of surgical repair performed.
- Understanding of the anatomic structures and their rate of healing.
- Understand positions and activities that stress the healing structure.
- Proper selection of manual therapy and exercise interventions applied at the appropriate phase of healing.

[1]*Prehabilitation, if appropriate, is described in the Nonoperative Rehabilitation section of this chapter.*

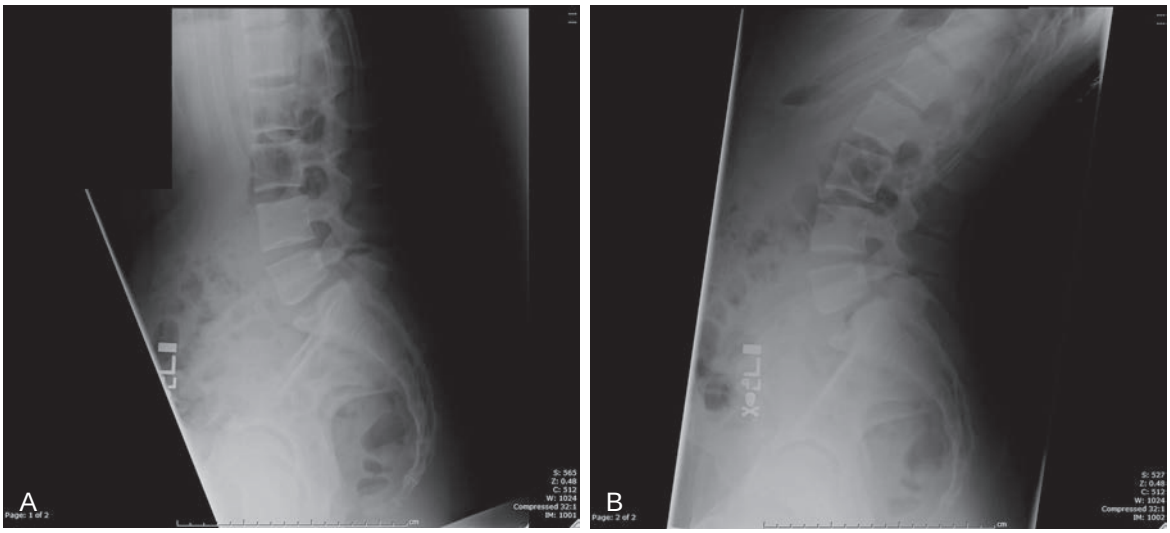

FIGURE 20-5. Spinal radiographs. **A,** Lateral view in flexion. **B,** Lateral view in extension.

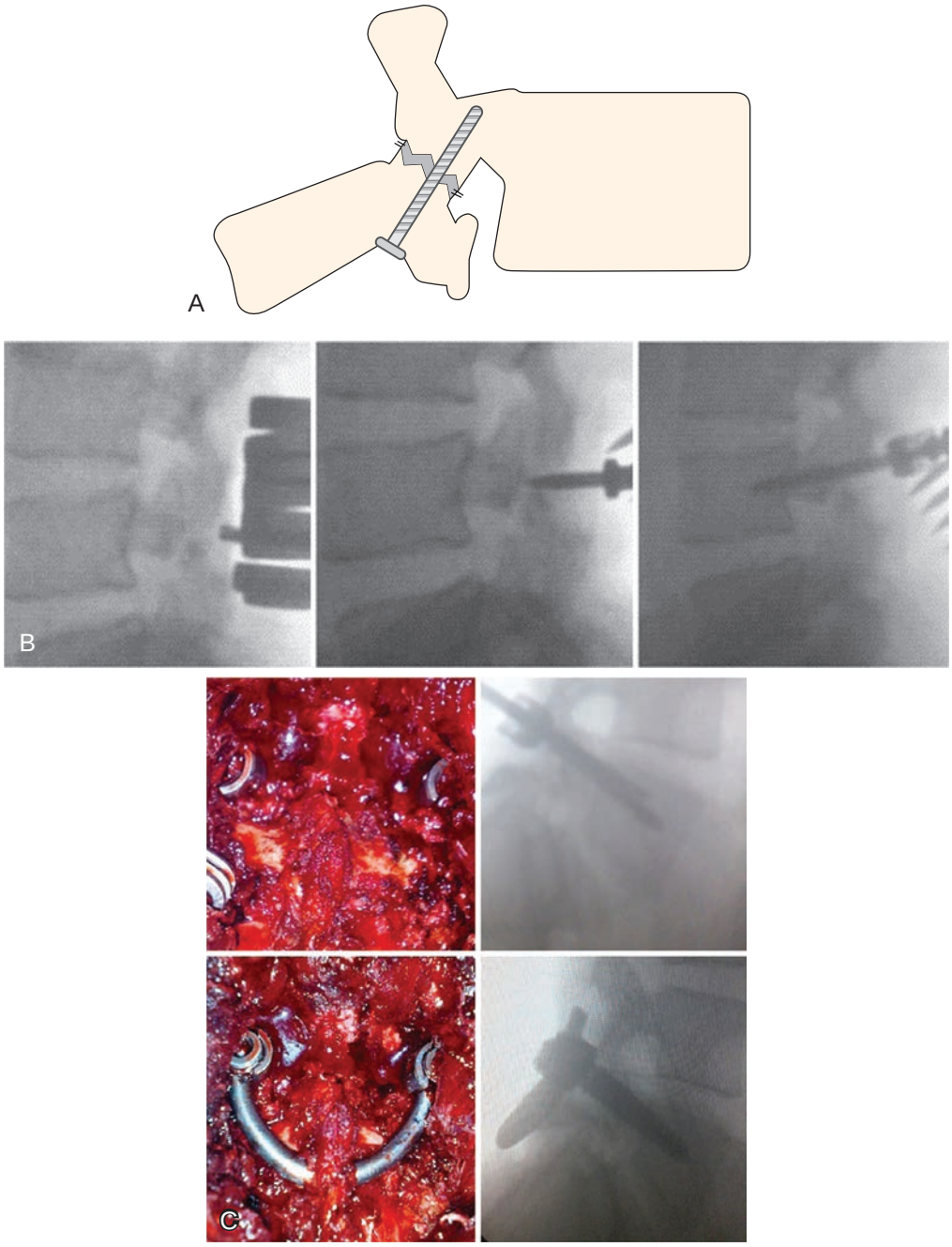

FIGURE 20-6. A, Single lag screw fixation as described by JE Buck in 1970. *(Redrawn from Drazin D, Shirzadi A, Jeswani S, et al: Direct surgical repair of spondylolysis in athletes: Indications, techniques, and outcomes. Neurosurg Focus 31(5):1-12, 2011.)* **B,** Intraoperative fluoroscopic images of the steps for a percutaneous technique of radiological guidance for screw insertion, without violating the facet joint. **C,** Intraoperative view of the construct (left) and lateral fluoroscopic images depicting screws insertion into the L4 pedicles (right).

Phase I Immediate Postoperative Period (days 0 to 7)

Goals

- Protect the surgical site to promote wound healing
- Decrease pain and inflammation
- Establish good body mechanics for safe, independent self-care and activities of daily living (ADLs) such as donning/doffing clothing, transfers, and gait.
- Educate on proper bed mobility and positioning

Protection

- Soft bracing (corset) or hard bracing (thoracolumbosacral orthosis [TLSO]) is optional per surgeon. Should never be required, but may be worn for comfort.
- Good body mechanics to promote patient comfort and proper positioning to prevent stress to the healing posterior structures (see body mechanics/positioning section below).

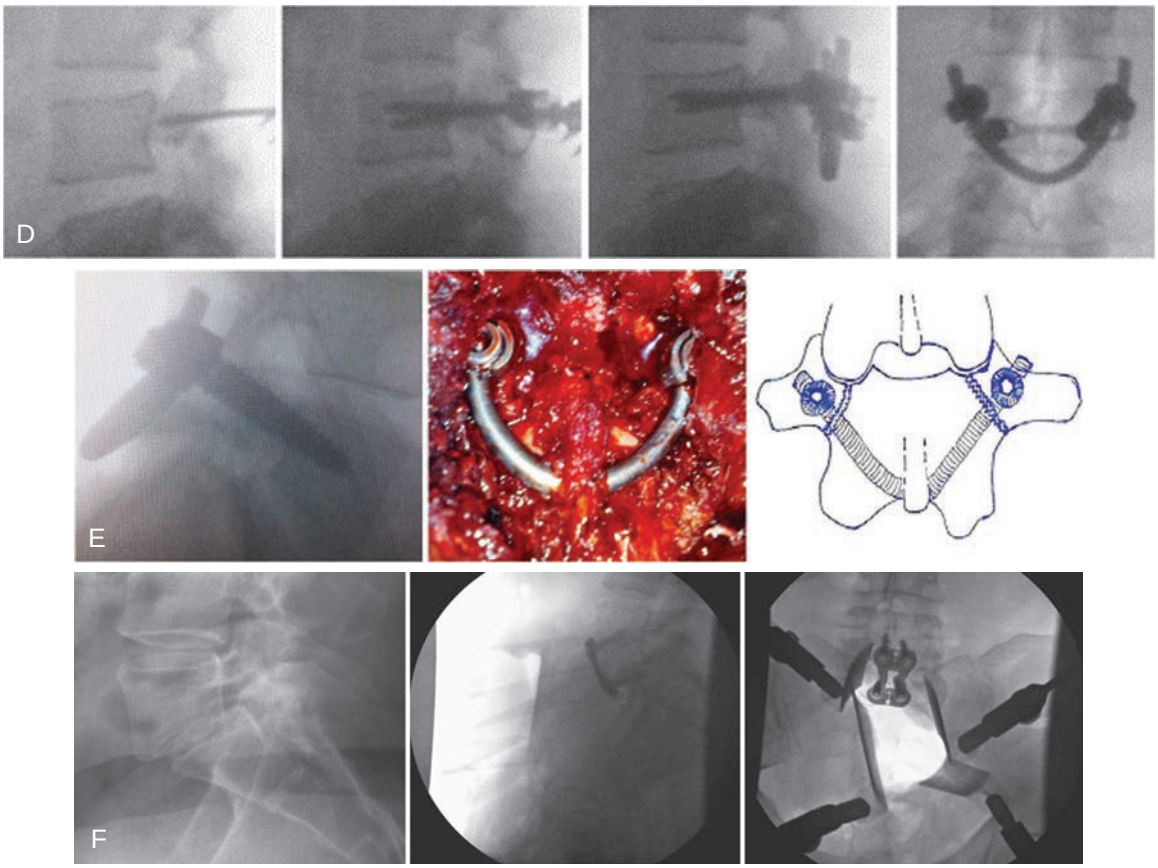

FIGURE 20-6. cont'd D, Intraoperative fluoroscopic images of the steps of the procedure (left to right), showing the defect (left) and screw insertion into the L4 pedicles with intraoperative posteroanterior view of the construct (right). **E,** Intraoperative fluoroscopic lateral image (left), operative view of the construct (center) and a graphic representation of the procedure (right). **F,** Fluoroscopic lateral image preoperative (left), lateral image intraoperative (center) and anterior image intraoperative. *(B to F from Eldin MM. Minimal: Access direct spondylolysis repair using a pedicle screw-rod system: A case series. J Med Case Rep 6:396, 2012.)*

Management of Pain and Swelling

- Oral pain medications
- Cryotherapy to decrease pain and inflammation

Proper Body Mechanics and Positioning

- Using pillows or bolsters to find a position of comfort to reduce stress on repaired structures.
- Instructions to avoid driving, prolonged sitting, lifting, bending, and twisting.
- Use lumbar roll when sitting
  - Maintain neutral posture
- Bed mobility/positioning
  - Log rolling, instruct in proper transfers
  - Pillow between knees when side lying
  - Pillow under knees when supine

Therapeutic Exercises

- Gentle nerve gliding
- Deep breathing exercises
- Ambulation progression daily as tolerated
  - Use assistive device as needed

Milestones for Progression to the Next Phase

- Assuming the athlete is progressing without complications (signs of infection, signs and symptoms of repair failure, and intractable pain limiting AROM tolerance) they are progressed to the next phase.

Phase II (weeks 1 to 6)

Goals

- Protect the surgical site to promote wound healing
- Decrease pain and inflammation
- Maintain nerve root mobility
- Establish good body mechanics for safe, independent self-care
- Educate on proper bed mobility and positioning
- Assuming the athlete is progressing without complications (signs of infection, signs and symptoms of repair failure, and intractable pain limiting AROM tolerance) they can progress to the next phase.

Protection

- Soft bracing (corset) or hard bracing (TLSO) is optional per surgeon. Should never be required, but may be worn for comfort.
- Good body mechanics to promote patient comfort and proper positioning to prevent stress to the healing posterior structures (see body mechanics/positioning section below).

Management of Pain and Swelling

- Oral pain medications is continued as needed
- Electro-therapy such as: transcutaneous electrical nerve stimulation (TENS), high voltage pulsed current (HVPC), or interferential current (IFC)
- Cryotherapy to decrease pain and inflammation

Proper Body Mechanics and Positioning

- Using pillows or bolsters to find a position of comfort to reduce stress on repaired structures
- Instructions to avoid driving, prolonged sitting, lifting, bending, and twisting
- Use lumbar roll when sitting
  - Maintain neutral posture
- Bed mobility/positioning
  - Log rolling, instruct in proper transfers
  - Pillow between knees when side lying
  - Pillow under knees when supine

Therapeutic Exercises

- Deep breathing exercises (supine/prone)
  - Crocodile breathing (Figure 20-7)
- Ambulation progression as tolerated
  - Use assistive device as needed
  - Progress to treadmill when independent
- Nerve mobilizations (Figure 20-8)
- Glute sets, quad sets, pelvic tilts, short arc quads, ankle pumps

Milestones for Progression to the Next Phase

- Assuming the athlete is progressing without complications (signs of infection, signs and symptoms of repair failure, and intractable pain limiting AROM tolerance) they are progressed to the next phase.

Phase III (weeks 6 to 11)

Goals

- Continue to protect surgical site
- Control pain and inflammation
- Improve nerve root mobility
- Improve lower extremity and thoracic mobility
- Improve core stability
- Increase walking tolerance and cardiovascular conditioning

Protection

- Continue good body mechanics to promote patient comfort and proper positioning to prevent stress to the healing structures.



FIGURE 20-7. Crocodile breathing.



FIGURE 20-8. Nerve mobilizations. **A,** Start. **B,** Finish.

TIMELINE 20-2: **Postsurgical Rehabilitation after Lumbar Spinal Fusion for Spondylolysis**

PHASE I (days 1 to 7)	PHASE II (weeks 1 to 6)	PHASE III (weeks 7 to 11)

• Bracing is optional
• Gentle nerve gliding
• Protection of incision
• Cryotherapy/oral pain meds
• Gentle nerve gliding
• Deep breathing exercises
• Ambulation daily as tolerated
• Avoid driving, prolonged sitting, lifting, bending, and twisting.
• Use lumbar roll when sitting
  • Maintain neutral posture
• Bed mobility /positioning
  • Log rolling, instruct in proper transfers
  • Pillow between knees when side lying
  • Pillow under knees when supine
	• Continue bracing if instructed
	• PT modalities (cryotherapy, e-stim)/oral meds
	• Continue proper body mechanics
	• Deep breathing exercises, crocodile breathing
	• Nerve gliding
	• Gait training
	  • Progress to treadmill when independent
	• Bed mobility, positioning
	  • Log rolling, instruct in proper transfers (bed to chair/car)
	  • Pillow between knees when side lying
	  • Pillow under knees when supine
	• Glute sets
	• Quad sets
	• Ankle pumps
	• Short arc quads
	• Pelvic tilts
	• Sit in chair for all meals
	  • Sit at 30+ minute intervals throughout the day
	  • Bending, twisting, lifting per patient tolerance
	• Posture education: use lumbar roll when sitting
	  • Maintain neutral posture
		• Continue with Phase II activities focusing on individual impairments
		• PT modalities as needed (cryotherapy, e-stim)
		• Scar mobilizations once incisions are closed
		• Lumbar spine/hip ROM
		  • Knee to chest, supine rotation, prone extension
		• Nerve mobilizations
		• Manual therapy techniques:
		  • Thoracic spine joint mobilizations
		  • Hip joint mobilizations
		• Therapeutic exercises: isometrics
		  • Glute squeezes
		  • Heel lifts
		• Lower body rolling
		• Lumbar/core stabilization exercises
		  • Dying bug (after Week 8)
		  • Quadruped diagonals
		  • Superman (after Week 8)
		  • Bridging (single/double leg)
		• Push-up progression: wall to table to chair
		• Abdominal crunches beginning at 9 weeks postop; NO sit-ups
		• Treadmill: walking progression program
		• Elliptical trainer
		• StairMaster
		• Pool therapy
		  • Hip flex/ext, int/ext rotation, and abduction/adduction
		• Lower extremity flexibility/stretches
		  • Quad stretches
		  • Glutes/hip Rotators
		  • Gastroc-soleus stretches
		  • Hip flexors stretches
		  • Hamstring stretches
		• Half-kneeling in-line posture
		• Walking progression program
		  • Treadmill
		• Elliptical trainer
		• StairMaster
		• Lower extremity balance activities
		• Wall squats with abdominal bracing
		• Forward lunges
		• May begin lifting and bending using proper biomechanics

TIMELINE 20-2 Postsurgical Rehabilitation after Lumbar Spinal Fusion for Spondylolysis (Continued)

PHASE IV (weeks 12 to 20)

- Continue appropriate previous exercises from Phase III
- Continue lumbar spine AROM
  - Quadruped heel rocking
  - Tall kneeling heel sits
  - Prone press-ups
- Continue thoracic spine joint mobilizations (P-A, transverse)
- Continue hip joint mobilizations (A-P, P-A, lateral)
  - Graded joint mobilizations progressing to include grades III to IV
- Continue scar mobilization as needed
- Foam rolling over thoracolumbar paraspinals
- PROM focusing on gentle end-range stretching.
- Thermotherapy may be used prior to stretching
- Continue lower extremity flexibility/stretches
  - Hamstrings
  - Quads
  - Glutes
  - Glutes/hip Rotators/piriformis
  - Adductors
  - Gastroc-soleus
- Nerve mobilizations as needed
- Continue lumbar/core stabilization exercises
  - Upper body rolling
  - Lower body rolling
  - Active SLR
    - Quadruped diagonals
    - Half/tall kneeling chops
    - Half/tall kneeling lifts
- Sit-up progression
- Lat pulldowns
- Seated rows
- Chest press
- Dips
- Calf raises (seated/standing)
- Progression of lower extremity strength training exercises
  - Progress to jogging/running for cardiovascular conditioning at week 12.
  - Front squats may be initiated with medicine ball hugs instead of bar.
- Cardiovascular endurance
  - Jogging to running
  - Elliptical trainer
  - StairMaster
- Neuromuscular dynamic stability exercises:
  - Lower extremity balance activities (i.e., single leg balance, BOSU ball, etc.)
  - Lower extremity single-leg balance activities are progressed
  - Progressed with decreased base of support, open chain or unstable surface
- Axial compression drills: closed chain on unstable surface (i.e., Airex pad, weighted ball, tilt boards)
- Manual perturbation to the trunk while in dynamic closed chain loaded position, such as half or tall kneeling.
- Cardiovascular endurance:
  - Treadmill jogging
  - StairMaster
  - Elliptical trainer
- Lower body strengthening
  - Closed kinetic chain exercises and open chain resistance exercises
- Functional exercises
  - Deadlifts/hip hinging progression
  - Front squats
  - Forward and side lunges
  - Step-ups
  - Pushups progression – knees to regular
- Plyometrics
  - Lower extremity plyometric drills (i.e., multidirectional lunges, side hops, etc.)
- Sport-specific exercises
  - Lower extremity sports-specific drills in a controlled environment at 12 to 16 weeks postoperatively (i.e., hopping, jumping, changes in direction/agility drills)

PHASE V (weeks 21 to 52)

- Continue appropriate previous exercises from Phase IV
- Continue to increase lumbar AROM
- Manual therapy techniques
  - Continue as above to achieve full thoracolumbar and hip mobility.
  - Joint mobilization grades III to IV as indicated.
- Soft tissue techniques
  - Scar mobilizations as necessary
- Full lumbo-pelvic-hip stretching techniques
  - Continued use of sustained end range stretching
- Progress lower extremity, gluteal and hip strength exercises.
- Multijoint movements
  - Front squats, power cleans, military press, etc.
- Continue Phase IV resistance exercises with progression
- Sensorimotor exercises (proprioception, kinesthesia)
  - Ball toss exercises in standing
  - D1/D2 movements with cables
  - Medicine ball trunk rotations
  - Rapid repositioning drills and reaction movement drills
- Open (OKC) and closed (CKC) kinetic chain exercises
- Advancing the Phase IV exercises in accordance with sport-specific demands
  - OKC: Kettle bell swings and snatches, lower and upper extremity PNF patterns OKC/CKC: Tall or half-kneeling with diagonal lift and chop resistance
  - CKC: Side planks, front planks, and weight shifts on stable and progress to unstable surfaces.
- Advance endurance sets to strength exercises (repetitions of 10-15 per set).
- Neuromuscular dynamic stability exercises:
  - Push-up progression then leads to dynamic floor pushups.
  - Resistance exercises in standing progress from double- to single-leg stance, asymmetrical resistance, and unstable surfaces as necessary
- Plyometrics
  - Begin with chest pass motions into a rebounder and progressing to single arm tosses
  - Overhead bilateral medicine ball slams and overhead medicine ball catching
  - Continue lower extremity plyometric drills (i.e., multidirectional lunges, side hops, etc.)
- Functional exercises
  - Continue deadlifts, front squats, and lunges
  - Overhead strengthening is incorporated as well as lower extremity agility drills including ladder and hurdle drills, and running progression (intervals, sprints).
  - Resistance exercises in standing progress from double-leg to single-leg stance, asymmetrical resistance, and unstable surfaces.
- Begin lower extremity agility program
- Sport-specific exercises
- Lower and upper extremity sports specific drills
  - Progression to formal strength and conditioning commences once full gross strength, AROM, and are pain-free with activity.

Management of Pain and Swelling

- Electrotherapy (TENS, HVPC, and IFC) is continued for pain and muscle guarding as needed
- Cryotherapy as needed

Proper Body Mechanics and Positioning

- May begin lifting and bending with proper body mechanics

Techniques for Progressive Increase in Range of Motion

- Lumbar spine/hip AROM
  - Knee to chest, supine rotation, prone extension

Manual Therapy Techniques

- Thoracic spine joint mobilizations
- Hip joint mobilizations

Soft Tissue Techniques

- Scar mobilization to postsurgical incisions once closed to minimize incisional adhesions.
  - Cross-friction is performed to assist with full tissue mobility in lumbar region.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Lower extremity stretches
  - Hamstrings
  - Quads
  - Glutes/hip rotators
  - Adductors
  - Gastroc-Soleus

Other Therapeutic Exercises

- Isometrics
  - Glute squeezes
  - Heel lifts
- Nerve mobilizations
- Lumbar/core stabilization exercises
  - Lower body rolling
  - Bridging (double leg/double leg with leg ext/single leg) (Figures 20-9 to 20-11)
  - Superman (after Week 8)
  - Dying bug (after Week 8)
  - Quadruped diagonals (Figure 20-12)
- Pool therapy
  - Pool-based exercises using the water for resistance may be incorporated during this phase if the incisions are well healed. Exercises should include reciprocal motions of Hip flex/ext, int/ext rotation, and abduction/adduction.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Abdominal crunches beginning 9 weeks postoperatively
- NO sit-ups

Sensorimotor Exercises

- Half-kneeling in-line balance (Figure 20-13)
- Active straight leg raise with core activation (Figure 20-14)

Techniques to Increase Cardiovascular Endurance

- Treadmill: walking progression program
- Elliptical trainer
- StairMaster

Neuromuscular Dynamic Stability Exercises

- Lower extremity balance activities (i.e. single-leg balance, BOSU ball, etc.)



FIGURE 20-10. Double-leg bridge with leg extention.



FIGURE 20-9. Double-leg bridge.



FIGURE 20-11. Single-leg bridge.

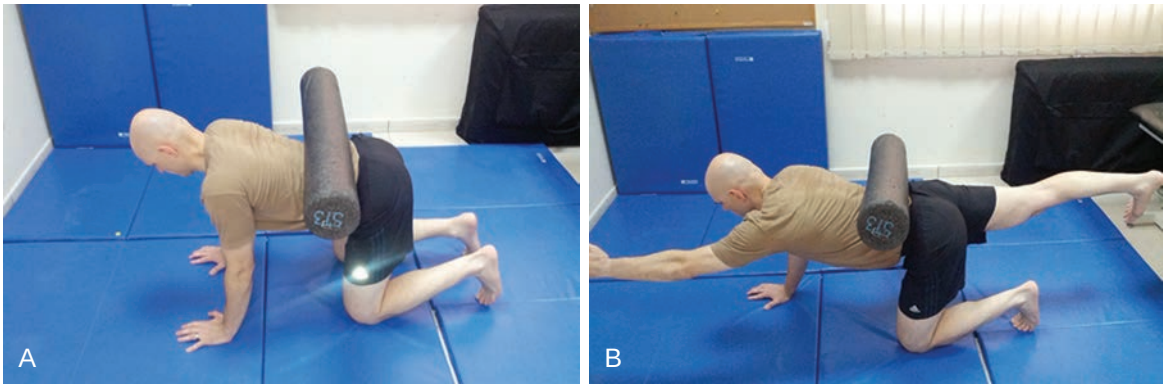

FIGURE 20-12. Quadruped diagonals. **A,** Start. **B,** Finish.



FIGURE 20-13. Half-kneeling in-line balance. *(From Rainey CE: The use of trigger point dry needling and intramuscular electrical stimulation for a patient with chronic low back pain: A case report. Int J Sports Phys Ther 8:145-161, 2013.)*



FIGURE 20-14. Straight leg raise with core activation. *(From Rainey CE: the use of trigger point dry needling and intramuscular electrical stimulation for a patient with chronic low back pain: A case report. Int J Sports Phys Ther 8:145-161, 2013.)*

Functional Exercises

- Wall squats with abdominal bracing
- Forward lunges

Phase IV (weeks 12 to 20)

Goals

- Independent with ADLs
- Increased trunk and extremity strength
- Maintenance of a neutral spine during corrective exercises
- No episodes of lumbar instability

Protection

- Continue good body mechanics to promote patient comfort and proper positioning to prevent stress to the healing structures.

Management of Pain and Swelling

- Oral NSAID therapy as needed
- IFC electrical stimulation for pain control as needed
- Cryotherapy or thermotherapy is used posttherapy to mitigate postexercise inflammation and soreness or exercise-induced inflammation.

Techniques for Progressive Increase in Range of Motion

- Continue lumbar spine AROM
  - Quadruped heel sits (Figure 20-15)
  - Tall kneeling heel sits (Figure 20-16)
  - Prone press-ups

Manual Therapy Techniques

- Continue thoracic spine joint mobilizations (P-A, transverse)
- Continue hip joint mobilizations (A-P, P-A, lateral)
  - Graded joint mobilizations progressing to include grades III to IV may be incorporated.



FIGURE 20-15. Quadruped heel sit. **A,** Start. **B,** Finish.

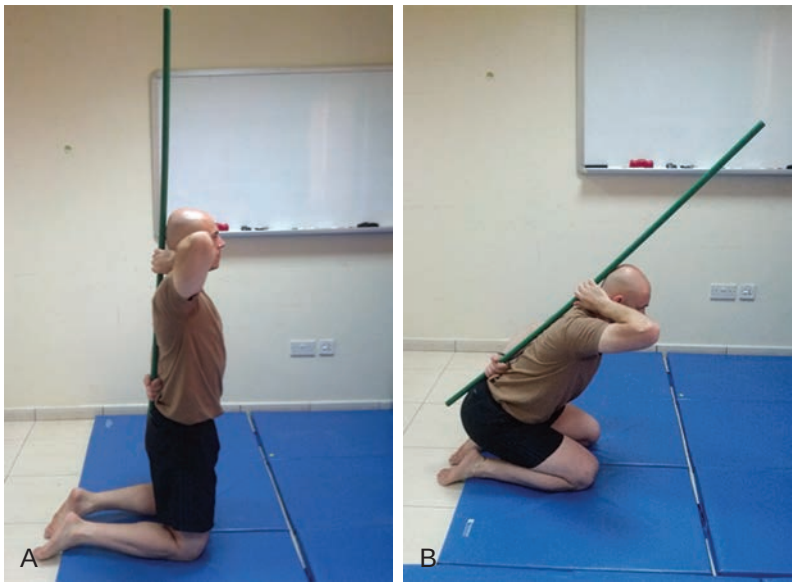

FIGURE 20-16. Tall kneeling heel sit. (**A**) Start. (**B**) Finish.

Soft Tissue Techniques

- Continue scar mobilization as needed
- Foam rolling over thoracolumbar paraspinals (Figure 20-17)

Stretching/Flexibility Techniques for the Musculotendinous Unit

- Passive range of motion (PROM) focusing on gentle end-range stretching.
- Thermotherapy may be used prior to stretching and tissue flexibility to facilitate muscle relaxation
- Continue lower extremity stretches
  - Hamstrings
  - Quads
  - Glutes/hip rotators/piriformis
  - Adductors
  - Gastroc-soleus



FIGURE 20-17. Foam rolling over paraspinals.



FIGURE 20-18. Half-kneeling chop. **A,** Start. **B,** Finish.



FIGURE 20-19. Half-kneeling lift. **A,** Start. **B,** Finish.

Therapeutic Exercises

- Nerve mobilizations as needed
- Continue lumbar/core stabilization exercises
  - Upper body rolling
  - Lower body rolling
  - Quadruped diagonals
  - Half/tall kneeling chops (Figure 20-18)
  - Half/tall kneeling lifts (Figure 20-19)

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Spinal flexion progression

Techniques to Increase Muscle Strength, Power, and Endurance

- Lat pulldowns
- Seated rows
- Chest press
- Dips
- Calf raises (seated/standing)
- Progression of lower extremity strength training exercises
- Progress to jogging/running for cardiovascular conditioning at week 12
- Front squats may be initiated with medicine ball hugs instead of bar

Techniques to Increase Cardiovascular Endurance

- Jogging to running
- Elliptical trainer
- StairMaster

Neuromuscular Dynamic Stability Exercises

- Lower extremity balance activities (i.e., single leg balance, BOSU ball, etc.).
  - Lower extremity single-leg balance activities are progressed.
  - Deadlift repatterning to single-leg deadlifts with neutral spine (Figure 20-20).
- Positions progressed with decreased base of support, open chain or unstable surface.
- Axial compression drills: closed chain on unstable surface (i.e. Airex pad, weighted ball, tilt boards).
- Manual perturbation to the trunk while in dynamic closed chain loaded position, such as half or tall kneeling.

Other Therapeutic Exercises

- Cardiovascular: treadmill jogging, StairMaster, and elliptical trainer with increased resistance.
- Lower body strengthening is progressed and may include closed kinetic chain exercises and open chain resistance exercises.

Functional Exercises

- Deadlifts/hip hinging progression (Figure 20-21)
- Front squats

- Forward and side lunges
- Step-ups
- Pushups
  - Closed-chain activities progress to include a pushup progression beginning with wall pushups, advancing to table height pushups and pushups on knees, to finally floor pushups.

Plyometrics

- Lower extremity plyometric drills (i.e., multidirectional lunges, side hops, etc.).

Sport-Specific Exercises

- Lower extremity sports-specific drills in a supervised/controlled environment at 12 to 16 weeks postoperatively (i.e., hopping, jumping, changes in direction/agility drills).

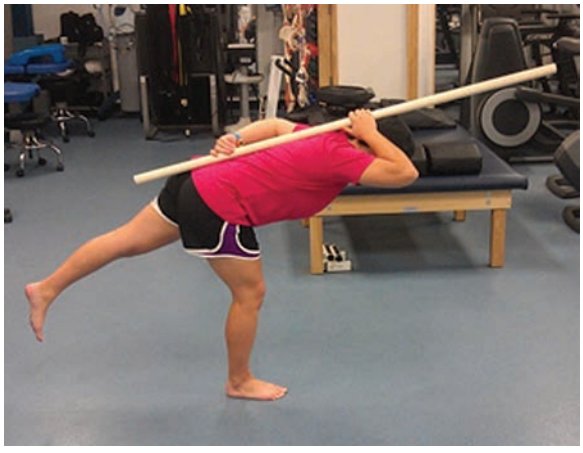

FIGURE 20-20. Single-leg deadlift with neutral spine. *(From Rainey CE: The use of trigger point dry needling and intramuscular electrical stimulation for a patient with chronic low back pain: A case report. Int J Sports Phys Ther 8:145-161, 2013.)*

Outcome Measures

- Patient reported outcome measures can be implemented at 12 weeks and administered at month 3, 6, 9, and 12. Outcome measures that have been used in the literature for lumbar spinal fusion include Oswestry Disability Index (ODI).

Phase V (weeks 21 to 52)

Goals

- Return to sport activities
- Improve trunk and extremity strength
- Improve muscular endurance
- Thoracic spine and hip full PROM

Management of Pain and Swelling

- Oral NSAIDs as needed.
- IFC electrical stimulation for pain control as needed.
- Cryotherapy or thermotherapy is used posttherapy to mitigate postexercise inflammation and soreness or exercise-induced inflammation.

Techniques for Progressive Increase in Lumbar Range of Motion

Manual Therapy Techniques

- Continue as above to achieve full thoracolumbar and hip mobility.
- Joint mobilization grades III to IV as indicated (use caution on surgical site).

Soft Tissue Techniques

- Scar mobilizations as necessary.

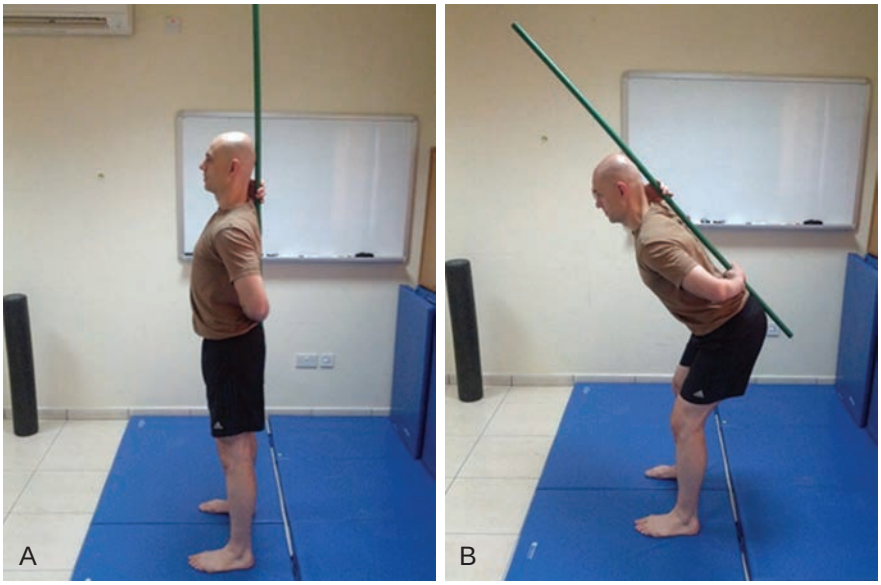

FIGURE 20-21. Deadlift. **A,** Start. **B,** Finish.

Stretching/Flexibility Techniques for the Musculotendinous Unit

- Athletes are instructed in full lumbo-pelvic-hip stretching techniques.
- Continued use of sustained end range stretching to achieve desired symmetrical or required mobility.
- Preperformance/exercise stretching should focus on functional movement patterns, then prepare the athlete for return to sport activity.

Other Therapeutic Exercises

- Progress lower extremity, gluteal, and hip strength exercises.
- Integrated training activities at this stage should include multijoint movements (i.e., front squats, power cleans, military press, etc.)

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Previous exercises with progressive resistance.
- Focus in the late stage of recovery is on establishing preinjury levels of function.

Sensorimotor Exercises

- Ball toss exercises in standing
- D1/D2 movements with cables
- Medicine ball trunk rotations
- Rapid repositioning drills and reaction movement drills

Open and Closed Kinetic Chain Exercises

- Advancing the previous exercises in accordance with sport-specific demands
- OKC: Kettle bell swings and snatches, lower and upper extremity PNF patterns (Figure 20-22)
- OKC/CKC: Tall or half-kneeling with diagonal lift and chop resistance exercises
- CKC: Side planks, front planks, and weight shifts on stable and progress to unstable surfaces.
  - BOSU ball can be used for progression of pushups to uneven surfaces for CKC activities.

Techniques to Increase Muscle Strength, Power, and Endurance

- Advance endurance sets to strength exercises (repetitions of 10 to 15 per set).
- Implement an undulating periodization model for strength training

Neuromuscular Dynamic Stability Exercises

- Pushup progression then leads to dynamic floor pushups.
- Resistance exercises in standing progress from double- to single-leg stance, asymmetrical resistance, and unstable surfaces as necessary to replicate anticipated performance demands.

Plyometrics

- Plyometrics are initiated with chest pass motions into a rebounder and progressing to single arm tosses.
- Overhead bilateral medicine ball slams and overhead medicine ball catching.
- Continue lower extremity plyometric drills (i.e., multidirectional lunges, side hops, etc.).
- Advanced to increasing level of difficulty.

Functional Exercises

- Continue deadlifts, front squats, and lunges.
- Overhead strengthening is incorporated as well as lower extremity agility drills including ladder and hurdle drills as well as running progression (intervals, sprints).
- Resistance exercises in standing progress from double-leg to single-leg stance, asymmetrical resistance and unstable surfaces.
- Begin lower extremity agility program.

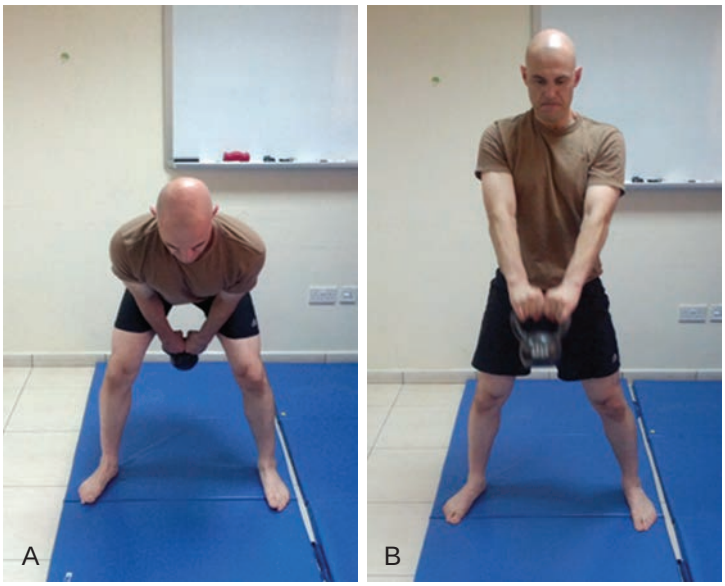

FIGURE 20-22. Kettlebell swings. **A,** Start. **B,** Finish.

Sport-Specific Exercises

- Lower and upper extremity sport-specific drills
- Progression to formal strength and conditioning commences once athletes have full gross strength, AROM and are pain-free with activity.

Outcome Measures

- Patient reported outcome measures (see Phase IV).

Milestones/Criterion-Based Rehabilitation Guidelines for Progression to the Next Stage

- CKC testing may include the CKC upper and lower extremity Y-balance test
- Power tests may include the vertical jump, standing backward overhead medicine ball throw, and standing rotational medicine ball throw. Preinjury test values would provide the best measure of functional recovery as sport/position-specific normative data is limited.

Criteria for Return to Sport

General

- Normal lumbar-pelvic-hip body mechanics.
- Full thoracic and hip mobility without instability.
- CKC testing and integrated functional movement tests with good quality of motion, maintenance of core stability throughout the tests with no report of lumbar pain or instability.

Sport-Specific

- Implementation of return to sport criteria must include a demand/needs analysis of the chosen sport. The rehabilitation specialist should be able to analyze the demands on the lumbar-pelvic-hip complex and create a sufficient series of tests and exercises to ensure readiness for return to preinjury levels of activity.

After Return to Sport

Continuing Fitness or Rehabilitation Exercises

- Total body strengthening exercises.

Exercises and Other Techniques for Prevention of Recurrent Injury

- Prevention of recurrence requires continued maintenance of dynamic neuromuscular control (strength, mobility, kinesthetic awareness, and proprioception). Degradation in any of these areas could put the athlete at risk for reinjury if they continue to place a high degree of physical demands on the hardware.
- While sport-specific training is essential to ensure readiness for return to sport, a training program that does not include reactive drills and a diversity of training modalities can result inability to adapt to the ever-changing demands of athletic competition.

Evidence

Drazin D, Shirzadi A, Jeswani S, et al: Direct surgical repair of spondylolysis in athletes: Indications, techniques, and outcomes. *Neurosurg Focus* 31:1–12, 2011.

This article reviews the surgical techniques of spondylolysis repairs in athletes. The authors' literature search found that the single lag screw fixation (Buck) outcomes for athletes was a >90% return to preoperative sports performance. (Level V evidence).

Micheli LJ, Wood R: Back pain in young athletes: Significant differences from adults in causes and patterns. *Arch Pediatr Adolesc Med* 149:15–18, 1995.

This article reviews the back pain in young athletes and the differences from adults in causes and patterns. The authors found that spondylolysis and spondylolisthesis are responsible for up to 47% of low back pain in adolescent athletes. (Level V evidence).

Radcliff KE, Kalantar SB, Reitman CA: Surgical management of spondylolysis and spondylolisthesis in athletes: Indications and return to play. *Curr Sports Med Rep* 8:35–40, 2009.

This article reviews the surgical indications of a spondylolysis and spondylolisthesis and the return to play in athletes. (Level V Evidence).

Rubery PT, Bradford DS: Athletic activity after spine surgery in children and adolescents: Results of a survey. *Spine (Phila Pa 1976)* 27:423–427, 2002.

The article reviewed 721 members of the Scoliosis Research Society via survey regarding their opinions and experience with athletic activity after spine surgery performed on children and adolescents. The article showed varying approaches to postoperative athletic activity. (Level V evidence).

Soler T, Calderon C: The prevalence of spondylolysis in the Spanish elite athlete. *Am J Sports Med* 28:57–62, 2000.

This article reviewed 3152 case histories of high-level athletes to determine which sports had a higher prevalence of spondylolysis. The article recommends systematic radiological examination of the lumbar spine in athletes considered to be at greater risk of developing spondylolysis. (Level V evidence).

Multiple-Choice Questions

QUESTION 1. In a symptomatic athlete, the diagnosis of spondylolysis (pars defect) as the etiology for lumbosacral pain is best confirmed with:

A. Computed tomography (CT)
B. Oblique lumbar radiographs
C. Magnetic resonance imaging (MRI)
D. Single-photon-emission computed tomography (SPECT)

QUESTION 2. The pathophysiology of spondylolysis is thought to be caused by:

A. Repetitive truncal twisting while loaded
B. Forceful hyperflexion with resistance
C. Multiple factors including repetitive lateral bending
D. Regular mechanical flexion, extension, and trunk rotation

QUESTION 3. The patient outcome results of pars fractures that have formed fibrous union vice nonunion are inferior to those that have healed with bony union.

A. False
B. True

QUESTION 4. Sport-specific exercises and drills are introduced:

A. At 5 to 6 weeks following surgery if the incision is well healing and without signs or symptoms of infection.
B. When the patient is able to effectively demonstrate grades III and IV mobilization.
C. Postoperatively in order to enhance osseous blood influx thereby facilitating more rapid bone healing rates.
D. In a supervised/controlled environment at 3 to 4 months following surgical management.

QUESTION 5. When considering surgical management of a pars interarticularis fracture that has progressed from spondylolysis to spondylolisthesis, current evidence shows:

A. That a properly performed Gill procedure to decompress the neural elements results in the most rapid return to unrestricted sport.
B. That even with radiculopathy, instrumented arthrodesis alone without decompression, will result in an acceptable outcome and resolve symptoms.
C. Improved outcomes with reduction of high grade slippage (Myerding grade III or higher) compared with in-situ arthrodesis.
D. Less intraoperative blood loss and more rapid return to unrestricted sport with percutaneous (minimally invasive instrumented) lumbar fusion surgical techniques.

Answer Key

QUESTION 1. Correct answer: **D** (see Indications for Surgical Treatment)

QUESTION 2. Correct answer: **D** (see Brief Summary of Surgical Treatment: Postsurgical)

QUESTION 3. Correct answer: **A** (see Brief Summary of Surgical Treatment: Postsurgical)

QUESTION 4. Correct answer: **D** (see Phase IV: Sport-Specific)

QUESTION 5. Correct answer: **B** (see Brief Summary of Surgical Treatment: Surgical)

BEYOND BASIC REHABILITATION: RETURN TO GYMNASTICS AFTER OPERATIVE REPAIR OF SPONDYLOLYSIS

Charles E. Rainey, PT, DSc, DPT, OCS, SCS, CSCS, FAAOMPT, Stewart M. Kerr, MD, Gregg Ziemke, PT, MS, MHA, OCS, and Leslie C. Hair, PT, DSc, OCS, FAAOMPT

Introduction

ASPECTS OF GYMNASTICS THAT REQUIRE SPECIAL ATTENTION IN REHABILITATION

- Range of motion/flexibility
- Lumbar/core stability
- Hyperextension movements
- Activities that require heavy spinal loads
- Spondylolysis and spondylolisthesis are responsible for up to 47% of low back pain in adolescent athletes.[1]
- Athletes who participate in sports that involve repetitive lumbar hyperextension, such as gymnastics, are at higher risk of developing these conditions (Figure 20-23*A* to *D*).[2]
- Soler and Calderon reviewed 3152 elite athletes and reported spondylolysis in 27% of throwing athletes, 17% of gymnasts, and 17% of rowers.[3]
- After a surgical repair of spondylolysis, rehabilitation is needed for return to function and sport. Rehabilitation for the athlete should begin quickly after surgery and consist of educating the patient regarding the proper way to transfer in/out of bed and to get dressed, ambulation and nerve mobilizations, and progression to core strengthening and low-impact cardiovascular activity at 2 weeks postoperatively.

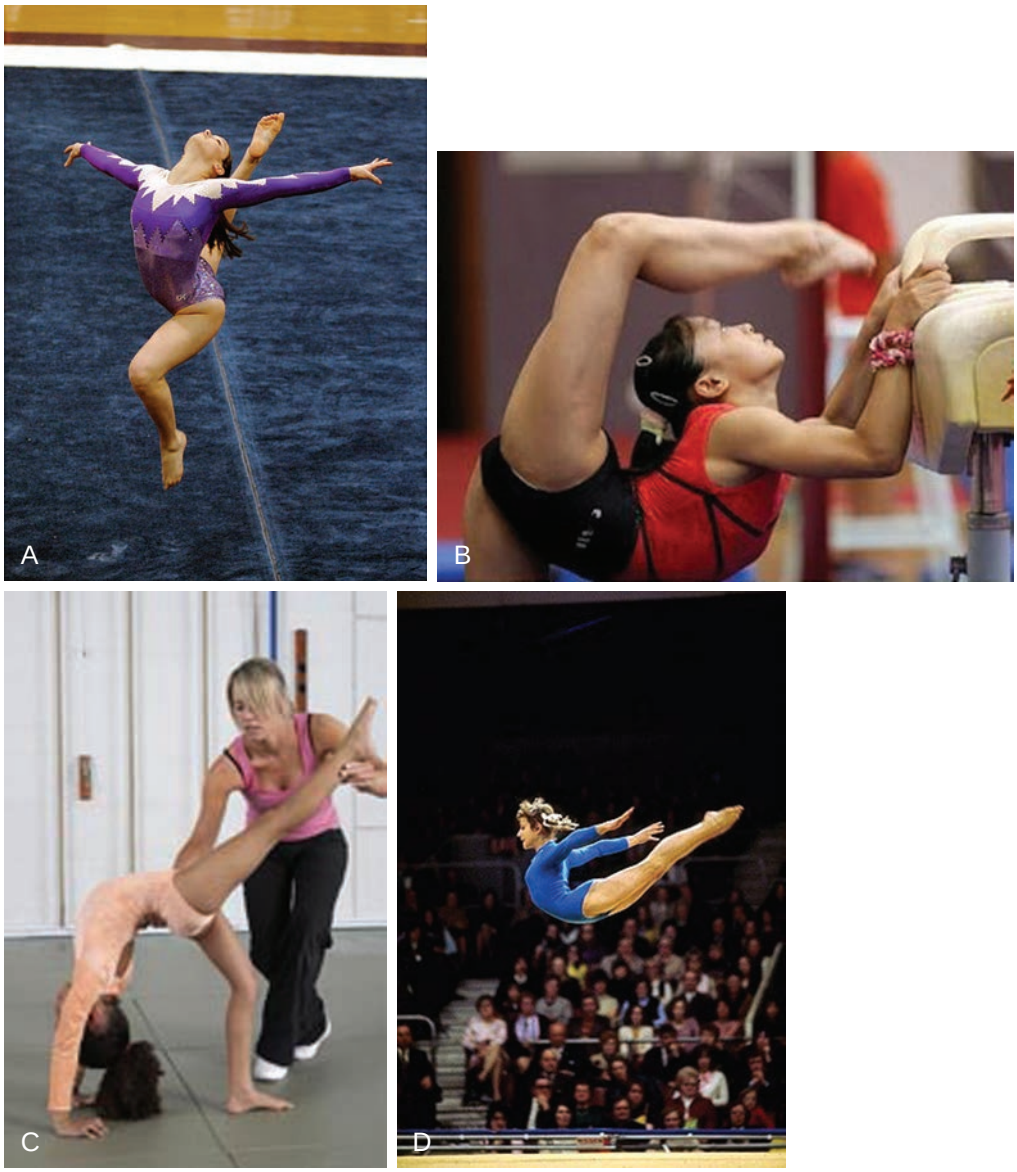

FIGURE 20-23A TO D. Gymnasts performing higher risk hyperextension movements/activities.

Literature

- There is no information on return to play (RTP) criteria after direct pars repair. Published recommendations for return to noncontact sports after fusion for spondylolisthesis are controversial.[4]
- Rubery and Bradford conducted a survey of 261 members of the Scoliosis Research Society who commonly treat spondylolisthesis.[5] They found that 62% to 66% of surgeons allowed return to low-impact, noncontact sports by 6 months postoperatively for both low-grade and high-grade slips.[5]
- Eck and Riley disagree and suggest delaying return to noncontact sports for 1 year.[6]
- The most common sports that surgeons forbade patients to resume after spondylolisthesis fusion were gymnastics, football, rugby, wrestling, weightlifting, skydiving, and bungee jumping.[5]
- Although some authors do not restrict return to contact sports after fusion for spondylolisthesis, they advise that athletes participating in activities that require extreme mobility or involve heavy loads may be limited after surgery.[4]
- Herman et al. allow unrestricted RTP in athletes who are asymptomatic, have achieved stable fusion, and are fully rehabilitated to their previous playing capacity.[7] This typically occurs within 1 year after surgery. The authors believe that a single-level lumbosacral fusion has minimal impact on spine function, whereas a multilevel fusion may impair mobility and performance.[7]
- Radcliff et al. caution that fusion may be a career-ending surgery for activities that require extreme lumbar hyperextension, such as gymnastics and dance. It was stated that athletes participating in sports that involve heavy loads may be reduced from highly competitive to recreational.[8]

Phase I: Advanced Strength and Conditioning Programs (weeks 1 to 4)

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- Training continuum
- Flexibility/joint mobility
- Core stability/strengthening
- Low-impact cardiovascular training
- Training for optimum muscle balance
- Training for optimum muscle functional strength

Training Principles Used in the Design of the Program

- Principle of progression
- Principle of overload
- Principle of individualization

Application of Acute Training Variables

- Repetitions and sets may vary depending on where the patient is on the training continuum. Athletes should begin with spinal rehabilitation slowly, focusing on flexibility/range of motion and basic static stability exercises.
- Advance to dynamic stability exercises in a progressive manner, avoiding any pain during motor control activities. If pain occurs, exercises should be decreased to a less advanced stage of the rehabilitation program.
- The quality of exercises is far more important than the quantity.
- Rest periods should be at least 1 minute but can be as long as required to promote the highest exercise quality. This allows the muscle to have full recovery between sets and reinforces motor learning.
- Strengthening exercise sessions should be separated by at least one full day to allow the muscle to fully heal from any breakdown caused by training. This allows the muscle to fully recover between sets.
- Repetitions: 6 to 10
- Sets: 3 to 5
- Rest interval: 1 minute
- Intensity: submaximal (<50% one repetition maximum [1RM])
- Training frequency: 2 to 4 days per week (allow 2 to 4 days recovery)
- Training duration: 30 to 60 minutes
- Training volume: total number of repetitions completed in training session will vary
- Specific exercises used in the training:
  - Lower body rolling
  - Lumbar/core stabilization exercises
    - Dying bug
    - Quadruped diagonals (see Figure 20-7)
    - Superman
    - Bridging (double/single leg) (see Figures 20-4 to 20-6)
  - Pushup progression
  - Abdominal crunches
  - Cardiovascular endurance
    - Treadmill
    - Elliptical trainer
    - StairMaster
  - Lower extremity flexibility/stretches
    - Quad stretches
    - Glutes/hip rotators
    - Gastroc-soleus stretches
    - Hip flexors stretches
    - Hamstring stretches
  - Half-kneeling in-line balance (see Figure 20-8)
  - Lower extremity balance activities
  - Wall squats with abdominal bracing
  - Forward lunges

Phase II: Performance Enhancement Training Techniques (weeks 5 to 12)

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- Multiplanar training activities
- Training for optimum functional movement
- Neuromuscular dynamic stability exercises
- Functional training

Training Principles Used in the Design of the Program

- Principle of progression
- Principle of overload
- Principle of variation
- Principle of individualization
- Principles of specificity: specific adaptation to imposed demands (SAID)

Application of Acute Training Variables

- Repetitions and sets for Phase II will again vary depending on the activity.
- For strengthening activities, 3 sets of 10 to 15 repetitions with increased intensity will work to progress to full strength.
- Intensity should still be kept to submaximal but progress as patients tolerates working towards full strength by the start of Phase III.
- Avoiding consecutive days of training will allow adequate amounts of rest, which is important to decrease the chance of re-rupture.
- Duration should last from 30 to 60 minutes, depending on endurance level of the athlete.
- Repetitions: varies depending on activity
- Sets: 3 to 5
- Rest interval: At least 1 minute between sets
- Intensity: moderate to high
- Training frequency: 1 to 3 times per week (no consecutive days)
- Training duration: 30 to 60 minutes
- Specific exercises used in the training:
  - Continue appropriate previous exercises from Phase I

TIMELINE 20-3: **Return to Gymnastics After Lumbar Fusion**

PHASE I (weeks 1 to 4)

- Lower body rolling
- Lumbar/core stabilization exercises
  - Dying bug
  - Quadruped diagonals
  - Superman
  - Bridging (single/double leg)
- Pushup progression
- Abdominal crunches
- Cardiovascular endurance
  - Treadmill
  - Elliptical trainer
  - StairMaster
- Lower extremity flexibility/stretches
  - Quad stretches
  - Glutes/hip rotators
  - Gastroc-soleus stretches
  - Hip flexors stretches
  - Hamstring stretches
- Half-kneeling in-line posture
- Lower extremity balance activities
- Wall squats with abdominal bracing
- Forward lunges

PHASE II (weeks 5 to 12)

- Continue appropriate previous exercises from Phase I
- Continue lower extremity flexibility/stretches
  - Hamstrings
  - Quads
  - Glutes
  - Glutes/hip rotators/piriformis
  - Adductors
  - Gastroc-soleus
- Continue lumbar/core stabilization exercises
  - Upper body rolling
  - Lower body rolling
  - Active SLR
  - Quadruped diagonals
  - Half/tall kneeling chops
  - Half/tall kneeling lifts
- Sit-up progression
- Lat pulldowns
- Seated rows
- Chest press
- Dips
- Calf raises (seated/standing)
- Progression of lower extremity strength training exercises
  - Front squats with bar or medicine ball hugs
- Cardiovascular endurance
  - Jogging to running
  - Elliptical trainer
  - StairMaster
- Neuromuscular dynamic stability exercises
  - Lower extremity balance activities (single-leg balance, BOSU ball, etc.)
  - Axial compression drills: closed chain on unstable surface (Airex pad, weighted ball, tilt boards)
  - Manual perturbation to the trunk while in dynamic closed chain loaded position
  - Half/tall kneeling
- Lower body strengthening
  - Closed kinetic chain exercises and open chain resistance exercises
- Functional exercises
  - Deadlifts/hip hinging progression
  - Front squats
  - Forward and side lunges
  - Step-ups
  - Pushup progression: knees to regular
- Plyometrics
  - Lower extremity plyometric drills (multidirectional lunges, side hops, etc.)
- Sport-specific exercises
  - Lower extremity sport-specific drills in a controlled environment (hopping, jumping, changes in direction/agility drills)

PHASE III (weeks 13 to 24)

- Continue appropriate previous exercises from Phase II
- Full lumbo-pelvic-hip stretching techniques
  - Continued use of sustained end range stretching
- Progress lower extremity, gluteal, and hip strength exercises.
- Multijoint movements
  - Front squats, power cleans, military press, etc.
- Continue Phase II resistance exercises with progression
- Sensorimotor exercises (proprioception, kinesthesia)
  - Ball toss exercises in standing
  - D1/D2 movements with cables
  - Medicine ball trunk rotations
  - Rapid repositioning drills and reaction movement drills
- Open (OKC) and closed (CKC) kinetic chain exercises
- Advancing the Phase II exercises in accordance with sport-specific demands
  - OKC: Kettle bell swings and snatches, lower and upper extremity PNF patterns
  - OKC/CKC: Half/tall kneeling with diagonal lift and chop resistance exercises
  - CKC: Side planks, front planks, and weight shifts on stable and progress to unstable surfaces.
- Advance endurance sets to strength exercises (repetitions of 10 to 15 per set)
- Neuromuscular dynamic stability exercises:
  - Pushup progression then leads to dynamic floor pushups
  - Resistance exercises in standing progress from double to single leg stance, asymmetrical resistance, and unstable surfaces as necessary
  - Kettle bell Turkish get-ups
- Plyometrics
  - Begin with chest pass motions into a rebounder and progressing to single arm tosses
  - Overhead bilateral medicine ball slams and overhead medicine ball catching
  - Continue lower extremity plyometric drills (i.e., multidirectional lunges, side hops, etc.)
- Functional exercises
  - Continue deadlifts, front squats, and lunges
  - Kettle bell swings
  - Overhead strengthening is incorporated as well as lower extremity agility drills including ladder and hurdle drills and running progression (intervals, sprints)
  - Resistance exercises in standing progress from double-leg to single-leg stance, asymmetrical resistance, and unstable surfaces
  - Begin lower extremity agility program
- Sport-specific exercises
- Lower and upper extremity sport-specific drills
  - Progression to formal strength and conditioning commences once full gross strength, AROM, and are pain-free with activity.

- Continue lower extremity flexibility/stretches
  - Hamstrings
  - Quads
  - Glutes
  - Glutes/hip rotators/piriformis
  - Adductors
  - Gastroc-soleus
- Continue lumbar/core stabilization exercises
  - Upper body rolling
  - Lower body rolling
  - Active straight leg raise with core activation (see Figure 20-10)
  - Quadruped diagonals
  - Half/tall kneeling chops (see Figure 20-13)
  - Half/tall kneeling lifts (see Figure 20-14)
- Sit-up progression
- Lat pulldowns
- Seated rows
- Chest press
- Dips
- Calf raises (seated/standing)
- Progression of lower extremity strength training exercises
  - Front squats with bar or medicine ball hugs
- Cardiovascular endurance
  - Jogging to running
  - Elliptical trainer
  - StairMaster
- Neuromuscular dynamic stability exercises
  - Lower extremity balance activities (i.e., single-leg balance, BOSU ball, etc.)
  - Deadlift repatterning to single-leg deadlifts with neutral spine (see Figure 20-24)
  - Lower extremity single-leg balance activities are progressed.
  - Progressed with decreased base of support, open chain, or unstable surface.
- Axial compression drills: closed chain on unstable surface (i.e., Airex pad, weighted ball, tilt boards)
- Manual perturbation to the trunk while in dynamic closed chain loaded position
  - Half or tall kneeling



FIGURE 20-24. Single-leg deadlift with neutral spine. *(From Rainey CE: The use of trigger point dry needling and intramuscular electrical stimulation for a patient with chronic low back pain: A case report. Int J Sports Phys Ther 8:145–161, 2013.)*

- Lower body strengthening
  - Closed kinetic chain exercises and open chain resistance exercises
- Functional exercises
  - Deadlifts/hip hinging progression (see Figure 20-16)
  - Front squats
  - Forward and side lunges
  - Step-ups
  - Push-ups progression: knees to regular
- Plyometrics
  - Lower extremity plyometric drills (i.e., multidirectional lunges, side hops, etc.)
- Sport-specific exercises
  - Lower extremity sport-specific drills in a controlled environment (i.e., hopping, jumping, changes in direction/agility drills)

Phase III: Sport-Specific Training (weeks 13 to 24)

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- Low-impact plyometric training
- Functional training
- Sport-specific training

Training Principles Used in the Design of the Program

- Principle of progression
- Principle of overload
- Principle of variation
- Principle of individualization
- Principles of specificity; specific adaptation to imposed demands (SAID)

Application of Acute Training Variables

- The intensity for plyometrics varies depending on the activity and should start from relatively easy exercises, such as skipping, and progress to more difficult or higher intensity exercises like depth jumps.
- The frequency of plyometric training should range from 1 to 3 sessions per week allowing 48 to 72 hours of recovery between sessions.
- Rest between sets is generally 2 to 3 minutes allowing a work-to-rest ratio of 1:5 to 1:10.
- Training volume is determined by how many times the athlete's foot contacts the floor and should range between 100 to 140 contacts depending on the individual.
- Repetitions: varies depending on activity.
- Plyometrics: 100 to 140 contacts per session.
- Sets: 3 to 5
- Rest interval: work-to-rest ratio of 1:5 to 1:10 (2 to 4 minutes)
- Intensity: moderate to high
- Training frequency: 1 to 3 times per week (no consecutive days)

- Training duration: 30 to 60 minutes
- Specific exercises used in training:
  - Continue appropriate previous exercises from Phase II
  - Full lumbo-pelvic-hip stretching techniques
    - Continued use of sustained end range stretching
  - Progress lower extremity, gluteal, and hip strength exercises.
  - Multijoint movements
    - Front squats, power cleans, military press, etc.
  - Continue Phase II resistance exercises with progression
  - Sensorimotor exercises (proprioception, kinesthesia)
    - Ball toss exercises in standing
    - D1/D2 movements with cables
    - Medicine ball trunk rotations
    - Rapid repositioning drills and reaction movement drills
  - Open (OKC) and closed (CKC) kinetic chain exercises
  - Advancing the Phase II exercises in accordance with sport-specific demands
    - OKC: Kettle bell swings and snatches, lower and upper extremity proprioceptive neuromuscular facilitation (PNF) patterns
    - OKC/CKC: Tall or half-kneeling with diagonal lift and chop resistance exercises
    - CKC: Side planks, front planks, and weight shifts on stable and progress to unstable surfaces.
  - Advance endurance sets to strength exercises
  - Neuromuscular dynamic stability exercises
    - Pushup progression then leads to dynamic floor pushups
    - Resistance exercises in standing progress from double- to single-leg stance, asymmetrical resistance, and unstable surfaces as necessary
    - Kettle bell Turkish get-ups (Figure 20-25)
  - Plyometrics
    - Begin with chest pass motions into a rebounder and progressing to single arm tosses
    - Overhead bilateral medicine ball slams and overhead medicine ball catching
    - Continue lower extremity plyometric drills (i.e., multidirectional lunges, side hops, etc.)
  - Functional exercises
    - Continue deadlifts, front squats, and lunges
    - Kettle bell swings (see Figure 20-22)
    - Overhead strengthening is incorporated as well as lower extremity agility drills including ladder and hurdle drills and running progression (intervals, sprints).
    - Resistance exercises in standing progress from double-leg to single-leg stance, asymmetrical resistance and unstable surfaces
    - Begin lower extremity agility program
    - Sport-specific exercises
    - Lower and upper extremity sports specific drills
  - Progression to formal strength and conditioning commences once full gross strength, AROM, and are pain-free with activity.

Sports Performance Testing

General Information

- General patient history
- Subjective questionnaires: VAS, ODI, SF-36
- Medical history
- Sports injury history
- Surgical history
- Chronic conditions/medication

Objective Tests

- Movement performance screening: Functional Movement Screen (FMS). Studies have shown that FMS reliably predicts injury risk in many active populations/sports, including volleyball, soccer, basketball, football, and military.[9–11]
- Dynamic movement testing: upper/lower body Y Balance Test[12–13]

Specific Criteria for Progression to the Next Stage to Determine Readiness for Gymnastics

- The Functional Movement Screen and Y Balance Test can be used to determine the risk of injury and movement asymmetries when considering an athlete's return to sport.[9–13]
- Progress to advance stages per patient pain tolerance.
- Li and Hresko state athletes may return to sport when they demonstrate normal strength, normal ROM, and no pain with sport-specific activity.[3]

Specific Criteria for Release to Unsupervised Complete Participation in Gymnastics

- Complete resolution of symptoms and maintenance of all objective testing (normal strength, ROM, movement assessment, injury risk appraisal, etc.) used to determine readiness for gymnastics.

Recommended Ongoing Exercises

- Lumbar/core stabilization exercises, along with thoracic spine and hip mobility activities, are essential to be maintained and continued indefinitely while the athlete is participating in the sport.



FIGURE 20-25. Turkish get-up. **A,** Phase 1. **B,** Phase 2. **C,** Phase 3. **D,** Phase 4. **E,** Phase 5. **F,** Phase 6. **G,** Phase 7.

Evidence

Eck JC, Riley LH, III: Return to play after lumbar spine conditions and surgeries. *Clin Sports Med* 23:367–379, 2004.

This article reviews the return-to-play criteria following lumbar spine conditions and surgeries (including spinal fusions) and their respected sport-specific restrictions. (Level V evidence).

Herman MJ, Pizzutillo PD, Cavalier R: Spondylolysis and spondylolisthesis in the child and adolescent athlete. *Orthop Clin North Am* 34:461–467, vii, 2003.

This article reviews the pathophysiology of spondylolysis and spondylolisthesis in the adolescent athlete. (Level V evidence).

Jackson DW, Wiltse LL, Cirincoine RJ: Spondylolysis in the female gymnast. *Clin Orthop Relat Res* 117:68–73, 1976.

This article reviews the pathophysiology of spondylolysis in a particular athlete sub-class: the female gymnast. (Level V evidence).

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This article reviews the outcomes and return-to-play criteria for athletes that underwent lumbar spine surgery to include lumbar disc herniation, spondylolysis and spondylolisthesis, degenerative disc disease, spinal stenosis, and scoliosis. (Level V evidence).

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Rubery PT, Bradford DS: Athletic activity after spine surgery in children and adolescents: Results of a survey. *Spine (Phila Pa 1976)* 27:423–427, 2002.

The article reviewed 721 members of the Scoliosis Research Society via survey regarding their opinions and experience with athletic activity after spine surgery performed on children and adolescents. The article showed varying approaches to postoperative athletic activity. (Level V evidence).

Soler T, Calderon C: The prevalence of spondylolysis in the Spanish elite athlete. *Am J Sports Med* 28:57–62, 2000.

This article reviewed 3,152 case histories of high-level athletes were evaluated to determine which sports had a higher prevalence of spondylolysis. The article recommended systematic radiological examination of the lumbar spine in athletes considered to be at greater risk of developing spondylolysis. (Level V evidence).

Schneiders AG, Davidsson A, Hörman E, et al: Functional Movement Screen normative values in a young, active population. *Int J Sports Phys Ther* 6:75–82, 2011.

This article reviewed the normative values of the Functional Movement Screen in an active athletic population. (Level III evidence).

Chorba RS, Chorba DJ, Bouillon LE, et al: Use of a functional movement screening tool to determine injury risk in female collegiate athletes. *N Am J Sports Phys Ther* 5:47–54, 2010.

This article reviewed the use of the Functional Movement Screen in determining injury risk in an active population such as female collegiate athletes. (Level III evidence).

Kiesel K, Plisky PJ, Voight ML: Can serious injury in professional football be predicted by a preseason functional movement screen? *N Am J Sports Phys Ther* 2:147–158, 2007.

This article reviewed the probability of administrating a preseason Functional Movement Screen in its ability to predict serious injury in professional football athletes. (Level III evidence).

Lehr ME, Plisky PJ, Kiesel KB, et al: Field expedient screening and injury risk algorithm categories as predictors of noncontact lower extremity injury. *Scan J Med Sci Sport* 23:e225–e232, 2013.

This article reviewed the lower body Y Balance Test and an injury risk algorithm that determined noncontact lower extremity injury within an active population. (Level III evidence).

Butler RJ, Southers C, Gorman PP, et al: Differences in soccer players' dynamic balance across levels of competition. *J Athl Train* 47:616–620, 2012.

This article reviewed lower body Y Balance Test scores for soccer players across various levels of competition. (Level III evidence).

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8. Rubery PT, Bradford DS: Athletic activity after spine surgery in children and adolescents: Results of a survey. *Spine (Phila Pa 1976)* 27:423–427, 2002.
9. Schneiders AG, Davidsson A, Hörman E, et al: Functional Movement Screen normative values in a young, active population. *Int J Sports Phys Ther* 6:75–82, 2011.
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11. Kiesel K, Plisky PJ, Voight ML: Can serious injury in professional football be predicted by a preseason functional movement screen? *N Am J Sports Phys Ther* 2:147–158, 2007.
12. Lehr ME, Plisky PJ, Kiesel KB, et al: Field expedient screening and injury risk algorithm categories as predictors of noncontact lower extremity injury. *Scan J Med Sci Sport* 23:e225–e232, 2013.

13. Butler RJ, Southers C, Gorman PP, et al: Differences in soccer players' dynamic balance across levels of competition. *J Athl Train* 47:616–620, 2012.

Multiple-Choice Questions

QUESTION 1. Core strengthening and low-impact cardiovascular activity can begin at what week in the rehabilitation program?

A. Week 2
B. Week 6
C. Week 8
D. Week 12

QUESTION 2. Authors advise that athletes may be limited after surgery if they participate in activities that require:

A. Decreased mobility
B. Extreme mobility
C. Heavy loads
D. Both B and C

QUESTION 3. Authors caution that fusion may be a career-ending surgery for activities that require extreme:

A. Hyperflexion
B. Hyperextension
C. Excessive rotation
D. Decreased extension

QUESTION 4. Name a subjective questionnaire that can be used during lumbar fusion rehabilitation.

A. NDI
B. DASH
C. ODI
D. LEFS

QUESTION 5. At what percentage do surgeons allow return to low-impact, noncontact sports by 6 months postoperatively for both low-grade and high-grade slips?

A. 10% to 16%
B. 22% to 28%
C. 40% to 48%
D. 62% to 66%

Answer Key

QUESTION 1. Correct answer: **A** (See Phase I, Sport-specific concepts of integrated training)

QUESTION 2. Correct answer: **D** (See Literature)

QUESTION 3. Correct answer: **B** (See Literature)

QUESTION 4. Correct answer: **C** (See General information)

QUESTION 5. Correct answer: **D** (See Literature)

Chapter 21



Musculoskeletal Thoracic and Chest Injuries

INTRODUCTION

Paul F. Reuteman, PT, DPT, MHS, OCS, ATC, and Scott A. Escher, MD

Epidemiology

Age, Sex, Sport, and Position

Thoracic Pain

- Musculoskeletal thoracic pain is not as common as cervical or lumbar pain; however, it is typically more prevalent in the athletic population.
- Musculoskeletal sources of pain have been linked to both the costovertebral joints[1] and the facet joints of the thoracic vertebrae.[2] Little data exist on the frequency of pain associated with these structures.
- Thoracic disc injuries are quite rare because of the relative hypomobility of the thoracic spine. They account for only 0.15% to 4% of symptomatic disc herniations of the spine.[3,4]
- Even though thoracic pain is less prevalent, evolving evidence indicates that manual therapy interventions addressing impairments of the thoracic spine may be associated with enhanced outcomes of individuals with neck, shoulder, and upper extremity pain.[5–9]

Chest Wall Pain

- The anatomical structures that can cause chest wall pain are quite varied. A thorough examination is required to consider all the sources of pain.
- In athletes with chest pain, the first priority is to consider potentially life-threatening causes. Structures of the cardiovascular and gastrointestinal system must be considered.
- In the primary care setting, the cause of chest pain is benign in approximately 80% of cases, of which musculoskeletal chest pain accounts for almost 50%.[10]
- Musculoskeletal sources of chest wall pain in athletes can occur in the ribs, sternum, articulations of the ribs and sternum, and myofascial structures. Injury to these structures is commonly a result of direct trauma or overuse. The incidence of these conditions is 13% to 30% in patients seeking care in an emergency department with a primary complaint of chest pain.[11,12]
- Sports associated with musculoskeletal sources of chest pain include golf, baseball, and wrestling.
- Female rowers are especially susceptible to chest and rib injuries.[13]
- Overhead athletes participating in sports such as basketball, tennis, or weightlifting have been found to be susceptible to first rib injuries.[14]

Pathophysiology

Intrinsic Factors

Thoracic Pain

- An association between hypomobility of the thoracic spine and the presence of neck pain has been well documented in the literature.[5,6] It is generally accepted that a similar association exists between thoracic pain but, ironically, evidence is less compelling for this association.

- Postural conditions that create an accentuated thoracic kyphosis and forward head posture have been found to correlate with thoracic and periscapular pain.[15]
- A hyperkyphosis of the *nonpostural* type (nonreversible) is often associated with Scheuermann's disease.[16] To date, there has not been any correlation between pain and the presence of Scheuermann's disease. It has been hypothesized from a biomechanical perspective that intense athletic exercise and training regimens may lead to further progression of hyperkyphosis conditions of either postural or nonpostural types.[16]

Chest Wall Pain

- It is difficult to isolate common underlying impairments associated with pathologies such as costochondritis, stress fractures of the ribs or sternum, and strains of the intercostal muscles. Hypomobility of the thoracic spine and ribs may be associated with these conditions.[17–19] Muscle tightness, especially of the pectoralis minor and serratus anterior, may also contribute to abnormal mechanical stresses to the anterior-lateral structures.
- Athletes are especially susceptible to stress fractures of the rib. The first rib is the most common rib to sustain a stress fracture. It has a point of relative weakness where a deep groove exists for the subclavian artery. Strong contractions of the anterior scalene muscles while a traction force applied to the arm during forceful overhead motion may exceed the bone's loading capacity.[14,20]
- Ribs 4 through 8 are also susceptible to stress fractures. These stress fractures are commonly associated with a strong contraction of the serratus anterior as the athlete moves forcefully into a side-bending and flexion motion, as in golf and softball pitching.[14]

Extrinsic Factors

- A majority of extrinsic factors associated with musculoskeletal thoracic and chest wall pain deals with training errors. A study that sampled 2270 adolescents between 8 and 18 years of age found that increased angles of thoracic kyphosis were associated with greater cumulative training times. Of all the athletes studied, gymnasts trained the most each year and showed the largest thoracic curve. Lack of sports participation was associated with the smallest curve. Age and sex did not significantly have an effect on the degree of curvature.[21]
- Other correlations exist between muscle activity and the prevalence of rib stress fractures and costochondritis. Rowers and golfers are especially prone to rib stress fractures and costochondritis.[22,23]
- In rowers, the co-contraction of the serratus anterior and external obliques exerting opposite forces on the ribs may lead to rib failure.[22] In golfers, the swing mechanics appear to have an influence on the prevalence of stress fractures. Of 19 golfers diagnosed with a rib stress fracture, 16 had stress fractures on their leading side.[24] Electromyography of the serratus anterior on the lead side has shown the muscles to be active during the entire swing.[25]

Traumatic Factors

- As mentioned, musculoskeletal injury to the chest wall and thoracic region are commonly associated with overuse activity.
- However, trauma is also associated with injuries to the chest and thorax. Athletes participating in high collision sports such as football, rugby and wrestling are most susceptible to injuries such as rib fractures. Traumatic rib fractures are quite painful but commonly respond to rest and conservative management. The immediate concern associated with rib fractures is the potential for injury to the underlying tissue.
- Any trauma to the chest may result in a pneumothorax (puncture of the lung and pleura and deflating of the lung) or a laceration of the spleen, liver, or kidney. All of these are considered life-threatening emergencies.
- Complaints of shortness of breath, pain with deep breathing, severe chest or abdominal pain, and asymmetrical chest expansion associated with direct trauma to the chest requires immediate medical attention.
- Another indicator of injury is Kehr's sign, which is pain in the left scapular region referred from the peritoneal cavity. This is considered a classic sign of a ruptured spleen.
- Blood in the urine is considered a sign associated with trauma to the kidney.

Classic Pathological Findings

- It is uncommon for overuse conditions of the thoracic spine and chest wall to present with pathological findings.
- Costochondritis, rib stress fractures, and thoracic musculoskeletal pain rarely present with cardinal signs of inflammation (localized swelling, increased tissue temperature, redness).
- Traumatic fractures to the ribs, sternum or thoracic spine are often accompanied by localized swelling, increased tissue temperature, ecchymosis, and point tenderness.

Clinical Presentation

History

- A thorough subjective examination and history is critical for any person that has primary complaints of either thoracic or chest wall pain.
- Professional responsibilities require the practitioner to especially ask questions regarding the cardiovascular system. Specific concern is if the athlete complains of chest pain and tightness or shortness of breath with activity or a general decrease in exercise tolerance.
- Once cardiovascular conditions have been ruled out, common subjective complaints associated with musculoskeletal sources of thoracic and chest pain may be addressed.

Thoracic Pain

- Common complaints associated with musculoskeletal thoracic pain include pain along the spine, either bilaterally or unilaterally. Pain in the thoracic region

may be very specific to the level of the dysfunction or it may be vague because of the referral patterns associated with the thoracic facet joints.[2]
- The onset of pain may correlate with an increase in the athlete's training volume and intensity.
- Pain is commonly aggravated with movement of the thoracic spine, especially with rotation and/or extension. Deep breathing and coughing will often exacerbate the pain as well.

Chest Wall Pain

- As with thoracic pain, musculoskeletal causes of chest wall pain are often associated with a change in activity or from direct trauma.
- Pain is localized to the costosternal or costochondral joints or along the ribs. Pain is usually exacerbated with upper extremity motions such as horizontal adduction or trunk rotation and/or extension.
- Athletes may report symptoms with increased activity or repetitions of a specific motion (e.g., trunk rotation with flexion) or with deep breathing.
- In the presence of costochondritis, pain may be associated with a popping sensation in the vicinity of the costochondral joint.[17] This popping sensation may be quite painful when it occurs but may provide a temporary reduction of symptoms.
- In the presence of stress fractures, athletes commonly complain of specific pain at the region of the fracture. This pain may be present at rest but is certainly aggravated with activity.
- First rib stress fractures often produce dull, aching pain in the neck and shoulder complex.
- Stress fractures to the middle ribs (usually 4 to 8) are accompanied with complaints of mid-costal pain especially with deep breathing or rolling over in bed.[1]
- In the presence of a traumatic fracture of a rib, the athlete can usually recall a single event in which the chest wall suffered a direct blow.

Physical Examination

Abnormal Findings

- A standardized protocol to assess chest and thoracic pain has been proposed by several authors.[10,26] It consists of three parts: a structured interview, a general health examination, and a specific manual examination of the muscles and joints of the neck, thoracic spine, and chest wall. The use of a standardized protocol to evaluate for musculoskeletal chest pain has been found to have substantial interobserver reliability.[26]
- Once it has been deemed from the interview and general health examination that the source of pain is stemming from the musculoskeletal system, the examination attempts to reproduce the patient's pain by implying mechanical stresses to the anatomical structures.
- Assessment of the following is necessary: Active motion of the trunk, palpation, mobility assessment of the thoracic spine, and assessment of flexibility of the muscles in the thoracic region. A thorough examination will identify impairments necessary to address in the intervention plan.
- For musculoskeletal conditions of both the thorax and chest, common findings include pain and/or limited motion during active range of motion (ROM) of the thoracic region. Range of motion of the thoracic region is commonly assessed in standing and/or sitting and specific attention is paid to flexion, extension, and rotation (Figures 21-1 to 21-4). Provocation of symptoms is deemed a more valuable finding during motion assessment because it is challenging to measure exact degrees of motion. To further elicit symptoms, overpressure may be applied at the end range of motion (Figures 21-5 to 21-7).



FIGURE 21-1. Assessment of active thoracic flexion.

- Determination of palpable tenderness provides more specific detail of the location of the patient's symptoms. Palpation of posterior structures includes the erector spinae muscles, the spinous and transverse processes, and the posterior and lateral ribs. Palpation of anterior structures includes the sternum, sternocostal joints, costochondral joints, anterior ribs, pectoralis minor/major, subclavius, and intercostal muscles.
- Many authors have identified aberrant or decreased mobility of the thoracic spine as a contributing factor in many of the overuse injuries of the thorax and chest.[17–19,26]
- Assessment of thoracic mobility is commonly performed by applying a posterior to anterior (PA) pressure to different levels of the thoracic spine when the patient is in a prone position (Figure 21-8). The clinician assesses the magnitude of motion with respect to the force applied and qualitatively determines joint



FIGURE 21-2. Assessment of active thoracic extension.

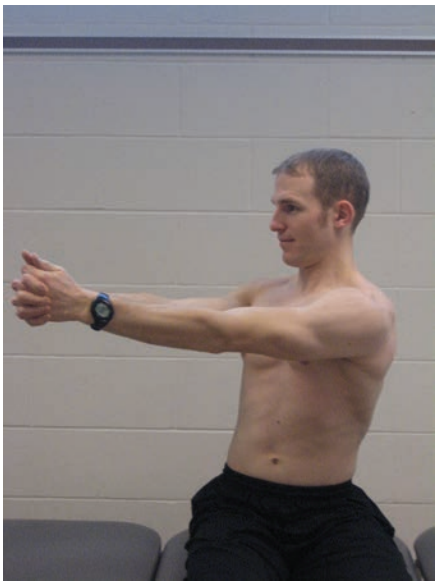

FIGURE 21-3. Assessment of active thoracic right rotation.

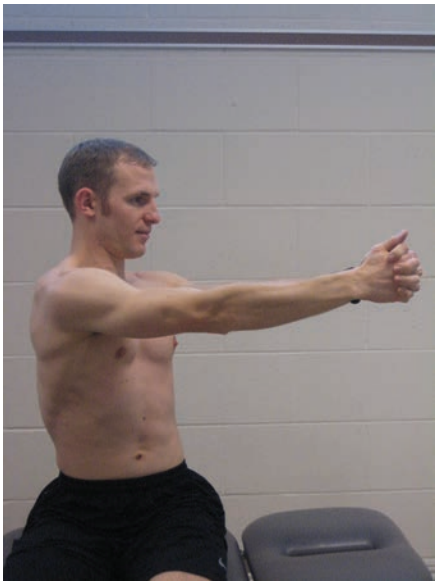

FIGURE 21-4. Assessment of active thoracic left rotation.

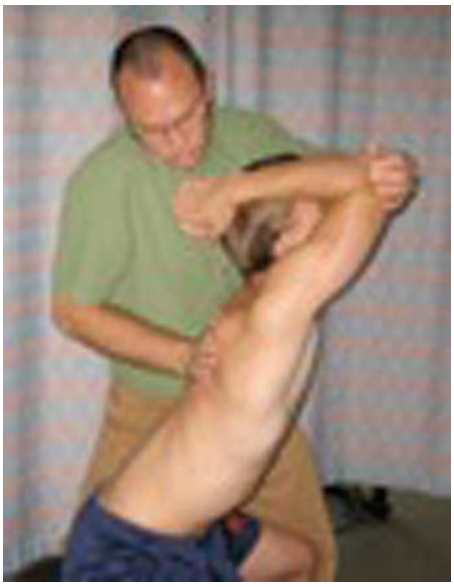

FIGURE 21-5. Assessment of thoracic extension with overpressure.

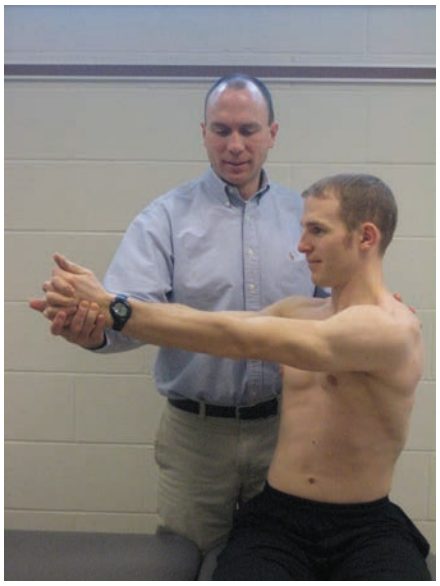

FIGURE 21-6. Assessment of thoracic right rotation with overpressure.

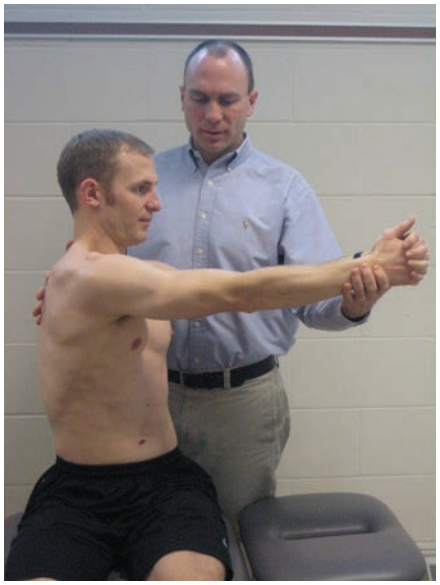

FIGURE 21-7. Assessment of thoracic left rotation with overpressure.



FIGURE 21-8. Assessment of posterior-anterior mobility of the thoracic spine.

stiffness.[27,28] In addition to assessing joint stiffness, the clinician also inquires about pain during the application of force. Both intra- and inter-assessment reliability was found to be moderate to very good for both joint mobility and pain provocation assessment.[27]

Pertinent Normal Findings

- As described, a thorough evaluation must be performed to rule out non-musculoskeletal causes of chest and thoracic pain. It is important to take a clear history of the present symptoms and a general health history of the athlete.
- In the presence of musculoskeletal pain, normal findings should be found during the assessment of vital signs, auscultation of the heart, lung, and neck, abdominal palpation, and a neurological examination of the extremities.
- If the patient does not present with any significant signs or symptoms associated with the gastrointestinal and cardiovascular system, the clinician should proceed onto assessment of the musculoskeletal structures.

Imaging

Thoracic Pain

- If the athlete has sustained a traumatic injury, it is standard practice to order a traditional series of radiographic films of the thoracic spine.
- Other imaging studies to assess for fractures in the thoracic region may include the use of a bone scan, CT scan, or MRI.
- In the absence of traumatic injuries of the thoracic region, imaging of the thoracic spine typically does not provide much benefit.

Chest Pain

- Again, if the athlete has sustained a traumatic injury, it is standard practice to order a traditional series of radiographic films of the chest.
- For overuse injuries, a bone scan may be used to diagnose the presence of a stress fracture. A CT scan or MRI may also be ordered for more detail of the bony structures. The MRI has an added benefit of visualization of the soft tissue structures of the thorax.

Differential Diagnosis

- Currently a diagnosis of musculoskeletal chest and thoracic pain can be difficult to establish because there is no reference standard to verify the diagnosis. Except for traumatic fractures or stress fractures of the thorax, there are no diagnostic tests to confirm a diagnosis of musculoskeletal pain.
- Therefore any musculoskeletal pain is often a diagnosis made when other conditions have been excluded.
- Some of the conditions that could be confused with chest and thoracic musculoskeletal pain include
  - Gastroesophageal reflux diseases (GERD): Athletes often present with burning retrosternal pain and may have a dry cough and sore throat.
  - Pancreatitis: Acute pancreatitis causes severe epigastric and lower chest pain, it may be associated with vomiting and can be life threatening. Blood tests are performed to rule out this condition.
  - Exercise-induced asthma (EIA): Symptoms of EIA include chest tightness/pain, dyspnea, wheezing, coughing, and fatigue. Diagnosis is confirmed by stress pulmonary function testing or methacholine challenge testing.
  - Lower respiratory infections: These can include bronchitis, influenza, and pneumonia. Inflammation of the pleura and overuse of the muscles around the chest wall from excessive coughing are often a cause of chest pain. These conditions can be accompanied by a fever and dyspnea.
  - Spontaneous pneumothorax: This is an uncommon condition associated with severe chest pain and shortness of breath. Diagnosis is confirmed by chest films. An association with Alpha-1 antitrypsin (AAT) deficiency has been identified with this condition.
  - Pericarditis: This is an inflammation of the pericardium usually caused by an infection. Chest pain is the primary symptom and is often worsened by lying down and relieved by sitting forward. It typically presents with characteristic ECG changes including upward-concave ST-segment elevation in all leads.[29] A complication of pericarditis may be pericardial effusion, which may be seen on an echocardiography.
  - Myocarditis: This is an inflammatory disease of the heart most commonly caused by a viral infection or noninfectious agents such as drugs (e.g., cocaine). Physical activity increases the inflammation seen in myocarditis and leads to complications of dilated cardiomyopathy, heart failures, arrhythmias, and death.[29] Symptoms include chest pain, fatigue, dyspnea, reduced exercise tolerance, and/or palpitations. Diagnostic studies include an ECG, echocardiography, cardiac MRI, or an endomyocardial biopsy.

Treatment

Nonoperative Management

- Because of the infrequent nature of musculoskeletal chest and thoracic pain in athletes, there is a lack of high-level randomized trials that assess best practice for intervention. Case reports dominate the literature on treatment options.
- Therefore a majority of the intervention, whether the pain is anterior or posterior, is intended to address underlying impairments of the cervical, thoracic, and lumbar region that have been identified during the examination of the athlete (e.g., thoracic hypomobility, muscular tightness, poor trunk strength and endurance, postural considerations).
- Special consideration must be made in the management of rib stress fractures. Treatment of first rib stress fractures involves immobilization of the upper extremity in a sling for 4 weeks with a gradual return to activity.
- Management of other rib stress fractures requires relative rest for 4 to 6 weeks. Light training and

cardiovascular conditioning may be undertaken during this time. Return to full competition is commonly allowed around 8 weeks.

Guidelines for Choosing Among Nonoperative Treatments

- Manual therapy options
  - Thoracic posterior-anterior (PA) and anterior-posterior (AP) mobilizations or thrust manipulations. Currently only one study, a nonrandomized trial with several limitations, has assessed the effectiveness of manual therapy directed at the thoracic spine to address chest and thoracic pain.[30] In this study, approximately 75% of the patients described a self-reported improvement in pain and general health following treatment involving thrust techniques to the thoracic region.
  - Several studies have identified a subset of patients with neck and shoulder pain that may benefit from these manual therapy interventions. It is believed that these techniques may enhance general mobility of the thoracic spine and costovertebral joints resulting in decreased pain and enhanced function.[5,6,9,31]
  - Soft tissue mobilizations to the tight and tender musculature of the thoracic and chest region
- Self-mobilization of the thoracic spine. These exercises are prescribed as a supplement to the manual therapy interventions described above.
- Stretching of musculature of the trunk with special attention to the pectoralis major/minor and the latissimus dorsi.
- Strengthening of the musculature of the trunk with special attention to the lower/middle trapezius and serratus anterior.

Surgical Indications

- There are no surgical indications for the pathologies discussed in this chapter.

Evidence

Coriss EE, Higgins HW: First rib stress fractures in throwing athletes. *Am J Sp Med* 33(9):1400–1404, 2005.

This report describes a unique case of a 20-year-old baseball player with a first rib stress fracture of the dominant arm. Differential diagnosis and intervention are discussed. (Level V evidence)

Davis BA, Finnoff JT: Diagnosis and management of thoracic rib pain in rowers. *Curr Sports Med Rep* 2:281–287, 2003.

This report reviews the literature and describes the various causes of rib pain in rowers and also provides insight into methods to make an appropriate diagnosis and develop an effective intervention plan. (Level V evidence)

Gregory PL, Biswas AC, Batt ME: Musculoskeletal problems of the chest wall in athletes. *Sports Med* 32(4):235–250, 2002.

This is a review intended to assist the clinician on diagnosing chest wall pain in athletes by identifying the possible causes as reported in the literature. (Level V evidence)

Rambey IM: Costochondritis: Are the symptoms and signs due to neurogenic inflammation? Two cases that responded to manual therapy directed towards posterior spinal structures. *Man Ther* 13:82–86, 2008.

This is a series of two case reports of individuals with musculoskeletal related chest pain that depicts the use of manual therapy to enhance outcomes. (Level IV evidence)

Sik EC, Batt ME, Heslop LM: Atypical chest pain in athletes. *Curr Sports Med Rep* 8(2):52–58, 2009.

This review looks at the possible causes of atypical chest pain in athletes, focusing on conditions that are more common in athletes than the general population or have a link to exercise. (Level V evidence)

Stochkendahl MJ, Christensen HW: Chest pain in focal musculoskeletal disorders. *Med Clin North Am* 94:259–273, 2010.

This is a review article that discusses the different sources of chest pain and differential diagnosis of different pathologies, and describes a systematic examination for chest pain that leads to appropriate intervention. (Level V evidence)

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Multiple Choice Questions

QUESTION 1. Which of the following statements is true regarding kyphosis of the thoracic spine?

A. Thoracic manipulation has been found to decrease the kyphosis of the thoracic spine.
B. A strong correlation exists between thoracic pain and kyphosis angles of the thoracic spine.
C. Thoracic kyphosis angles were found to increase with greater training times and intensity.
D. Those participating in swimming were found to have the greatest kyphosis angles.

QUESTION 2. Which of the following is NOT a sign or symptom associated with a pneumothorax?

A. Shortness of breath
B. Bruising of the costal region
C. Asymmetrical chest expansion
D. Pain with deep breathing

QUESTION 3. Which of the following statements regarding assessment of thoracic mobility is true?

A. Thoracic mobility is assessed in a posterior to anterior direction while the athlete is prone. It has been found to have adequate reliability.
B. Thoracic mobility is assessed in a posterior to anterior direction while the athlete is supine. It has been found to have adequate reliability.
C. Thoracic mobility is assessed in a posterior to anterior direction while the athlete is prone. It has been found to have poor reliability.
B. Thoracic mobility is assessed in a posterior to anterior direction while the athlete is supine. It has been found to have poor reliability.

QUESTION 4. Which of the following statements is inaccurate regarding myocarditis?

A. There are very few symptoms associated with myocarditis.
B. Myocarditis may be caused by a viral infection or noninfectious agents (e.g., cocaine).
C. A complication associated with myocarditis may be potential death.
D. Diagnostic studies to confirm myocarditis include ECG, echocardiography, cardiac MRI, or an endomyocardial biopsy.

QUESTION 5. Which statement is true regarding the use of thoracic manipulations/mobilizations?

A. Thoracic manipulations have been found to be very specific to a segment of the thoracic spine.
B. Strong evidence exists for the use of thoracic manipulation for musculoskeletal pain of the thoracic region
C. A subset of patients has been identified in the literature that may benefit from these techniques.

Answer Key

QUESTION 1. Correct answer: **C** (see Pathophysiology)

QUESTION 2. Correct answer: **B** (see Pathophysiology)

QUESTION 3. Correct answer: **A** (see Clinical Presentation)

QUESTION 4. Correct answer: **A** (see Differential Diagnosis)

QUESTION 5. Correct answer: **C** (see Treatment)

NONOPERATIVE REHABILITATION OF MUSCULOSKELETAL THORACIC SPINE AND CHEST INJURIES

Paul F. Reuteman PT, DPT, MHS, OCS, ATC

GUIDING PRINCIPLES OF NONOPERATIVE REHABILITATION

- In the presence of acute traumatic fractures or stress fractures of the ribs or thoracic vertebrae, time must be allowed for adequate healing of the fracture. Typically, active rest is prescribed in the first 4 to 6 weeks of treatment. For the sake of this chapter, we will be focusing on pain and impairments not related to a confirmed fracture.
- Conservative management is guided by an impairment-based approach. Common impairments associated with musculoskeletal thoracic and chest pain include:
  - Postural considerations
  - Thoracic and cervical motion restrictions.
  - Thoracic and rib hypomobility
  - Muscular tightness, especially the pectoralis major/minor and the latissimus dorsi
  - Poor neuromuscular control, strength and endurance of muscles of the thoracic region, especially the serratus anterior, lower and middle trapezius and the spinal muscles

Phase I (weeks 2 to 4)

Protection

- In the presence of acute pain that is quite debilitating, early protection and "active rest" is advocated. Avoidance of provocative activities while still allowing the athlete to engage in tolerable cardiovascular conditioning and/or strengthening is recommended.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Thoracic posterior-anterior (PA) and anterior-posterior (AP) mobilizations or thrust manipulations (Figs 21-9 to 21-11). Currently, only one study, a nonrandomized trial with several limitations, has assessed the effectiveness of manual therapy directed at the thoracic spine to address chest and thoracic musculoskeletal pain.[1] Approximately 75% of patients studied described a self-reported improvement in pain and general health after treatment involving thrust techniques to the thoracic region.
- Several studies have identified a subset of patients with neck and shoulder pain that may benefit from these manual therapy interventions. It is believed that these techniques may enhance general mobility of the thoracic spine and costovertebral joints and improve rehabilitation outcomes.[2–7] These techniques are thought to be quite general and are not intended to target one specific segment.[8] Mobilizations and thrust manipulations have been found to have no greater negative side effects than therapeutic exercise.[9]

Soft Tissue Techniques

- Soft tissue mobilization to musculature of the thoracic and chest region. Special attention is directed to the structures that are tight and/or tender (pectoralis minor, thoracic paraspinal muscles).

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Self-mobilization of the thoracic spine performed by the patient to enhance extension and rotation range of motion (Figs. 21-12 to 21-15).

TIMELINE 21-1: **Nonoperative Rehabilitation of Musculoskeletal Thoracic and Chest Injuries**

PHASE I (weeks 0 to 4)	PHASE II (weeks 4 to 12)

• "Active rest": Engaging in activity that does not provoke pain
• Manual therapy interventions:
  • Thoracic mobilizations and thrust manipulations
  • Soft tissue mobilization
• Self-range of motion to the thoracic region with specific attention to extension and rotation
• Self-stretching with specific attention to the latissimus dorsi and pectoralis minor
• Strengthening with specific attention to the serratus anterior and the lower trapezius
	• Manual therapy interventions as stated earlier to address further pain and impairments.
	• Continued self-stretching and range of motion.
	• More advanced strengthening with specific attention to addressing core stability
	• Gradual return to athletic activity as the patient tolerates



FIGURE 21-9. Prone PA mobilization and thrust manipulation to the mid thoracic spine.

- Stretching of musculature of the trunk with special attention to the pectoralis major/minor and the latissimus dorsi

Other Therapeutic Exercises

- Appropriate muscle strength and balance of the primary muscles of the scapulothoracic region (trapezius, serratus anterior, rhomboids and pectoralis minor) is critical for coordinated movement of the shoulder complex and the thoracic region. These muscles attach distally on the scapula and have a significant proximal attachment on both the thoracic spine and ribs. Strengthening of these muscles enhances outcomes for shoulder rehabilitation but they must also be considered in the management of musculoskeletal chest and thoracic pain.
- Muscle activation and strengthening exercises are initiated in phase I of the rehabilitation with specific attention to the serratus anterior and middle and lower trapezius.
- A common progression of serratus anterior strengthening involves: Supine scapular protraction → pushups with a plus (scapular protraction) → dynamic hug with a Thera-Band → serratus punch at 120°[10] (Figs. 21-16 to 21-19).



FIGURE 21-10. Supine AP thrust manipulation to the mid thoracic spine.



FIGURE 21-11. Supine AP thrust manipulation to the upper thoracic spine.



FIGURE 21-12. Self mobilization of the thoracic spine into extension over a therapy ball.



FIGURE 21-13. Self mobilization of the thoracic spine into extension over the edge of a table.



FIGURE 21-14. Self mobilization of the thoracic spine into extension over the edge of a chair.



FIGURE 21-15. Self mobilization of the thoracic spine into rotation while side sitting in a chair.

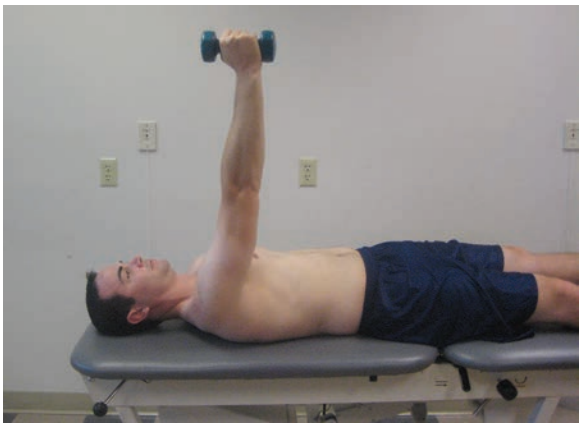

FIGURE 21-16. Supine scapular protraction.



FIGURE 21-17. Push up with a plus (scapular protraction).

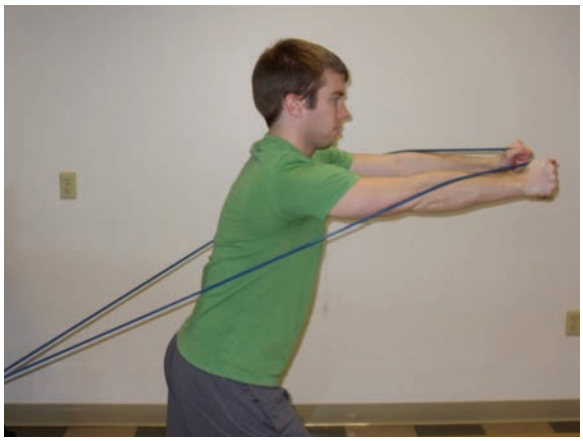

FIGURE 21-18. Dynamic hug with a Thera-Band.

- A common progression of lower trapezius strengthening exercises involves: Bilateral external rotation in standing with use of a Thera-Band → prone horizontal abduction with glenohumeral joint externally rotated at 90° → prone horizontal elevation with glenohumeral joint at 120°[10] (Figs. 21-20 to 21-22).

Milestones for Progression to the Next Phase

- Near pain-free range of motion of the thoracic spine noted, especially into extension and rotation.
- Improved mobility of the thoracic spine and little to no pain reported during assessment of mobility.
- Symmetrical flexibility of the pectoralis major/minor and serratus anterior muscles noted during standardized assessment of muscle length.
- Adequate neuromuscular control of the lower trapezius and serratus anterior as indicated during the exercises prescribed to effectively progress to activities that involve more functional strengthening and endurance.



FIGURE 21-19. Serratus punch at 120° with a Thera-Band.

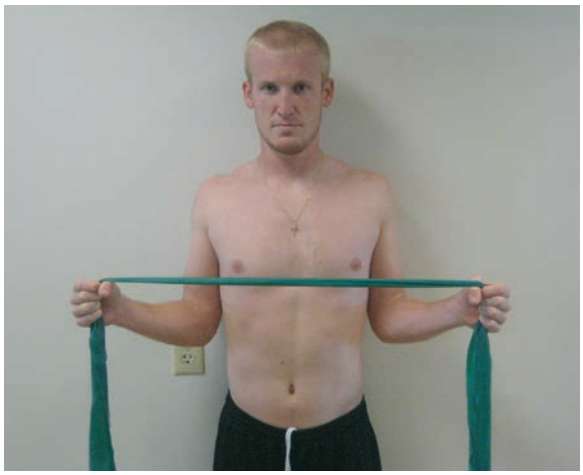

FIGURE 21-20. Bilateral external rotation in standing with use of a Thera-Band.

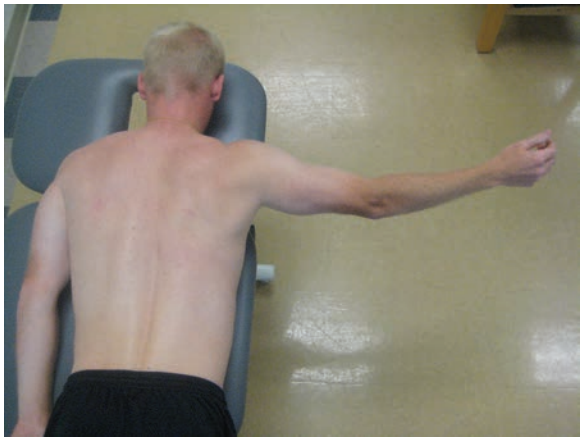

FIGURE 21-21. Prone horizontal extension with glenohumeral joint externally rotated at 90°.



FIGURE 21-22. Prone horizontal extension with glenohumeral joint at 120°.



FIGURE 21-23. Prone planks on a therapy ball with scapular protraction.

Phase II (weeks 4 to 12)

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- In the presence of persistent pain that has less effect on overall function but still limits the athlete from competing in their sport, continued manual therapy interventions are considered but more advanced strengthening exercise are recommended.
- The manual therapy, soft tissue, and stretching techniques explained above are continued as needed to address remaining impairments of the thoracic spine and ribs.

Other Therapeutic Exercises

- For Phase II, other therapeutic exercises are prescribed involving advanced core stability with specific attention to the following:
  - Deep abdominal strengthening activities in a plank position on a therapeutic ball where the patient can also focus on serratus activation (prone planks on a therapy ball) (Fig. 21-23). Further challenges are imposed to facilitate transverse trunk stability (Figs. 21-24 to 21-25).



FIGURE 21-24. Prone planks on a therapy ball with hip extension.



FIGURE 21-25. Prone planks on a therapy ball with hip flexion and trunk rotation.



FIGURE 21-27. Prone on a therapy ball, bilateral glenohumeral extension.

- Bridging activities with resisted upper extremity motion (ex: PNF lift and chop) (Fig. 21-26).
- Prone exercises over a therapy ball involving active glenohumeral extension, horizontal abduction and elevation to further challenge the posterior scapulothoracic muscles (Figs. 21-27 to 21-29).
- Other exercises may be initiated that replicate the motion of the athlete during their sport activity.

Evidence

Christensen HW, Vach W, Gichangi A: Manual therapy for patients with stable angina pectoris: A nonrandomized open prospective trial. *J Manipulative Physiol Ther* 28:654–661, 2005.

This prospective, nonrandomized study of 50 patients with musculoskeletal chest pain assessed the effectiveness of manual therapy approaches to manage the patients' symptoms. At a 4-week follow up, 75% of subjects reported an improvement in pain and function assessed by an 11-point pain scale and a SF-36 form respectively. (Level IIc evidence)

Cleland JA, Glynn P, Whitman JM, et al: Short-term effects of thrust versus nonthrust mobilization/ manipulation directed at



FIGURE 21-28. Prone on a therapy ball, bilateral glenohumeral horizontal abduction.



FIGURE 21-26. Bridging on a therapy ball with PNF chop.



FIGURE 21-29. Prone on a therapy ball, bilateral glenohumeral elevation.

the thoracic spine in patients with neck pain: A randomized clinical trial. *Phys Ther* 87(4):431–440, 2007.

This prospective randomized clinical trial of 60 patients compared the use of thoracic non-thrust mobilization to thrust manipulation in the treatment of their neck pain. Subjects in the thrust manipulation group exhibited significantly higher scores on the GROC Scale and reduction in pain four days following treatment. No difference in the frequency, duration, and types of side effects existed between the two groups. (Level Ic evidence)

Cleland JA, Mintken PE, Carpenter K, et al: Examination of a clinical prediction rule to identify patients with neck pain likely to benefit from thoracic spine thrust manipulation and a general cervical range of motion exercise: multi-center randomized clinical trial. *Phys Ther* 90(9):1239–1250, 2010.

This multicenter randomized clinical trial of 140 patients with a primary complaint of neck pain compared therapeutic exercise to therapeutic exercise and manipulation in the treatment of their pain. Subjects were randomly assigned to two groups. Those who received thoracic spine manipulation exhibited significantly greater improvements in disability at both 4 weeks and 6 months and in pain at 1-week follow-up. (Level Ib evidence)

Grindsaff TL, Beazell JR, Saliba EN, et al: Treatment of a female collegiate rower with costochondritis: A case report. *J Man Manip Ther* 18(2):64–68, 2010.

This case report provides insight into the characteristics, examination, clinical impressions and intervention of a 21-year-old female collegiate rower with multiple episodes of costochondritis over a one year period. (Level IV evidence)

Ian Rabey M: Costochondritis: Are the symptoms and signs due to neurogenic inflammation. Two cases that responded to manual therapy directed towards posterior spinal structures. *Man Ther* 13:82–86, 2008.

This study reviewed two patients who were diagnosed with costochondritis. Both patients were managed with manual therapy approaches, including oscillatory joint mobilizations and thrust manipulations, to enhance upper and mid thoracic spinal mobility and improve motor control of the scapulothoracic muscles. Both subjects had favorable outcomes of care. (Level IV evidence)

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Multiple-Choice Questions

QUESTION 1. Which muscles should be strengthened in the early phase of rehabilitation for patients with musculoskeletal thoracic and chest pain?

A. Pectoralis minor and latissimus dorsi
B. Lower trapezius and serratus anterior
C. Upper trapezius and levator scapulae
D. Deep abdominals and gluteus maximus

QUESTION 2. Which of the following statements are true regarding joint mobilizations/manipulations of the thoracic region?

A. Thrust manipulations should be avoided in the thoracic region.
B. Thrust manipulations have been found to have greater side effects than mobilizations.
C. Thrust manipulations of the thoracic spine have been found to be helpful in decreasing pain and improving function.

QUESTION 3. "Active rest" is defined by which of the following?

A. The athlete may engage in cardiovascular conditioning and general strengthening as long as it does not reproduce their symptoms.
B. The athlete should rest for the first 4 weeks of rehabilitation and not engage in any cardiovascular or strengthening activities.
C. The athlete visualizes self-performing the sport-specific activity.

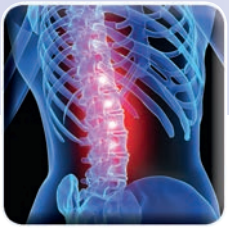
Answer Key

QUESTION 1. Correct answer: **B** (see Phase I)

QUESTION 2. Correct answer: **C** (see phase I)

QUESTION 3. Correct answer: **A** (see phase I)

Chapter 22



Cervical Spine Strains, Sprains, and Burners

INTRODUCTION

Nelson S. Saldua, MD

Epidemiology

- Cervical injuries often occur in contact sports. Approximately 1.4 million athletes play tackle football annually at the high school, collegiate, or professional levels.
- Cervical injuries occur in 10% to 15% of football players. Although these injuries can occur in a player of any position, there does seem to be a predilection for linemen, defensive ends, and linebackers.

Pathophysiology

Intrinsic Factors

- Cervical ligament sprains can occur with any forced neck motion that results in stretching or tearing of the cervical ligaments.
- Athletes with preexisting cervical stenosis are predisposed to some cervical injuries during the collisions inherent to contact sports.
- The Pavlov-Torg ratio is a radiographic measurement for detecting the presence of cervical stenosis (or tight cervical spine canal). Using a lateral cervical radiograph, it is determined by measuring the anterior-posterior width of the spinal canal and dividing that by the anterior-posterior length of the cervical vertebral body. Cervical stenosis is present if this ratio is less than 0.8 (Figure 22-1).
- "Burners" or "stingers" usually occur after a direct blow to the neck and/or shoulder resulting in downward displacement of the ipsilateral shoulder with concomitant lateral neck flexion to the contralateral shoulder. This results in a traction injury to the ipsilateral brachial plexus. Another mechanism of injury includes an extension-compression model. In this case, the cervical spine is extended and then lateral flexion results in a compression injury of the brachial plexus (Figure 22-2).

Extrinsic Factors

- Use of helmets in tackle football has decreased the incidence of head injuries but may have led to more cervical spine injuries. The postulated reason for this

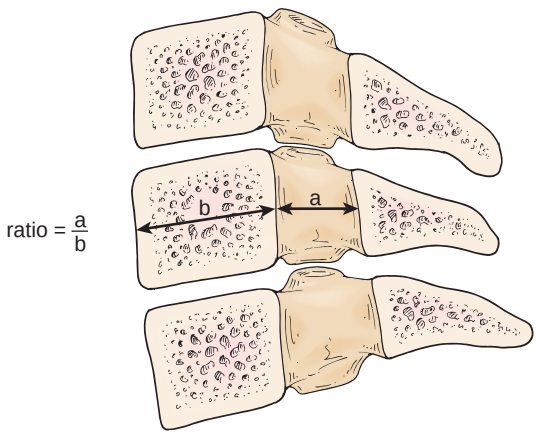


FIGURE 22-1. The Pavlov-Torg ratio is determined by dividing the anterior-posterior diameter of the spinal canal by the anterior-posterior length of the adjacent vertebral body.

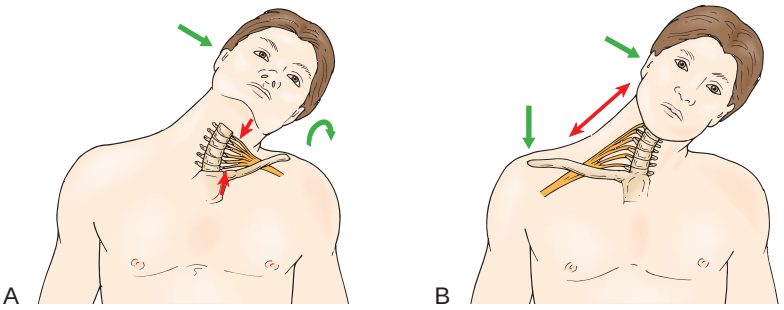


FIGURE 22-2. The two proposed mechanisms for stingers/burners are either traction to the brachial plexus or compression of the brachial plexus.

increase is the tackling technique of using the crown of the head as the initial point of contact with the opposing player (Figure 22-3).
- The postulated reason for this increase is using the tackling technique of using the crown of the head as the initial point of contact with the opposing player.

Traumatic Factors

- Axial loading of the head and neck can lead to bony and ligamentous injuries to the cervical spine.
- Because of the normal lordosis of the cervical spine, when the cervical spine is flexed to approximately 30° the cervical spinal vertebral bodies become a straight column. Axial loading of this straight column does not allow the force applied to be dissipated by the paraspinal muscles and is therefore applied directly to the spinal column.

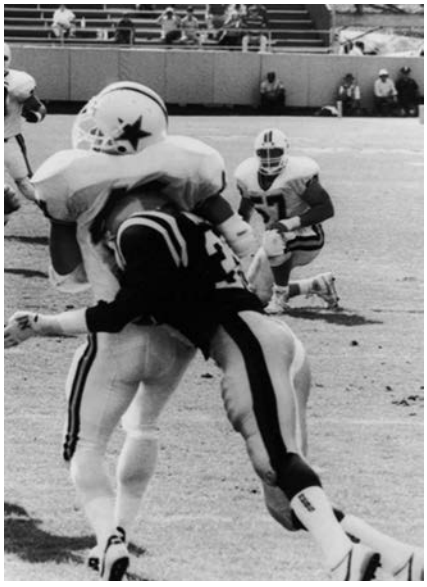


FIGURE 22-3. Use of the helmet as the initial point of contact is a risk factor for cervical injuries. In this position, the cervical vertebral column is straight, and this loss of normal lordosis is postulated to transmit more energy to the vertebral column directly rather than allowing the energy to be dissipated by the paraspinal muscles.

- Enforcement of tackling rules (spearing, helmet-to-helmet contact) may also continue to decrease the risk, although the data are still lacking.

Classic Pathological Findings

- A cervical sprain is a ligamentous injury that often results from a direct collision. The athlete will usually complain of pain localized to the neck without upper extremity radiation. This pain can be provoked or worsened with direct palpation.
- Because of the pain associated with a cervical sprain, the athlete will often guard against active or passive range of motion of the cervical spine.
- The neurologic exam after a cervical sprain is nonfocal, with full and symmetric strength in both upper and lower extremities as well as lack of sensory deficits.
- A "burner" or a "stinger" is a transient neurologic event that affects one single upper extremity. The athlete often describes tingling, burning, or numbness in a nondermatomal pattern. Because this condition is usually caused by either a traction injury or a compression injury to the brachial plexus and not an individual nerve root, the patient's symptoms rarely follow a single dermatomal distribution.

Clinical Presentation

History

- A cervical sprain is a ligamentous injury that often results from a direct collision. The athlete will usually complain of pain localized to the neck without upper extremity radiation.
- A "burner" or a "stinger" is a transient neurologic event that affects one single upper extremity. The athlete often describes tingling, burning, or numbness in a nondermatomal pattern. Because this condition is usually caused by either a compression or a traction injury to the brachial plexus and not an individual nerve root, the patient's symptoms rarely follow a single dermatomal distribution.
- In the compression mechanism of injury, the cervical spine is extended and laterally flexed toward the ipsilateral side of symptoms. This extension and lateral

bending of the cervical spine results in compression of the brachial plexus.
- In the brachial plexus traction mechanism of injury, the cervical spine is a lateral bend toward the contralateral side, and concomitantly the ipsilateral upper extremity or shoulder is pushed downward. This results in a traction injury to the brachial plexus caused by the opposing directions of force applied.

Physical Examination

Abnormal Findings

- Cervical sprain: focal tenderness to palpation at maximum site of reported pain
- Burner/stinger: tingling, burning, or numbness of a single upper extremity in a nondermatomal pattern
- Transient quadriplegia/cervical cord neuropraxia (CCN): there is a focal neurologic deficit. Sensory symptoms can range from burning pain to tingling to loss of sensation.
- Motor symptoms can vary from mild weakness to complete paralysis. These abnormal neurologic exam findings can last from 10 minutes to 48 hours to resolve.

Pertinent Normal Findings

- The neurologic exam in cervical sprains and burners/stingers is generally nonfocal. There is full (5/5) and symmetric motor strength in both upper and lower extremities as well as lack of sensory deficits.
- In contrast, the neurologic exam in an athlete with transient quadriplegia with CCN will show a focal neurologic deficit that lasts from 10 minutes but can take up to 48 hours to resolve.

Imaging

- In a neurologically intact patient without cervical pain and without cervical tenderness to palpation, radiographic imaging may not be necessary. However, because almost all cervical sprains result in cervical pain and/or tenderness to palpation, this injury warrants further workup.
- Cervical fractures and dislocations can result in irreversible and permanent neurologic injury, there-by making cervical sprains and strains a diagnosis of exclusion. Cervical fractures and dislocations, as well as acute disc herniations, have potentially disastrous implications for the patient, so they must be ruled out when making the diagnosis of a cervical sprain.
- Plain radiographs of the cervical spine should include anterior-posterior, lateral, open mouth odontoid. A swimmer's view is sometimes necessary to view the cervicothoracic junction.
- Patients with decreased Torg ratios and with decreased foraminal height have been found in patients with chronic, recurrent stingers.
- If not evident on plain radiographs, a computed tomography scan of the cervical spine can be done to rule out any fracture or dislocation of the cervical spine.
- Magnetic resonance imaging (MRI) of the cervical spine can help to identify any compression of the neural elements, to include the spinal cord as well as the nerve roots. In addition, an MRI can occasionally show some increased signal within the spinal cord itself. This increased signal, also called myelomalacia, implies the presence of edema or trauma to the spinal cord.

Differential Diagnosis

- Stinger or burner
  - Pain and/or paresthesia in a single upper extremity
- Central cord syndrome
  - Extremity weakness that affects the upper extremities more than the lower extremities. Often seen after a cervical hyperextension injury in a patient with preexisting cervical stenosis.
- CNN, also known as transient quadriplegia
  - This results in deficits in motor and/or sensory function caudal to the level of the injury.

Treatment

Nonoperative Management

- Cervical spine immobilization in cervical orthosis
- Restriction from returning to contact sports
- No activity restrictions to include full return to participation in contact sports

Guidelines for Choosing Among Nonoperative Treatments

- If there is any suspicion of unstable cervical spine injury, the patient must not return to play. The cervical spine should be immobilized and the patient transferred to an appropriate facility to complete the imaging workup.
- Relative contraindications to return to participation in contact sports
  - Stinger that results in residual muscle weakness
  - Torg ratio less than 0.8 with one episode of CCN
  - MRI with degenerative disc disease after one episode of CCN
  - MRI with presence of cord deformation after one episode of CCN
- Absolute contraindications to return to participation in contact sports
  - MRI with cord edema or myelomalacia after one episode of CCN
  - Ligamentous instability after one episode of CCN
  - CCN lasting longer than 36 hours
  - Multiple episodes of CCN
- Some authors recommend that spear-tacklers' spine is a contraindication to return to contact sports. This is a clinical entity that includes:
  - Congenital narrowing of the spinal cord with Torg ratio less than 0.8
  - Loss of cervical lordosis or the presence of cervical kyphosis

- Posttraumatic radiographic abnormalities
- Prior history of using spear-tackling or helmet-to-helmet hitting techniques

Surgical Indications

- Absolute
  - Any fracture or dislocation that is etiology for abnormal neurologic exam finding
  - Any injury that results in instability of the cervical spine
- Relative
  - Recurrent episodes of transient quadriplegia/CCN that can be attributed to a compressive lesion on the spinal cord. The goal of any surgical intervention in this case would be to decrease the likelihood of further neurologic injury, not to return to competitive play.

Aspects of History, Demographics, or Exam Findings that Affect Choice of Treatment

- Cervical sprains are injuries to the ligaments of the cervical spine. In the absence of concomitant cervical fracture of injury of the intervertebral disc, these ligamentous sprains are rarely sufficient to cause instability of the cervical spine.
- Burners or stingers are by definition transient events and therefore require no surgical intervention.

Aspects of Clinical Decision Making When Surgery Is Indicated

- The goal of any surgical intervention in this case would be for preservation of neurologic function. Sprains and burners/stingers rarely warrant surgical intervention. Often a restriction from return to sport is sufficient to prevent future symptoms.
- The sporting injury can be the antecedent event that leads to radiographic workup, which then reveals a compressive lesion on the spinal cord. This can be from a large cervical disc herniation or from congenital cervical stenosis. In this case, surgical intervention can be performed with the goal of preservation of neurological function.

Evidence

Castro FP, Jr, Ricciardi J, Brunet ME, et al: Stingers, the Torg ratio, and the cervical spine. *Am J Sports Med* 25:603–608, 1997.

This prospective study of college football athletes showed that patients with recurrent stingers had smaller Torg ratio (0.75) than athletes who experienced only one stinger (0.87). (Level X evidence)

Kelly JD, Aliquo D, Sitler MR, et al: Association of burners with cervical canal and foraminal stenosis. *Am J Sports Med* 28:214–217, 2000.

This case series of patients who experienced upper extremity stingers/burners showed that on lateral radiographs, there was decreased foraminal height compared with asymptomatic control participants. (Level X evidence)

Meyer SA, Schulte KR, Callaghan JJ, et al: Cervical spinal stenosis and stingers in collegiate football players. *Am J Sports Med* 22:158–166, 1994.

This case series of 266 collegiate football players revealed 40 with at least one episode of an upper extremity stinger/burner. The authors proposed two mechanisms of injury, traction injury of the brachial plexus traction, and cervical extension/lateral bending. (Level X evidence)

Murone I: The importance of the sagittal diameters of the cervical spinal canal in relation to spondylosis and myelopathy. *J Bone Joint Surg Br* 56:30–36, 1974.

This clinical and radiographic study showed the correlation between sagittal diameter of the cervical spinal canal and the clinical symptoms associated with myelopathy. (Level X evidence)

Pavlov H, Torg JS: Roentgen examination of cervical spine injuries in the athlete. *Clin Sports Med* 6:751–766, 1987.

This original description of the Pavlov-Torg ratio proposed a radiographic determination of cervical stenosis that took into account the magnification of the radiograph itself. By relying on a ratio, rather than one measurement of distance, any potential magnification was eliminated. (Level X evidence)

Torg JS, Sennett B, Pavlov H, et al: Spear tackler's spine. An entity precluding participation in tackle football and collision activities that expose the cervical spine to axial energy inputs. *Am J Sports Med* 21:640–649, 1993.

Spear tacklers spine is defined, and 15 cases are reported by the authors. Of these 15, four sustained injuries that resulted in permanent neurologic deficits. The authors conclude that spear tackler's spine is a contraindication to return to contact sports. (Level X evidence)

Torg JS, Vegso JJ, O'Neill MJ, et al: The epidemiologic, pathologic, biomechanical, and cinematographic analysis of football-induced cervical spine trauma. *Am J Sports Med* 18:50–57, 1990.

In addition to defining the epidemiology of cervical injuries in tackle football, the authors were able to review game films of 60 cervical spine injuries. In 51 of these, the mechanism of injury was able to be determined, and axial loading was the mechanism in all 51 cases. (Level X evidence)

Multiple-Choice Questions

QUESTION 1. The Pavlov-Torg ratio is

A. the proportion of athletes who will sustain a cervical spine injury per season.
B. the anterior-posterior diameter of the spinal canal divided by the anterior-posterior length of the vertebral body.
C. abnormal when it is less than 0.8.
D. Both b and c

QUESTION 2. All of the following apply to the diagnosis of a cervical stinger/burner EXCEPT for:

A. unilateral upper extremity symptoms.
B. caused by a traction injury to the brachial plexus.
C. symptoms follow a specific dermatomal pattern.
D. symptoms are usually transient.

QUESTION 3. All of the following are contraindications to return to participation in contact sports EXCEPT for:

A. single episode of stinger/burner without residual muscle weakness.
B. single episode of stinger/burner with residual muscle weakness.
C. cervical injury in a neurologically intact patient with focal posterior midline tenderness to palpation and palpable stepoff.
D. single episode of cervical cord neuropraxia with a Pavlov-Torg ratio of less than 0.8.

QUESTION 4. A cervical sprain is a diagnosis of exclusion because

A. the workup, to include radiographs/CT scan/MRI, makes it impossible for the athlete to return to play in the same game.
B. cervical sprains happen infrequently.
C. the consequences of missing a cervical fracture or dislocation can include incomplete spinal cord injury or even paralysis.
D. cervical sprains are a common injury in contact sports.

Answer Key

QUESTION 1. Correct answer: **D** (see Pathophysiology)

QUESTION 2. Correct answer: **C** (see Clinical Presentation)

QUESTION 3. Correct answer: **A** (see Treatment)

QUESTION 4. Correct answer: **C** (see Clinical Presentation)

NONOPERATIVE REHABILITATION OF CERVICAL SPINE STRAINS, SPRAINS, AND BURNERS

Bradley S. Wells, DPT, CSCS, LT

GUIDING PRINCIPLES OF NONOPERATIVE REHABILITATION

- Restore cervical active range of motion early.
- After full cervical range of motion is established, progress to strength and postural training.
- Return to practice is prohibited until patient is completely asymptomatic with full range of motion, strength, and sensation.
- Return to game is prohibited until patient remains asymptomatic during practice.

Phase I (weeks 0 to 1)

Protection

- Soft cervical collar may be used as needed for protection and support but should be limited to avoid dependency and muscle deactivation.
- Borchgrevink et al. found that patients with neck sprains experienced better outcomes when they continued to engage in their normal, preinjury activities than those who were immobilized during the first 14 days after injury.

Management of Pain and Swelling

- Nonsteroidal antiinflammatory drugs (NSAIDs) and ice for decreased pain and inflammation.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- No passive range of motion in the acute phase to prevent excessive motion and stretching to injured segments

Stretching and Flexibility Techniques for the Musculotendinous Unit

- No passive range of motion in the acute phase to prevent excessive motion and stretching to injured segments

Other Therapeutic Exercises

- Isometric cervical muscle strengthening starting in neutral cervical position and progressing through full range of motion for initiation of cervical muscular strengthening

Activation of Primary Muscles Involved

- Muscle activation exercises for the trapezius, sternocleidomastoid, scalenes, levator scapulae, splenius capitis, and deep neck flexors

Techniques to Increase Muscle Strength, Power, and Endurance

- Isometric exercises are introduced and progressed as patient tolerates.

Milestones for Progression to the Next Phase

- No vestibular or visual dysfunctions
- No fracture or dislocations of cervical segments
- No extreme amounts of pain that would limit patient's ability to participate in rehabilitative program

Phase II (weeks 2 to 4)

Management of Pain and Swelling

- Moist heat pack with interferential current using electrical stimulation prior to mobility training may decrease stiffness and patient guarding prior to treatment.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Cervical mobilizations using multidirectional glides and posterior to anterior directed forces, starting with Grades I and II and progressing to Grades III and IV as patient tolerates for improved segmental mobility

Soft Tissue Techniques

- Soft tissue massage to cervical muscles and upper trapezius as needed for reduction in muscle tone, trigger point release, and improved cervical mobility

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Upper trapezius, scalene, and levator scapulae stretching, adding overpressure as tolerated

Other Therapeutic Exercises

- Chin tucks in supine position with towel behind head. The patient will lie flat on her/his back to help eliminate gravity and actively engage the deep neck flexors by gently nodding the head forward as if saying "yes" and slowly flattening out the lordotic curve of the cervical spine. Verbal cues and manual cues should be given to the patient to ensure proper form.
- Supine chin tucks with biofeedback cuff. Perform the previous exercise using biofeedback cuff in the lordotic curve of the cervical spine. Start with increasing the pressure 2 mm Hg above baseline and increase pressure in increments of 2 mm Hg until reaching 10 mm Hg and hold for 10 seconds. Perform 10 reps with 10-second holds.
- Progress to the performing chin tucks in seated position, allowing for patient to work against gravity in more functional position. Have patients maintain holds for up 30 seconds without the use of the biofeedback cuff. Be sure to monitor for correct form and give manual cues as needed.
- Upper extremity strengthening using progressive resistive exercises (PREs)
- Cervical muscle strengthening using PREs: Resisted cervical flexion, extension, and sidebending using light resistance with Thera-Band.
- Scapular strengthening using PREs

Activation of Primary Muscles Involved

- Deep neck flexors (longus capitis and longus colli)
  - The patient is first taught to perform a slow and controlled chin tuck, creating craniocervical flexion while flattening out the lordotic curve of the cervical spine.
  - The patient is then trained to increased control and endurance with the use of a biofeedback cuff.
  - Training then progresses into postural correction exercises in the sitting position, which is a more functional daily position.
  - The patient should be instructed to sit with a natural lordosis in the lumbar spine, gently retract the scapulae, and perform a slow chin tuck activating the longus capitis and longus colli.

Techniques to Increase Muscle Strength, Power, and Endurance

- Resisted cervical flexion, extension, and sidebending using Thera-Band and progressing resistance as tolerated.

TIMELINE 22-1: **Nonoperative Rehabilitation of Cervical Spine Strains/Sprains/Burners**

PHASE I (week 0 to 1)	PHASE II (weeks 2 to 4)	PHASE III (weeks 5 to 6)
• Gentle cervical AROM: All directions w/o overpressure • Cervical isometrics • Interferential current • Ice	• AROM/ AAROM/ PROM for full cervical ROM • Manual cervical mobilizations: Grade I/II → III/IV • Cervical PREs • Shoulder PREs • Scapular PREs • Deep neck flexor strengthening/ endurance training • Introduce throwing exercises using rebounder • Introduce light jogging program as tolerated	• Gym program • Plyometrics • Running

Plyometrics

- Throwing progression using weighted Theraballs and a rebounding trampoline for introduction of throwing and critique of throwing mechanics in preparation for sport-specific throwing

Functional Exercises

- Performing upper extremity proprioceptive neuromuscular facilitation training in the D1/D2 patterns will allow for strengthening in functional moments patterns with the incorporation of the scapula.
- Resistance should be progressive by starting with Thera-Band and progressing to the cable column as the athlete tolerates.

Milestones for Progression to the Next Phase

- Establish full pain-free cervical range of motion.
- Full pain-free shoulder range of motion
- No neurologic symptoms (radiculopathy, paresthesia)

Phase III (weeks 5 to 6)

Management of Pain and Swelling

- Ice as needed

Techniques for Progressive Increase in Range of Motion

Soft Tissue Techniques

- Soft tissue massage as needed to upper trapezius, sternocleidomastoid, scalene, and deep neck flexors

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Scalene, levator scapulae, upper trapezius stretching as needed

Activation of Primary Muscles Involved

- Strengthening exercises for trapezius, deltoids, pectoralis major, and rhomboids

Techniques to Increase Muscle Strength, Power, and Endurance

- Gym-based upper body strengthening program should be started focusing on muscles of the shoulders, chest, and back.
- Bench press, military press, power cleans, kettle bell swings, rows, burpees, pullups, and pushups should be incorporated in the gym and progressed slowly to make sure the athlete allows his or her body to adapt to increased training demands.

Plyometrics

- Box jumps and bounding exercise may be performed to train for control impact and landing for proper shock absorption and explosive moments.

Sport-Specific Exercises

- Sport-specific throwing program should begin, increasing distance and throw count as tolerated.

Milestones for Progression to Advanced Sport-Specific Training and Conditioning

- Full pain-free cervical range of motion
- Full pain-free shoulder range of motion
- No neurologic symptoms (radiculopathy, paresthesia)
- No functional limitations

Criteria for Abandoning Nonoperative Treatment and Proceeding to Surgery or More Intensive Intervention

- Persistent radiculopathies or paresthesias leading to muscle weakness or functional limitations

Performance Enhancement and Beyond Rehabilitation: Training/Trainer and Optimization of Athletic Performance

- Proper flexibility and strength of the neck and shoulders continue to be a focus for desired performance enhancement and injury prevention because stiffness and weakness are predisposing factors for burners.
- For football players, protective equipment such as raised shoulder pads, a cowboy collar, or a neck roll can reduce pressure on the neck and help augment shock absorption.
- Work with coaches and trainers on proper safe tackling technique to avoid further injury, keeping a more vertical and upright position to prevent dropping the shoulder and rotating the head and neck, which can result in lateral bending and extension of the cervical spine.
- Avoid hitting with the crown of the head to avoid axial compressive loading to the cervical spine.

Specific Criteria for Return to Sports Participation: Tests and Measurements

- Return to painfree cervical and shoulder range of motion
- Full strength and function

- Symptom free with no exacerbations with training or practice
- Normal upper extremity reflexes

Evidence

Borchgrevink G: Acute treatment of whiplash neck sprain injuries: A randomized trial of treatment during the first 14 days after a car accident. *Spine* 23:25–31, 1998.

This randomized study assessed the long-term consequences of whiplash cervical sprain in patients treated with two different rehabilitation programs during the first 14 days after injury. There was a significantly better outcome for patients in the act-as-usual group than those who took sick leave from work and were immobilized. (Level I evidence)

Feinberg J: Burners and stingers. *Phys Med Rehabil Clin North Am* 11:771–784, 2000.

This article defines stinger syndrome and the symptoms that are most commonly reported. Management, rehabilitation, and prevention guidelines are set for injury and return to sport. (Level III evidence)

Kelly J: Association of burners with cervical canal and foraminal stenosis. *Am J Sports Med* 28:214–217, 2000.

This retrospective study examined the images of 64 patients who sustained cervical burners. Significant differences were found between the burner and control groups for the mean minimum and mean average Pavlov ratios and foramen/vertebral body ratios. Scholastic athletes sustaining the burner phenomenon have an increased risk of cervical canal and foraminal stenosis as measured by the Pavlov and foramen/vertebral body ratios, respectively. (Level II-2 evidence)

Kuhlman G: The "Burner": A common nerve injury in contact sports. *Am Fam physician* 60:2035–2040, 1999.

This article reviews the pathophysiology, diagnostic testing, and management of athletes who sustain nerve injury from contact sports. Guidelines are reviewed for return to sport, prognosis, and steps that should be taken for future prevention of repeated injury. (Level II-3 evidence)

Safran M: Nerve injury about the shoulder in athletes, part 2. *Am J Sports Med* 32:1063–1076, 2004.

This two-part article is a review and an overview of the current state of knowledge regarding some of the more common nerve injuries seen about the shoulder in athletes, including long thoracic nerve, spinal accessory nerve, burners and stingers, and thoracic outlet syndrome. Each of these clinical entities is discussed independently, reviewing the anatomy, mechanism of injury, patient presentation (history and examination), the role of additional diagnostic studies, differential diagnosis, and management. (Level II-3 evidence)

Multiple-Choice Questions

QUESTION 1. Immediately following cervical sprain, patients should _____.

A. be immobilized
B. perform active range of motion
C. return to contact sports
D. be instructed to limit cervical range of motion

QUESTION 2. What type of strengthening should be introduced first following cervical sprain?

A. Isometric
B. Isotonic
C. Isokinetic
D. Plyometric

QUESTION 3. What criteria must be met for the athlete to return to sports?

A. Full cervical range of motion
B. No neurologic symptoms
C. Full strength
D. All of the above

QUESTION 4. Why is passive stretching avoided in the acute phase of a cervical sprain?

A. To prevent muscle tearing
B. To avoid headaches
C. To prevent paraspinal muscle spasms
D. This is not a requirement in the acute phase

QUESTION 5. What protective measures should be taken for football players who have sustained burners and are ready to return to sport?

A. Raised shoulder pads
B. Instruction on proper tackling technique
C. Cowboy collar
D. All of the above

Answer Key

QUESTION 1. Correct answer: **B** (see Phase I)

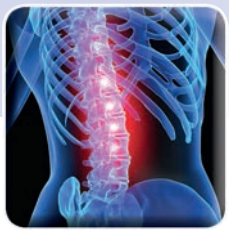
QUESTION 2. Correct answer: **A** (see Phase I)

QUESTION 3. Correct answer: **D** (see Phase III)

QUESTION 4. Correct answer: **C** (see Phase I)

QUESTION 5. Correct answer: **D** (see Phase III)

Chapter 23



Cervical Spine Disc Injuries

INTRODUCTION

Christopher K. Kepler, MD, MBA, Nikolaus S. Hjelm, MD, Gursukhmandeep S. Sidhu, MBBS, David Gendelberg, MD, and Alexander R. Vaccaro, MD, PhD

Epidemiology

- Disc degeneration is exceedingly common although only a small percentage of individuals with disc degeneration will need surgical intervention to address axial neck pain or a symptomatic herniated disc causing radiculopathy or myelopathy.
- In this sense, although athletic participation and subsequent injury may accelerate disc degeneration, this injury is by no means exclusively sport related.

Age

- Late twenties, early thirties, mean age of approximately 28 in series of professional rugby and American football players who underwent surgery for disc herniation

Sex

- Although disc degeneration occurs in both males and females, sports that require axial loading where disc herniation and return to play has been characterized in the literature are predominantly played at the professional level by men (rugby, American football).

Sport

- Rugby, American football

Position

- Rugby—heavy predominance of forward, especially first row (Figure 23-1); American football—most common in defensive players although also common in offensive lineman, running backs, and quarterbacks.

Pathophysiology

Intrinsic Factors

- Genetic factors account for approximately 70% of individual susceptibility.
- Many environmental factors have been proposed (occupational loading, tobacco, traumatic injury) and likely contribute but to a lesser degree than genetics.
- Congenital stenosis may contribute to susceptibility to radiculopathy or myelopathy related to a herniated disc (Figure 23-2).

Extrinsic Factors

- No extrinsic factors have been rigorously proved to be associated although predominance of defensive



FIGURE 23-1. Rugby scrum in which the players in the front line on each side push forward with their shoulders, head, and neck to gain an advantage. This tendency for high impact, repetitive load is thought to contribute to the high incidence of symptomatic cervical spine pathology in this group of players.



FIGURE 23-2. Lateral cervical spine radiograph of a patient with congenital stenosis. This diagnosis is made based on a ratio of the width of the spinal canal (**A**) to the width of the vertebral body (**B**) which is less than 0.8, a threshold suggesting the patient has congenital stenosis.

players in American football and front row players in rugby strongly suggests that repetitive axial loading is a risk factor.

Traumatic Factors

- Axial load

Classic Pathological Findings

- Radiculopathy
  - Myotomal weakness
- Myelopathy
  - Gait instability
  - Difficulty with fine motor control (e.g., buttoning shirt)
  - Difficulty performing repetitive tasks rapidly (Figure 23-3)
- Disc degeneration
  - None

Clinical Presentation

History

- Radiculopathy
  - May present with or without neck pain
  - Dermatomal pain, paresthesias or dysesthesias
- Myelopathy
  - May present with or without neck pain
  - Gait instability
  - Difficulty with buttons or handwriting
- Axial neck pain
  - Waxing-waning course
  - Pain may include any region of posterior head/neck from occiput to periscapular area

Physical Examination

Abnormal Findings

- Radiculopathy
  - Pain, paresthesias or dysesthesias found in dermatomal pattern
  - Myotomal weakness
  - Muscle atrophy in myotome possible but rare
  - Skeletal reflexes may be attenuated or absent compared with contralateral side
- Myelopathy
  - May have symptoms consistent with radiculopathy
  - Positive Hoffman's sign (Figure 23-4), Babinski's sign
  - Positive Romberg's sign, difficulty with tandem walk
  - Cannot perform repetitive activities rapidly (alternating hand slap on other hand) (see Figure 23-3)
  - Skeletal reflexes may be hyperactive, patient may demonstrate clonus
- Axial neck pain
  - None

Pertinent Normal Findings

- Radiculopathy
  - No Hoffman's reflex or Babinski's sign
- Axial neck pain
  - Normal neurological examination

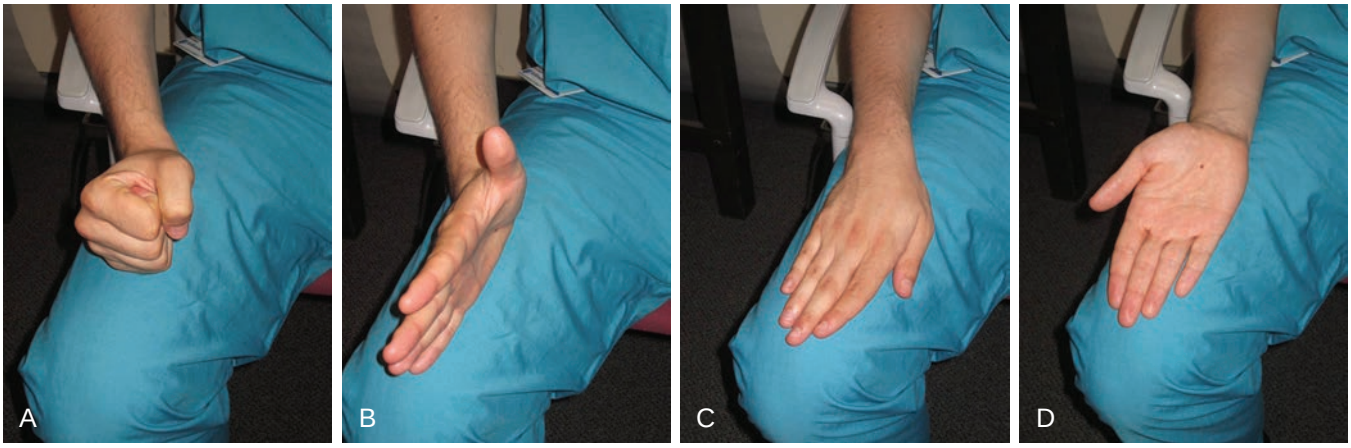


FIGURE 23-3. Players with cervical myelopathy due to spinal cord compression often have difficulty performing repetitive tasks quickly, such as closing (**A**) and opening (**B**) closing a clenched fist rapidly or slapping the palm (**C**) and then dorsum (**D**) of their hand on their anterior thigh.

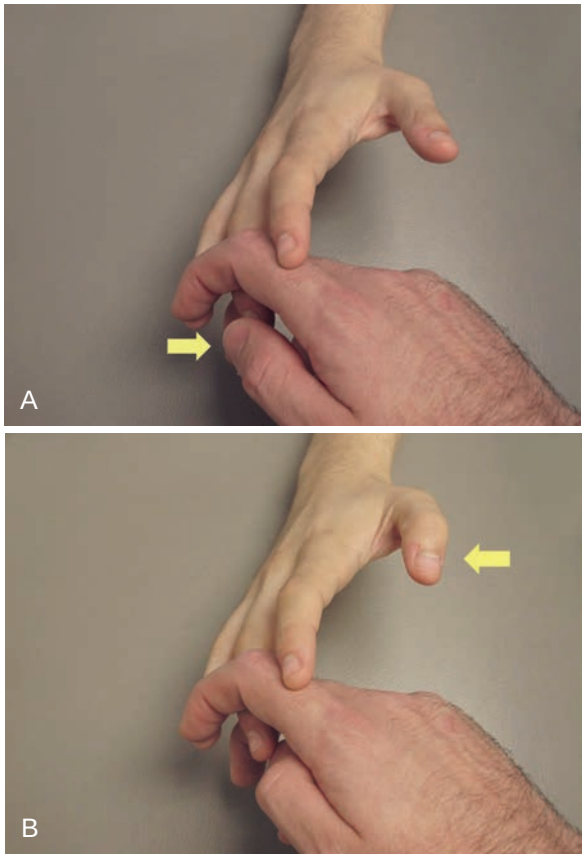


FIGURE 23-4. A, Hoffman's test is performed by stabilizing the middle phalanx of the third finger and flicking (*arrow*) or tapping the distal phalanx of the third finger. **B,** The test is positive when this action results in a reflexive flexion of the interphalangeal joint of the thumb (*arrow*), a finding suggestive of spinal cord compression.

Imaging

- Radiographs—to evaluate canal anteroposterior diameter to rule out congenital stenosis. Significant stenosis may be contraindication to contact sports participation.
- MRI—to evaluate disc degeneration, neural element compromise.
- CT occasionally helpful for further anatomic detail regarding congenital stenosis

Differential Diagnosis

- Peripheral nerve entrapment—median and ulnar neuropathy may mimic C6 and C8 radiculopathy, respectively (Figure 23-5). Differentiated by electromyogram (EMG).
- Neurological disease such as amyotrophic lateral sclerosis (ALS) or multiple sclerosis (MS). ALS diagnosed by EMG and findings that do not localize to cervical spine nerve roots, such as tongue fasciculations, MS differentiated by EMG and MRI and by discordant symptoms (e.g., cranial nerve involvement).
- Fibromyalgia—trigger points near cervical spine but also common over lower back, buttocks, and greater trochanter (Figure 23-6). Associated sleep disturbance nearly universal on history.

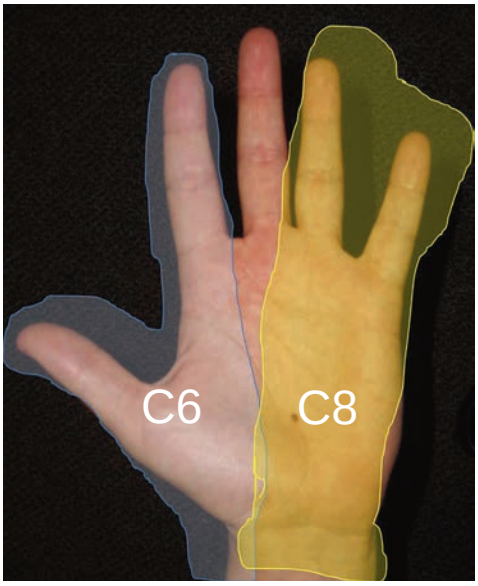


FIGURE 23-5. Dermatomes of the hand. C6 and C8 radiculopathy can be confused with peripheral compression of the median nerve and ulnar nerve, respectively, which have a similar distribution in the hand.

Treatment

Nonoperative Management

- Radiculopathy
  - Activity avoidance, nonsteroidal antiinflammatory medications, possible brief period of immobilization using soft collar, avoid narcotic use
  - Epidural steroid injections to nerve root at which symptoms localize
- Myelopathy
  - No role for nonsurgical treatment in young athlete
- Axial neck pain
  - Primarily nonsurgical treatment because the surgical result is often poor. Maintain range of motion (ROM), avoid prolonged immobilization.

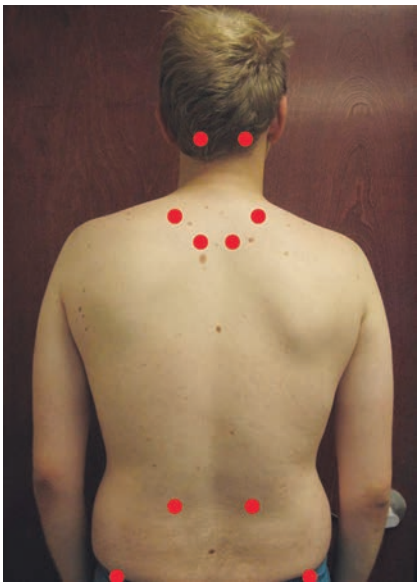


FIGURE 23-6. Stereotypic locations (*red circles*) of trigger points in patients with fibromyalgia.

- Nonsteroidal antiinflammatory medications useful, role of steroid injection unclear
- Avoid exacerbating activities.
- Pain management as necessary

Guidelines for Choosing Among Nonoperative Treatments

- Radiculopathy
  - Begin with activity avoidance and antiinflammatory medications and progress to epidural injections if the patient fails less invasive treatment.
- Myelopathy
  - N/A
- Axial neck pain
  - Initial treatment should focus on avoiding immobilization, maintaining range of motion with use of nonsteroidal antiinflammatory medication as necessary.
  - If pain cannot be managed otherwise, referral to pain management specialist may be useful.

Surgical Indications

- Radiculopathy
  - Incapacitating pain with failure of nonsurgical treatment
  - Progressive neurological deficit
  - Neurological deficit that fails to improve
- Myelopathy
  - Should be treated surgically in all young patients
- Axial neck pain
  - Surgical indications are failure of nonsurgical modalities, although indications for neck pain operations are heavily surgeon-dependent.

Aspects of History, Demographics, or Exam Findings That Affect Choice of Treatment

- History of improving radicular or axial neck pain symptoms may encourage longer trial of nonsurgical treatment as radiculopathy often resolves spontaneously, allowing the athlete to avoid surgery, and axial neck pain commonly has a waxing-waning course.
- Multiple affected levels (>2) in athletes with radiculopathy will preclude return to play if treated using spine fusion; athletes may elect for longer nonsurgical course rather than face career-ending surgery.
- Any signs or symptoms of myelopathy are an absolute indication for decompression and fusion.
- Patients with symptomatic disc herniation in the setting of congenital stenosis may be more likely to be treated with multilevel posterior surgery or anteroposterior surgery, which will often end the athlete's career.

Aspects of Clinical Decision Making When Surgery Is Indicated

- Kyphotic alignment of the cervical spine is a contraindication for posterior-only decompression and fusion.
- Athletes undergoing surgery for more than three affected levels will usually be treated with posterior decompression and fusion.
- Athletes with severe axial neck pain who elect to undergo surgery should be counseled that results are less predictable and, in general, inferior to surgery for radiculopathy or myelopathy.
- Motion-preserving surgery such as cervical disc replacement is contraindicated for contact athletes owing to the potential risk of component dislocation and spinal cord injury.

Evidence

Andrews J, Jones A, Davies PR, et al: Is return to professional rugby union likely after anterior cervical spinal surgery. *J Bone Joint Surg Br* 90(5):619–621, 2008.

This study reports the success of return to play in professional rugby players after surgical treatment for cervical disc herniation. (Level IV evidence)

Battie MC, Videman T, Kaprio J, et al: The Twin Spine Study: Contributions to a changing view of disc degeneration. *Spine J* 9:47–59, 2009.

This multinational study of a large cohort of twins establishes genetics as a major contributor to pathological disc degeneration and suggests a much smaller role for other environmental factors previously thought to play a significant role in disc degeneration, such as smoking and occupational hazards.

Hsu WH: Outcomes following nonoperative and operative treatment for cervical disc herniations in National Football League athletes. *Spine* 36(10):800–805, 2011.

This retrospective cohort study reports the success of return to play in NFL players after surgical treatment for cervical disc herniation. (Level IV evidence)

Rihn JA, Anderson DT, Lamb K, et al: Cervical spine injuries in American football. *Sports Med* 39(9):697–708, 2009.

This review article describes commonly seen cervical spine injuries and treatment strategies associated with American football, the most common sporting mechanism of cervical spine injury seen in the United States. (Review)

Torg JS, Ramsey-Emrhein JA: Management guidelines for participation in collision activities with congenital, developmental, or postinjury lesions involving the cervical spine. *Clin J Sport Med* 7(4):273–291, 1997.

This article outlines management guidelines for many cervical spine injuries, including those related to disc injury. (Review)

Multiple Choice Questions

QUESTION 1. Based on current evidence, approximately what percentage of individual susceptibility to disc degeneration is owing to genetic influences?

A. 15%
B. 40%
C. 70%
D. 90%

QUESTION 2. For which of the following ailments on the differential diagnosis for cervical radiculopathy or myelopathy is sleep disturbance nearly universally found on taking a thorough history?

A. Multiple sclerosis
B. Amyotrophic lateral sclerosis
C. Axial neck pain
D. Fibromyalgia

QUESTION 3. Which of the following treatment strategies is most appropriate for a young athlete presenting with signs of myelopathy?

A. Observation as long as the athlete can compete without limitations
B. Surgery
C. Initial use of aggressive PT with traction and core strengthening.
D. Expectant observation with surgery if the athlete has neurological decline

QUESTION 4. What is the likelihood of return to play of a football lineman treated with four level anterior cervical fusion?

A. Zero—return to play is contraindicated.
B. Unlikely—patients treated with four level fusion rarely are asymptomatic after surgery.
C. Likely provided that the player has painless range of motion after surgery
D. Likely, although the player will likely not attain the same level of competitiveness after surgery

Answer Key

QUESTION 1. Correct answer: **C** (see Pathophysiology)

QUESTION 2. Correct answer: **D** (see Differential Diagnosis)

QUESTION 3. Correct answer: **B** (see Treatment)

QUESTION 4. Correct answer: **A** (see Aspects of History, Demographics, or Exam Findings That Affect Choice of Treatment)

NONOPERATIVE REHABILITATION OF CERVICAL SPINE DISC INJURIES

Christopher K. Kepler, MD, MBA, Michael J. Ross, MD, Christopher Peduzzi, MA, ATC, Rick Burkholder, MS, ATC, and Alexander R. Vaccaro, MD, PhD

Guiding Principles of Nonoperative Rehabilitation

- Allow acute symptoms to resolve. Although cervical spine should be protected from secondary injury, prolonged use of a cervical collar is discouraged.
- Gradually, range of motion must be resumed once axial pain has decreased and radicular pain is absent.
- Return to play is possible only when full, painless range of motion is possible.

Phase I: Acute Injury Phase (weeks 0 to 3)

Protection

- Cervical collar *may* be used if necessary to reduce painful muscle splinting, but its use should be minimized to prevent muscle atrophy and excessive stiffness caused by immobility.

Management of Pain and Swelling

- Nonsteroidal antiinflammatory drugs (NSAIDs) as necessary. The use of narcotics is discouraged but may be necessary for an acute radiculopathy.

Techniques for Progressive Increase in Range of Motion

- Little range of motion should be pursued during the period of acute radicular or axial pain if such range of motion exacerbates pain. Gentle passive range of motion may be pursued as the acute pain phase begins to abate.

Soft Tissue Techniques

- Although recommended by some, the benefit of manual traction for cervical disc degeneration or radiculopathy is uncertain and not recommended. Modalities, such as heat, electrical stimulation, ultrasound, and others may be used based on personal preferences of the treating physician. Little data are available regarding the long-term efficacy of these modalities in treating patients with cervical spine injuries.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- None in Phase I other than gentle passive range of motion.

Other Therapeutic Exercises

- Upper extremity activities that could potentially exacerbate cervical radiculopathy via nerve root traction should be avoided during the acute phase.

- Depending on axial pain distribution, periscapular strengthening exercises may also exacerbate pain and should be delayed until pain is improving.

Activation of Primary Muscles Involved

- Paraspinal musculature involved in cervical extension, superficial and deep flexors involved in cervical flexion, which are exercised in short arc range of motion.

Sensorimotor Exercises

- Postural training should commence to encourage long-term training of core neck musculature, including include neck retraction and scapular stabilizer retraction exercises.

Functional Exercises

- None other than postural training

Milestones for Progression to the Next Phase

- Axial pain becomes tolerable without narcotic analgesics, radiculopathy is substantially diminished or absent.
- Patient can tolerate 15 to 30 minutes of nonimpact exercise such as on an elliptical machine from a cardiovascular standpoint.

Phase II (weeks 1 to 8): Range of Motion Recovery Phase

Management of Pain and Swelling

- NSAIDs as necessary

Techniques for Progressive Increase in Range of Motion

- Any stretching activities such as slow passive movement to limits of range of motion (extension, flexion, side bending, rotation) that result in worsening of symptoms, especially radicular symptoms, should be immediately eased and attempted again with decreased amplitude after a cool-off period of several days.

Manual Therapy Techniques

- Joint mobilizations and manipulation to maintain range of motion and modulate associated pain (Figure 23-7), manually assisted flexion, extension, and side bending cervical stretches.

Soft Tissue Techniques

- Massage, heat for muscle relaxation, other modalities per physician preference may provide temporary relief of muscular discomfort although there is little evidence that these modalities have any long-term benefit.

Stretching/Flexibility Techniques for the Musculotendinous Unit

- Passive and active cervical flexion, extension, and side bending stretching

Other Therapeutic Exercises

- Scapular movement therapy should be initiated—shoulder shrugs, shoulder rolls, and scapular retraction and depression exercises designed to stretch and begin to strengthen (Figure 23-8).
- Longus colli strengthening and re-education can be initiated via neck retraction exercises, which can be done first without resistance then against resistance using a weighted headpiece or headband in the prone position.
- Limited upper extremity exercises can be initiated with light weights. Provided light weights are used and the trunk is stabilized during lifting, there are no limitations with respect to the type of lifts that can be performed.

Activation of Primary Muscles Involved

- Until the athlete has regained full, painless range of motion, strengthening of paraspinal muscles and anterior flexors is deferred. What constitutes full range of motion varies from athlete to athlete and ultimately must be subjectively determined by the athletes themselves.

TIMELINE 23-1: **Postsurgical Rehabilitation of Cervical Spine Disc Injuries**

PHASE I (weeks 0 to 3)	PHASE II (weeks 1 to 8)	PHASE III (weeks 8+)
• Cervical collar • Antiinflammatory medications • Full ROM avoided until painless • Short arc ROM for strengthening paraspinal musculature • Heat, ultrasound used per physician preference	• Discontinue collar • Gentle passive ROM—extension, flexion, side bend, rotation • Heat, ultrasound, massage per physician preference • Scapular exercises • Longus colli strengthening, re-education • Upper extremity exercise based on sport-specific demands • Proprioceptive exercise for neck	• Manual joint and soft tissue mobilization, manipulation • Aggressive A+PROM • Isometric, antigravity and resisted exercises through full ROM • Antiinflammatory medications • Cardiovascular exercise • Continue scapular, longus colli, upper extremity strengthening • Strengthening of deep cervical flexors • Proprioceptive exercise for neck • Performance of all exercise wearing helmet for helmeted athletes • Weighted helmet for supraphysiological exercise as tolerated • Simulated game environment to assess readiness for return to play



FIGURE 23-7. Cervical mobilizations and manipulation by a therapist increases passive range of motion in a controlled setting and may also identify directions of motion in which the player continues to have difficulty. Cervical mobilizations and manipulation starting in the neutral position (**A**), may include side bend (**B**), rotation (**C**), and traction (**D**).

Sensorimotor Exercises

- A proprioceptive component can be added to postural exercises though the integration of isometric or isotonic resistance exercise with the use of a balance ball or unstable surface (Figure 23-9).

Open and Closed Kinetic Chain Exercises

- Gentle open kinetic chain exercises can be used for scapular strengthening although aggressive strengthening is deferred until the next stage.

Techniques to Increase Muscle Strength, Power, and Endurance

- Because of the risk of symptom recurrence with increased loading of the cervical spine because of the discogenic nature of the symptoms, muscle strengthening is deferred until a full, painless range of motion is established.

Functional Exercises

- Postural training and re-establishment of full range of motion to facilitate both activities of daily living as well as return to play.

Milestones for Progression to the Next Phase

- Full, painless range of motion. As in the preceding, the baseline range of motion will vary between individuals and must be judged by the athlete.
- No residual radiculopathic symptoms, minimal or absent axial pain symptoms

Phase III (weeks 8+): Strengthening Phase

Management of Pain and Swelling

- NSAIDs as necessary

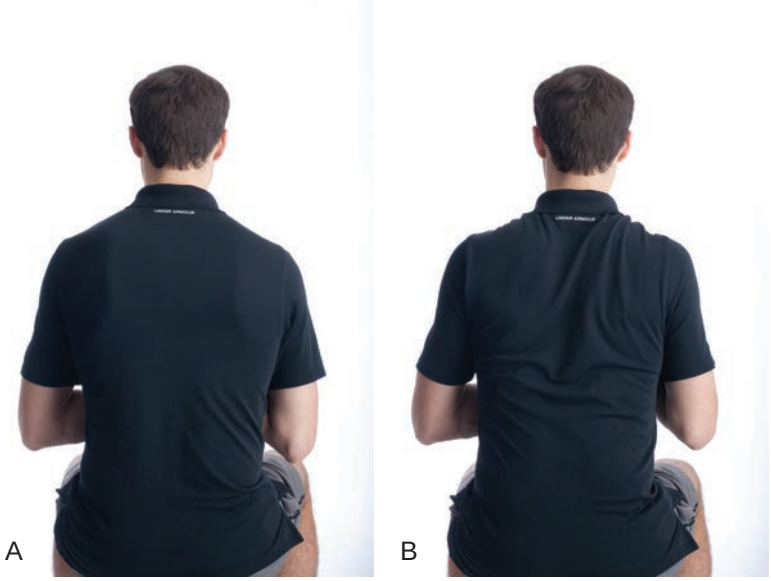


FIGURE 23-8. Neutral scapular position (**A**) and scapular retraction (**B**) are demonstrated. As players establish periscapular strength, resistance can be added with either resistance bands or weights.

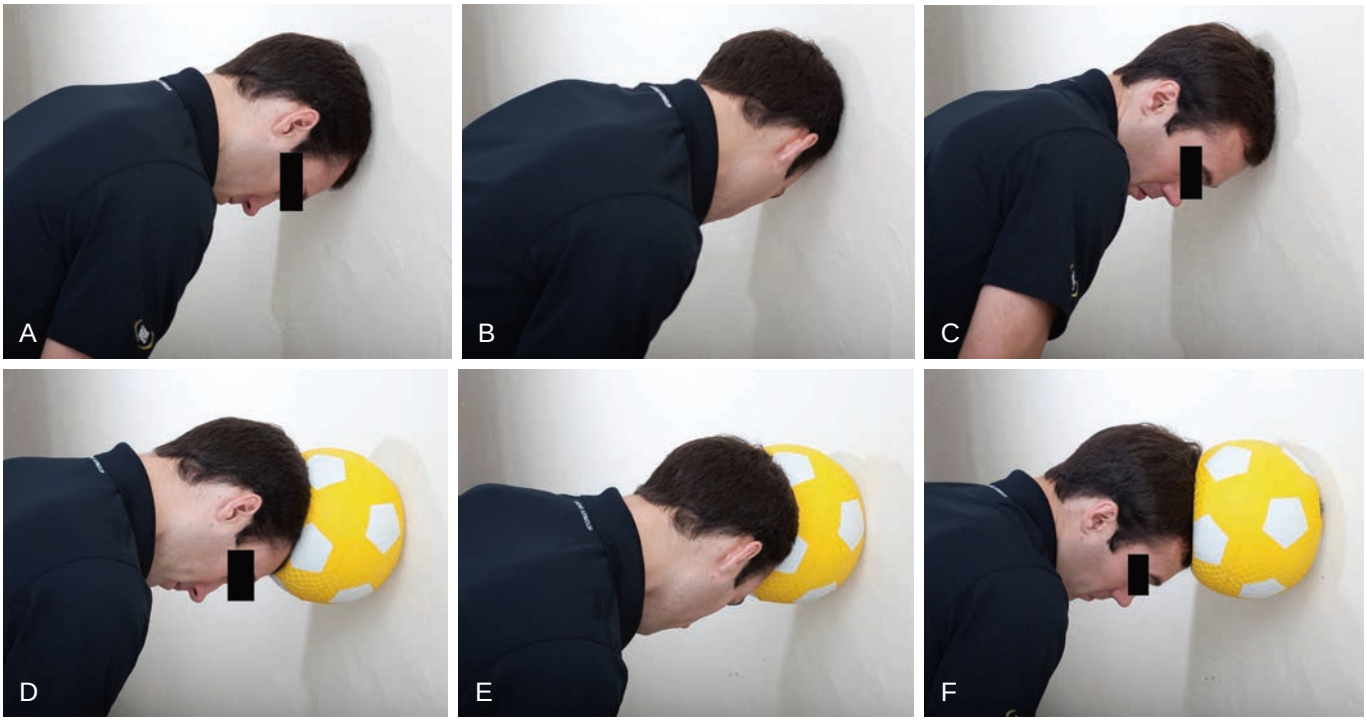


FIGURE 23-9. Progression that simultaneously works on both range of motion and proprioception against the wall (**A–C**) and using a ball (**D–F**).

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Joint mobilizations and manipulation to maintain range of motion and modulate associated pain, more aggressive manually assisted flexion, extension, and side bending cervical stretches

Soft Tissue Techniques

- Soft tissue mobilization to decrease apprehension, modalities as in the preceding

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Continue stretching exercises as outlined in Phase II.

Other Therapeutic Exercises

- Cardiovascular exercise and core strengthening should commence to facilitate a return to competition.
- Upper extremity and periscapular muscle open chain strengthening should be increased in preparation for resuming competition. Upper extremity exercises will be almost entirely sport-specific and will vary widely but are important because periods of neck immobilization during early recovery often indirectly result in limitation of upper extremity activity and associated loss of strength.
- Continue strengthening of longus colli and other paraspinal musculature progressing from isometric exercises to exercises bearing body weight. As described, the longus colli can be strengthened through neck retraction exercises. Additional exercises to build paraspinal strength include scapular stabilizer retraction and neck extension in the prone position to lift both the head and shoulders off the floor.

Activation of Primary Muscles Involved

- Core paraspinal muscles, such as longus colli, should be strengthened as described above to provide assistance to the superficial cervical flexors. The work load of the superficial cervical flexors should be decreased as these often tend to assume a disproportionate amount of post-injury work load.

Sensorimotor Exercises

- Proprioception training continues as in Phase II.

Open and Closed Kinetic Chain Exercises

- Although the focus of Phase III should be on strengthening of the cervical musculature, open kinetic chain exercises should be used for scapular and upper extremity strengthening and will vary widely by sport.

Techniques to Increase Muscle Strength, Power, and Endurance

- The tendency to preferentially recruit superficial flexors should be addressed. This can be accomplished by encouraging strengthening of the deep flexors using a chin tuck exercise (Figure 23-10).
- Flexion, extension, and side bending strength should be increased by progressing through a combination of isometric, antigravity and resisted exercises.

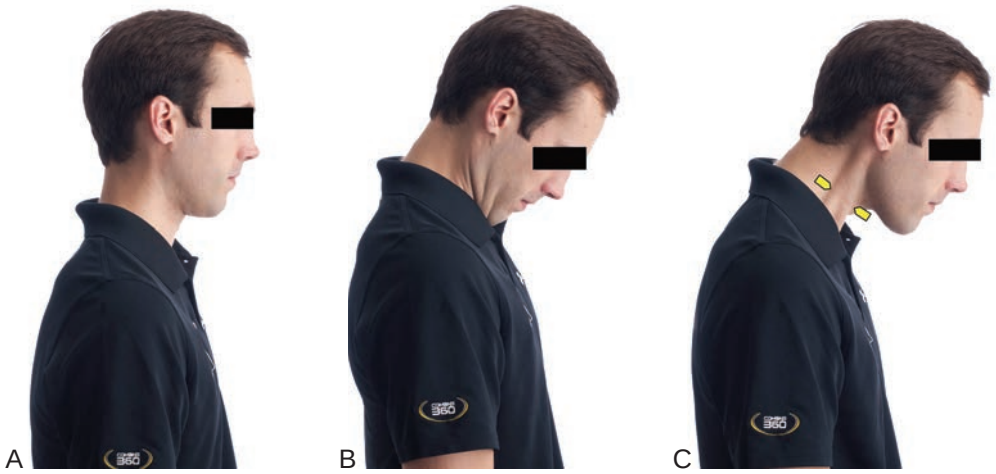


FIGURE 23-10. Chin tuck exercise. From the neutral position (**A**), the therapist must ensure that the player tightly tucks the chin to recruit the deep cervical flexors (**B**) and not allow the player to move their head too far forward (**C**), which preferentially recruits the sternocleidomastoid muscles (*arrowheads*).

Resistance can be provided through the use of rubber tubing, pulleys, or manual methods. When an increase in resistance results in recurrent symptoms, the amount of resistance should be decreased to continue strengthening. Loading can be advanced as tolerated.

Functional Exercises

- Continued stretching exercise to maintain full range of motion for sporting and everyday activities.

Sport-Specific Exercises

- Strengthening and stretching exercises can be done with helmet in place to simulate game time loading.
- Athletes should not return to sport wearing a collar. Players who require a collar to be able to perform athletically should not be playing, and there are no orthoses designed to provide the combination of mobility and stabilization which would be necessary in many sports.
- The principle of overload may be used to strengthen using a weighted helmet to increase muscle strength in a controlled environment.
- Simulated game situations may be helpful for assessing readiness to return to competition.

Milestones for Progression to Advanced Sport-Specific Training and Conditioning

- Full, painless range of motion with evidence of normal strength on manual muscle testing
- Before the contact athlete is allowed to return to play, the training staff should put the athlete through simulated gamelike activities emphasizing cervical flexion, extension and rotation activities that may provoke residual symptoms to ensure the athlete is ready to return to full contact activity.

Criteria for Abandoning Nonoperative Treatment and Proceeding to Surgery or More Intensive Intervention

- Progressive neurological symptoms or evidence of myelopathy
- Unrelenting pain which prohibits return to range of motion and strengthening

Tips and Guidelines for Transitioning to Performance Enhancement

- During the period in which an athlete is transitioned from a rehabilitation scheme to gradually return to play, the full complement of strengthening and stretching exercises should continue until the athlete is fully integrated into a normal training schedule.
- Even then, core strengthening and stretching should continue as an adjunct to customary sport-specific training to minimize the likelihood of symptom recurrence.

Performance Enhancement and Beyond Rehabilitation: Training/Trainer and Optimization of Athletic Performance

- Initial efforts should attempt to identify the mechanism of injury if known and evaluation the player for any underlying contributing weakness that can be addressed through targeted exercise to prevent recurrent injury.
- A period of transition to full training for the injured helmeted athlete may involve continuing all rehabilitation exercises with the helmet in place to increase the

load seen by cervical musculature and more closely simulate physiologic demands of competition.
- Before the contact athlete is allowed to return to play, the training staff should put the athlete through simulated gamelike activities emphasizing cervical flexion, extension, and rotation activities, which may provoke residual symptoms to ensure the athlete is ready to return to full contact activity.

Specific Criteria for Return to Sports Participation: Tests and Measurements

- Athlete is able to perform all sport-specific activities at full speed without pain.
- Athlete demonstrates no hesitation or compensatory movement when performing cervical flexion, extension or rotation in game simulations. As the contributions of cervical spine range of motion to most sporting activities is indirect, this must be assessed subjectively by the athlete and trainers or coaches who are observing the player at full speed practice.

Evidence

There are little published data exploring the use of rehabilitation techniques after cervical injury. The only available literature consists of review articles that communicate guidelines based on the experience of experts in the field.

Torg JS, Ramsey-Emrhein JA: Suggested management guidelines for participation in collision activities with congenital, developmental, or postinjury lesions involving the cervical spine. *Med Sci Sports Exerc* 29(7 suppl):S256–S272, 1997.

This article outlines management guidelines for many cervical spine injuries, including those related to disc injury. (Level IV evidence)

Vaccaro AR, Klein GR, Ciccoti M, et al: Return to play criteria for the athlete with cervical spine injuries resulting in stinger and transient quadriplegia/paresis. *Spine J* 2:351–356, 2002.

In addition to highlighting return to play criteria, this review article outlines the diagnostic workup necessary for patients with neurological symptoms after sporting injuries. (Level IV evidence)

Multiple Choice Questions

QUESTION 1. What is the principal goal of Phase II?

A. Resolution of acute pain
B. Strengthening of core muscles
C. Return to play
D. Restoration of range of motion

QUESTION 2. What is the role of a cervical orthosis in Phase I?

A. A soft cervical orthosis may be used but should be discontinued as quickly as symptoms allow.
B. A hard cervical orthosis should be used for 2 weeks to provide support followed by a transition to a soft collar for another 2 weeks.
C. Use of a cervical orthosis should be strongly discouraged.
D. A cervical orthosis (soft or hard) should be used for the entirety of Phase I to facilitate reduction in pain.

QUESTION 3. Which of the following indicates an injury not amenable to a course of nonsurgical treatment?

A. C5 radiculopathy
B. Axial neck pain which is severe on initial presentation
C. Bilateral symptoms of radiculopathy
D. Left arm pain in the C6 distribution accompanied by difficulty manipulating small objects and buttoning shirts.

QUESTION 4. What rehabilitation technique for helmeted athletes may ensure that the athlete can return to the supraphysiological demands placed on the neck during competition?

A. Strength training using resistance bands
B. Game simulation
C. Game simulation wearing a helmet
D. Endurance training using a linear periodization

Answer Key

QUESTION 1. Correct answer: **D** (see Phase II)

QUESTION 2. Correct answer: **A** (see Phase I)

QUESTION 3. Correct answer: **D** (see Criteria for Abandoning Nonoperative Treatment and Proceeding to Surgery or Other More Invasive Intervention)

QUESTION 4. Correct answer: **C** (see Performance Enhancement and Beyond Rehab: Training/Trainer, and Optimization of Athletic Performance)

BEYOND BASIC REHABILITATION: RETURN TO CONTACT SPORTS AFTER CERVICAL SPINE INJURY

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Aspects of Contact Sports That Require Special Attention in Rehabilitation

- Athletes are susceptible to secondary injury in contact sports secondary to loss of structural integrity related to the primary injury.
- Athletes are also susceptible to secondary injury in contact sports owing to impaired self-protection mechanisms related to decreased range of motion and muscle strength.
- Specific risks vary widely with the nature of individual contact sports, the use of a helmet or other protective devices and the level of competition.

Introduction

- Although serious cervical spine injuries are relatively rare in contact sports, the potential for catastrophic career-ending and life-altering consequences demands strict adherence to return to play criteria.
- The spectrum of severity of cervical spine injury is wide. Although some conditions, such as a stinger, will result in rapid abatement of symptoms and return to play, other more serious injuries or chronic conditions may require surgery that will substantially delay, or even preclude, return to play.
- For this reason, this chapter focuses on return to play after either a stable cervical spine fracture which does not preclude return to play or after one- or two-level spinal fusion in athletes without a contraindication to return to play.
- No guidance in the literature is available on rate of return to play in athletes after minor cervical fractures, likely because of the clinical insignificance of the most common injury patterns, such as spinous process fractures or nondisplaced compression fractures and the relative rarity that prevents any one clinician from assembling a series to report outcome.
- In contrast, chronic cervical disc injury leading to herniation or degeneration is much more common in sports that result in axial loading of the head and neck such as American football and rugby.
- In series describing outcomes after anterior cervical discectomy and fusion in professional football and rugby players, return to play at the same level of competition was remarkably similar at about 70%.

Phase I: Advanced Strength and Conditioning Programs

Periodization

- Undulating periodization is ideal for strength building and recommended during rehabilitation of the cervical spine after surgery or injury. Undulating periodization uses weekly cycles of increasing resistance. The cycle repeats: Hard, Harder, Hardest, Rest, Hard, Harder, and Hardest.

TIMELINE 23-2: **Postsurgical Rehabilitation of Cervical Spine Disc Injuries**

PHASE I (weeks 8 to 12 post injury/ postoperative)	PHASE II (weeks 12 to 15)	PHASE III (15+ weeks)
• Removal of collar after 2 weeks in case of 1 or 2 level spinal fusion, 8 weeks for fracture to allow for healing • Antiinflammatory medications avoided until 3 months post op or post injury • Full ROM avoided until painless • Short arc ROM for strengthening paraspinal musculature • Heat, ultrasound used per physician preference	• Discontinue collar • Aggressive cardiovascular training to regain fitness level • Gentle passive ROM—extension, flexion, side bend, rotation • Heat, ultrasound, massage per physician preference • Antiinflammatory medications • Scapular exercises • Longus colli strengthening, re-education • Upper extremity exercise based on sport-specific demands • Proprioceptive exercise for neck • Strengthening exercises using sport-specific training parameters	• Manual joint and soft tissue mobilization, manipulation • Aggressive A+PROM achieved before strengthening begins • Isometric, antigravity and resisted exercises through full ROM • Sport-specific training and strengthening depending on sport type: Tracking, Momentum Generator, or Support Sports • Weighted helmet for supraphysiological exercise as tolerated • Simulated game environment to assess readiness for return to play • Released to competition when full-speed simulation produces no pain, excess fatigue or loss of head/neck control even in simulation exceeding game length

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

1. Flexibility/joint mobility for joint stability is essential to rehabilitation of the neck after a spinal injury or surgery. For most sports, the neck is primarily used to position the head in space and does not play a direct role in competition with the exception of striking a ball with the head in soccer, which uses neck motion to transfer momentum to the ball and front row rugby players, who push in part with their neck to gain advantages during the scrum (see Figure 23-1 in the Introduction).
2. Training with optimum posture is important for all sports because of the importance of head position to integrate visual and auditory stimulation and for balance.
3. Sensorimotor and balance training
4. Core training is essential. Most of the paraspinal musculature can be considered core muscles.
5. Cardiorespiratory training helps maximize cervical musculature endurance to maintain head control even when fatigued.
6. Multiplanar training activities
7. Training for optimum muscle functional strength, to control the position of the head should it be subject to rapidly applied external force or when the body accelerates or decelerates quickly and the neck must accommodate to control the effect on the mass of the head.
8. Training for speed, agility, quickness (SAQ), again in the context of positioning the head in space to allow for integration of situational information and muscle coordination.
9. Plyometric training is not typically used for the neck in isolation but the neck must be able to accommodate to control head momentum when plyometric exercise are used in the rest of the body.
10. Functional training includes achieving a full range of motion to allow for activities of daily living.
11. Sport-specific training is particularly important for helmeted athletes where the neck bears a greater-than-physiological load and for sports such as cycling, which require a particular, somewhat unnatural neck position (neck extension with the body in the "tuck" position in order to visualize the road ahead, oftentimes, for extended periods of time) (Figure 23-11).

Olympic Lifts Used in the Training Program

- No specific lifts are typically used to rehabilitate the neck but good posture of the neck should be maintained during lifting to strengthen other parts of the body.

Training Principles Used in the Design of the Program

- Principle of specificity: specific adaptation to imposed demands (SAID) should be used to address sport specific demands considering variables, such as requirements for range of motion, endurance, speed and power.



FIGURE 23-11. The tuck position in cycling places the rider's head and neck in the hyperextended position necessary to see the road and other riders ahead.

Application of Acute Training Variables

- These training variables are applied differently depending on the sport-specific requirements. In general, because of the limited positions in space that the neck can occupy, exercises are typically limited to resisted flexion, extension, side bend, and rotation. Flexion, extension, and side bends are strengthened first by positioning the body such that each motion occurs against gravity and continues in the same manner as head weights or exercise bands are added to increase resistance. Rotational muscles are more difficult to strengthen but typically done with exercise bands held to the chin. Specific recommendations for specific sports follow.
- Sports that require endurance should arrange exercises into four sets of 15 to 20 repetitions with repetition tempo varying with the sport-specific demands. For instance, cyclists who require holding an extended neck position for "tuck" riding would use a slow repetition tempo of extension exercises to mimic long periods of isometric contraction.
- Sports requiring neck strength should perform exercises in three sets with 8 to 12 repetitions and should vary repetition tempo to accommodate sport-specific demands.
- Finally, sports requiring neck power should perform three sets of six to eight repetitions with rapid tempo.

Phase II: Performance Enhancement Training Techniques

- Rehabilitation of the neck after cervical spine injury is somewhat different from extremity musculoskeletal injuries in that the neck is primarily important in sport in an indirect manner.
- In this sense, general performance optimization will include identification and treatment of specific

structural or medical problems contributing to susceptibility to the index injury.
- Generalized performance enhancement training is not typically part of cervical spine rehabilitation, which focuses much more on sport-specific training once pain has subsided and range of motion has returned to normal.

Phase III: Sport-Specific Training

- For sport-specific training guidelines, sports will be broken up into three types depending on the contribution of the cervical spine to the sport. The three types we will use throughout this section include Tracking sports, Momentum Generator sports, and Support sports.
- Tracking sport examples include ball sports such as basketball, in which the neck is used primarily to position the head to follow the ball, see other players, or the field.
- In contrast, Momentum Generator sports primarily include soccer, in which the neck is important in imparting force to the ball when heading the ball.
- Finally, Support sports include helmeted sports in which a supraphysiological load is supported by the neck or sports such as martial arts, in which the neck must routinely respond to sudden acceleration or deceleration moments.

Periodization

- Undulating periodization is ideal for strength building and recommended during rehabilitation of the cervical spine after surgery or injury.

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- All sport types should utilize training with optimum posture, core training, cardiorespiratory training, training for optimal muscle balance, and neuromuscular dynamic stability exercises.
- These concepts as applied to rehabilitation of the neck, however, will mostly be used indirectly during exercises for the rest of the body with the exception of postural and core training, which are of primary importance to the neck itself.
- Flexibility and joint mobility are a requisite for even beginning sport-specific training for the neck, and athletes should not be considered for return to intensive training unless flexibility and mobility have returned to baseline after injury. Range of motion will vary from athlete to athlete and must ultimately be judged by the athletes themselves
- For Tracking sports, joint mobility and flexibility training incorporating multiplanar exercises are particularly important. Athletes must optimize functional power for sport-specific tasks, and rehabilitation should incorporate speed, agility, and quickness (SAQ) drills for sport-specific situations, such as quickly turning the head to visualize players or incoming balls during fast break drills in basketball, for example.
- For Momentum Generator sports, training should also focus on developing optimum functional power from sport-specific tasks, and SAQ drills are similarly important for coordinating the head-strike on a moving soccer ball.
- Finally, Support sports require the development of optimal functional strength and should focus on eccentric exercises, a rehabilitation strategy used to re-build strength as quickly as possible.

Training Principles Used in the Design of the Program

- The principle of variation is essential because of the often subconscious movement of the neck in many different activities, but this will be accomplished often unintentionally through routine sport-specific training with an overt focus on the neck, although appropriate posture must always be emphasized.
- The principle of progression should be employed in particular for Momentum Generator sports in order not to overburden the recovering and rebuilding neck musculature before adequate recovery has restored sufficient strength.
- As described in the preceding, the concept of specific adaptation to imposed demands is the largest determinant of rehabilitation protocol as neck function varies widely across different sports but is essential in nearly all sport.

Application of Acute Training Variables

- As described in Phase I, designing rehabilitation protocols for the neck depends heavily on the sport-specific demands and unique positional requirements.
- Sports that require endurance and have prolonged postural requirements such as cycling should arrange exercises into four sets of 15 to 20 repetitions with repetition tempo varying with the sport-specific demands but with a tendency toward slower repetition tempo.
- Sports requiring neck strength should perform exercises in three sets with 8 to 12 repetitions and also should vary repetition tempo to accommodate sport-specific demands.
- Finally, sports requiring neck power should perform three sets of six to eight repetitions with rapid tempo.
- Specific exercises for Tracking sports will emphasize complete recovery of range of motion and muscle stretching to accommodate restoration of the extremes of motion. Range of motion will vary from athlete to athlete and must ultimately be judged by the athletes themselves.
- Building strength is important for Momentum Generation sports and may use exercises with elastic exercise bands and a head harness.
- Finally, Support sports should focus on integrating eccentric exercises and exercises performed with the helmet in place when appropriate to optimize control of the head, especially during unpredictable acceleration and deceleration periods that are likely in sports like martial arts as well as helmeted contact supports like American football and hockey.

Sports Performance Testing

General Information

- Information about the injury history and mechanism of injury are important to identify potential weak or injured muscle groups that should be strengthened before return to play.
- Medical history should explore whether unsteadiness or imbalance may have contributed to the injury, especially as these can be associated with cervical spine pathology.
- Finally, the timing and nature of any prior cervical spine or neck surgery is important to learn about appropriate timing of return to play and any associated muscular deficits that may have resulted from surgical intervention (Figure 23-12).

Specific Tests

- Physiological assessments in the way of restoration of full, active range of motion are necessary not only before the athlete returns to play but full range of motion should be restored before high-level training starts. Range of motion will vary from athlete to athlete and must ultimately be judged by the athletes themselves.
- As the player returns to full training but before return to competition, the training staff should evaluation whether the player is able to demonstrate sport-specific neck control during explosive efforts in full-speed game situations and simulations. Range of motion will vary from athlete to athlete and must ultimately be judged by the athletes themselves; functional return of full range of motion in game situations can also be judged to some extent by coaches and trainers observing simulated game environments.
- Movement performance testing will vary from sport to sport. Examples include achievement of sufficient neck extension to see the horizon in cyclists in the "tuck" position, 180° of side to side head rotation in the supine position without lifting the shoulder blades from the ground (Figure 23-13) and painless chin-on-chest and vertical gaze in Tracking athletes (Figure 23-14).

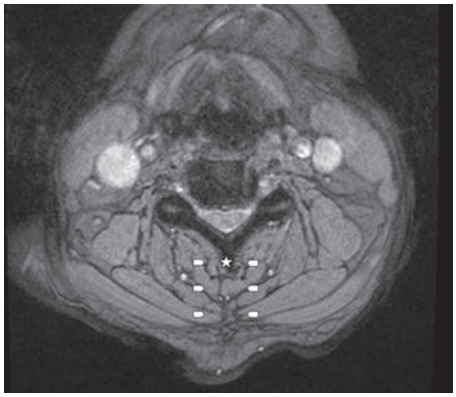


FIGURE 23-12. Axial MRI image of the cervical spine. The paraspinal muscles (*arrowheads*) are detached from the spinous processes (*star*) during the surgical approach. This dissection makes rehabilitation of these muscles challenging in the postoperative setting when an athlete is attempting to return to play.

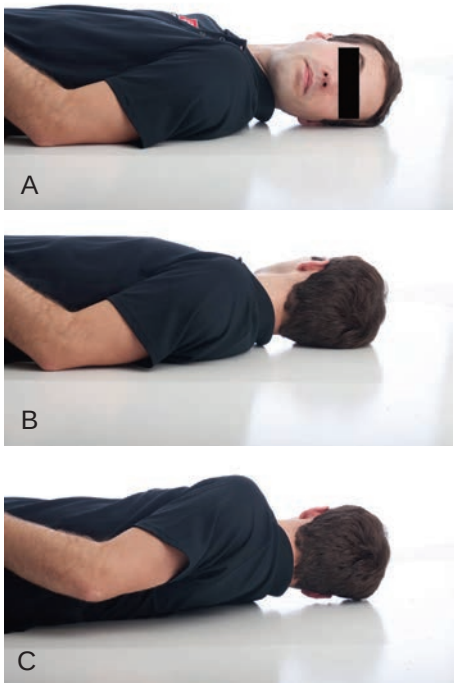


FIGURE 23-13. Side to side neck rotation is an example of a performance motion test that evaluates the athletes to perform uncompensated neck rotation which is essential in tracking sports as well as other types. The player should be able to rotate through a motion arc of 180° (**A**,**B**) without compensating for limited neck motion by rotating the entire body which results in elevation of a shoulder off the ground (**C**).

Specific Criteria for Progression to the Next Stage to Determine Readiness for Contact Sports

- Patients may progress to sport-specific training once they have achieved painless range of motion and have grossly normal neck strength. Range of motion and strength will vary from athlete to athlete and must ultimately be judged by the athletes themselves as there are no guidelines or standards for neck strength.
- Assessment of the latter requires experience on the part of the athletic trainer as the neck is an infrequent training target in most athletes not recovering from a specific injury or surgery.

Specific Criteria for Release to Unsupervised Complete Participation in Contact Sports

- Painless cervical spine control during full-speed game simulation, even after an extended period of simulation that exceeds the normal period of competition. Range of motion and strength will vary from athlete to athlete and must ultimately be judged by the athletes themselves as there are no guidelines or standards for neck strength. Functional exercises are often sport-specific and are constructed to assess the most demanding

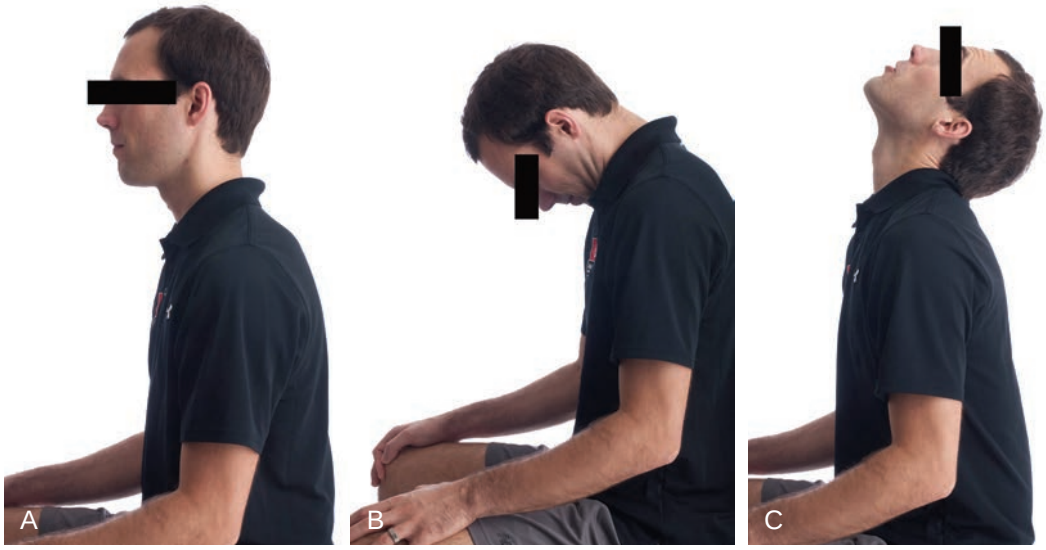


FIGURE 23-14. Starting in the neutral position (**A**), the player should be able to demonstrate the chin-on-chest position (**B**) and a vertical gaze (**C**) without any associated pain.

aspects of particular sports with respect to neck range of motion and/or strength. Examples include achievement of sufficient next extension to see the horizon in cyclists in the "tuck" position for extended periods of time, 180° of side to side head rotation in the supine position without lifting the shoulder blades from the ground (see Figure 23-13) and painless chin-on-chest and vertical gaze in Tracking athletes (see Figure 23-14).

Recommended Ongoing Exercises

Postural control should be practiced indefinitely, and patients with prior cervical injury must understand the importance of withdrawing from competition when fatigue threatens the ability to control the head as they are often susceptible to reinjury.

Evidence

There are little published data exploring the use of rehabilitation techniques after cervical injury. Other than articles describing rehabilitation theory in general, the only available literature that specifically addresses this topic of this chapter consists of review articles that communicate guidelines for return to play (see Evidence section for The Introduction and Nonoperative rehabilitation sections of this chapter) based on the experience of experts in the field.

Miranda F, Simão R, Rhea M, et al: Effects of linear vs. daily undulatory periodized resistance training on maximal and submaximal strength gains. *J Strength Cond Res* 25(7):1824–1830, 2011.

Undulatory resistance training demonstrated trends toward superior strength increases compared with linear periodization in a group of resistance trained men. (Level II evidence)

Prestes J, Frollini AB, de Lima C, et al: Comparison between linear and daily undulating periodized resistance training to increase strength. *J Strength Cond Res* 23(9):2437–2442, 2009.

This investigation compared linear and undulating periodized training programs and found that undulating regiments demonstrated a trend toward superior strength building. (Level II evidence)

Rhea MR, Ball SD, Phillips WT, et al: A comparison of linear and daily undulating periodized programs with equated volume and intensity for strength. *J Strength Cond Res* 16(2):250–255, 2002.

This prospective, randomized trial compares linear and undulating periodized programs to compare the relative ability of these programs to build endurance. (Level II evidence)

Multiple Choice Questions

QUESTION 1. What is the approximate rate of return to play for professional rugby forward or American football linemen after one or two level anterior cervical fusion procedures?

A. 70%
B. 50%
C. 95%
D. 15%

QUESTION 2. What is often used as a final step prior to release of an athlete to resume full, unsupervised training after a cervical surgery or injury?

A. Painless, full range of motion
B. Successful completion of sport-specific training exercises
C. Strength testing which demonstrates normal strength
D. Full speed game simulation with helmet if appropriate to the sport

QUESTION 3. To what does the abbreviation SAQ, used in the design of rehab regimens for return to athletics, refer?

A. Speed, Athleticism, Quickness
B. Speed, Agility, Quickness
C. Strength, Agility, Quality
D. Strength, Accuracy, Quality

QUESTION 4. How should exercises be arranged for return to sports requiring neck endurance?

A. Four sets of 15 to 20 repetitions
B. Four sets of six to eight repetitions
C. Six sets of 10 repetitions
D. Two sets of 20+ repetitions

Answer Key

QUESTION 1. Correct answer: **A** (see Introduction, Return to Play)

QUESTION 2. Correct answer: **D** (see Sports Performance Testing)

QUESTION 3. Correct answer: **B** (see Program Design/ Performance Training Program)

QUESTION 4. Correct answer: **A** (see Program Design/ Performance Training Program)

Chapter 24



Muscle Strains about the Hip and Thigh

INTRODUCTION

Timothy F. Tyler, MS, PT, ATC, and Stephen J. Nicholas, MD

Epidemiology

- Ice hockey and soccer players are particularly susceptible to adductor muscle strains.
- In professional ice hockey and soccer players throughout the world, approximately 10% to 11% of all injuries are groin strains.
- The level of experience is related to the incidence of groin strains.
- Athletes of all ages sustain groin strains.
- Older players have a higher incidence than younger ones.
- Goalkeepers have a higher incidence than position players.

Pathophysiology

- The adductor longus is the most commonly injured adductor during sporting activity (Figure 24-1).
- Groin strain injury is defined as any injury to the adductor muscle group that keeps a player out of a practice or a game, or requires the attention of the team physician.
- A groin strain is characterized by pain on palpation of the adductor tendons or the insertion on the pubic bone, or both, and groin pain during adduction against resistance.
- Groin strains are graded as a first degree strain if there is pain but minimal loss of strength and minimal restriction of motion. A second-degree strain is defined as tissue damage that compromises the strength of the muscle, but not including complete loss of strength and function. A third degree strain denotes complete disruption of the muscle tendon unit. It includes complete loss of function of the muscle.

Clinical Presentation

History

- Patient reports a feeling of a tearing in the groin region.
- Pain on push off injured lower extremity or change in direction.
- Decreased stability of the involved lower extremity on single leg stance.
- Inability to kick a ball.
- Inability to take slap shot/load body weight quickly on injured lower extremity.

Physical Examination

Abnormal Findings

- Decreased muscle force of the adductors.
- Pain on contraction of the adductor muscle group.
- Pain to passive abduction motion beyond normal range.
- Pain on palpation of the origin of the adductor longus.
- Inability to single limb stand against perturbation.
- A palpable defect of the muscle belly of the adductor longus.
- Ecchymosis in groin region.
- Swelling in groin region.
- Decreased step length.

Pertinent Normal Findings

- Symmetrical adductor force production of both lower extremities.
- Adductor strength greater than 80% abductor strength within each leg.

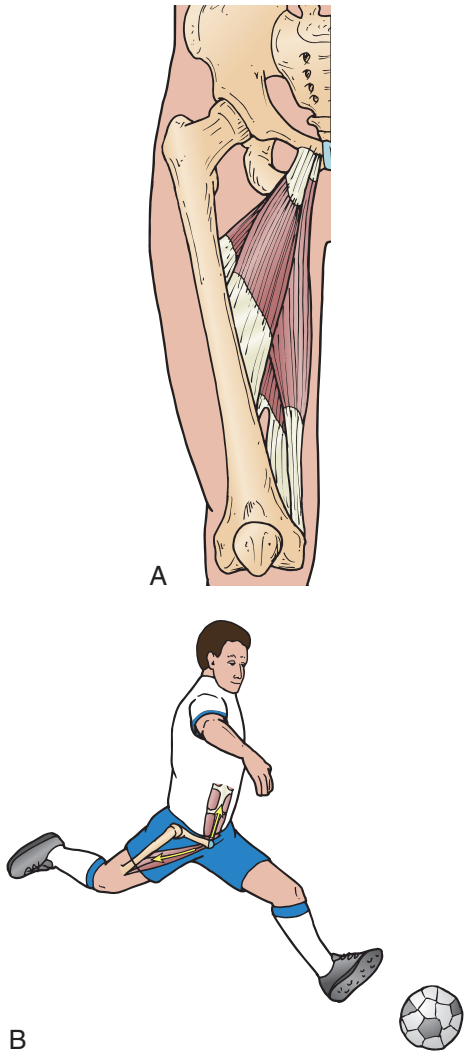


FIGURE 24-1. A, The location of the most frequently injured muscle in a groin strain, the adductor longus. **B,** An Adductor longus strain occurrence in sport.

Imaging

- X-rays
- CT scan
- MRI (Figure 24-2)

Differential Diagnosis

- Athletic pubalgia: injury to the transversalis fascia leading eventually to incompetency of the posterior inguinal wall. A diagnosis of exclusion
- Osteitis pubis: increased uptake on bone scan or CT scan at the pubic symphysis.
- Hernia: positive inguinal hernia exam.
- Hip-joint osteoarthrosis: hip X-ray revealing avascular necrosis or osteoarthritis of hip.
- Rectal or testicular referred pain: MRI of suspected region.
- A coexisting fracture of the pelvis or the hip: seen on X-ray.
- Hip flexor strain.

Treatment

Nonoperative Management

- Bracing/spica (Figure 24-3)
- Rehabilitation
- Correction of faulty biomechanics
- PRP

Guidelines for Choosing Among Nonoperative Treatments

- No bony avulsion
- No sports hernia



FIGURE 24-2. An MRI of a grade 3 adductor strain.



FIGURE 24-3. Example of a hip spica to provide support and protection to the adductors.

Surgical Indications

- Avulsion of the adductor longus
- Sports hernia

Aspects of History, Demographics, or Exam Findings that Affect Choice of Treatment

- The degree of the groin strain.
- Whether a palpable defect is present.

Aspects of Clinical Decision Making When Surgery Is Indicated

- MRI revealing bony involvement.
- Failed greater than 6 months of nonoperative treatment.

Evidence

Arnason A, Sigurdsson SB, Gudmundsson A, et al: Risk factors for injuries in football. *Am J Sports Med* 32(1 Suppl):5S–16S, 2004.

Height, weight, body composition, flexibility, leg extension power, jump height, peak O_2 uptake, joint stability, and history of previous injury were recorded for 306 male football players. Risk factors for a groin strain were a previous groin strain and decreased range of motion in hip abduction. Age and previous injury were identified as the main risk factors for injury among elite football players from Iceland. (Level III evidence).

Feeley BT, Powell JW, Muller MS, et al: Hip injuries and labral tears in the national football league. *Am J Sports Med* 36:2187–2195, 2008.

This descriptive epidemiology study defined the incidence and etiologic factors of intra- and extraarticular hip injuries in the NFL. The NFL Injury Surveillance System was used to define all hip-related injuries from 1997 to 2006. There were a total of 23,806 injuries from 1997 to 2006, of which 738 were hip injuries (3.1%) with an average of 12.3 days lost per injury. Muscle strains were the most common injury. Intraarticular injuries resulted in the most time lost. Contact injuries most likely resulted in a contusion, and noncontact injuries most often resulted in a muscle strain. (Level III evidence).

Hölmich P, Larsen K, Krogsgaard K, et al: Exercise program for prevention of groin pain in football players: a cluster-randomized trial. *Scand J Med Sci Sports* 20:814–821, 2010.

A total of 1211 soccer players were randomized to an exercise program aimed at preventing groin injuries or to a control group. The intervention program consisted of six exercises including strengthening, coordination, and core stability exercises. Twenty-two teams in each group completed the study, represented by 977 players. The risk of a groin injury was reduced by 31%, but this reduction was not significant. An analysis showed that having had a previous groin injury almost doubles the risk of developing a new groin injury and playing at a higher level almost triples the risk of developing a groin injury. (Level II evidence).

Robinson P, Barron DA, Parsons W, et al: Adductor-related groin pain in athletes: correlation of MR imaging with clinical findings. *Skeletal Radiol* 33:451–457, 2004.

The purpose of this study was to evaluate gadolinium-enhanced MR imaging in athletes with chronic groin pain and correlate with the clinical features. MR examinations performed in 52 athletes with chronic groin pain and 6 asymptomatic control athletes were independently reviewed by two radiologists masked to the clinical details. The extent and side of anterior pubis and adductor longus enthesis abnormality on MR imaging significantly and reproducibly correlated with the athletes' current symptoms in chronic adductor-related groin pain. (Level II evidence).

Tyler TF, Campbell R, Nicholas SJ, et al: The association of hip strength and flexibility on the incidence of groin strains in professional ice hockey players. *Am J Sports Med* 29:668–673, 2000.

This prospective study was conducted to determine whether hip muscle strength and flexibility play a role in the incidence of adductor and hip flexor strains in NHL ice hockey team players. Hip flexion, abduction, and adduction strength were measured in 81 players before two consecutive seasons. Preseason hip adduction strength was 18% lower in the players who subsequently sustained an adductor muscle strain compared with that of uninjured players. Adduction strength was 95% of abduction strength in the uninjured players, but only 78% of abduction strength in the injured players. A player was 17 times more likely to sustain an adductor muscle strain if his adductor strength was less than 80% of his abductor strength. (Level I evidence).

Multiple Choice Questions

QUESTION 1. When building an injury prevention program for groin strain, which muscle group should be strengthened?

A. Abductors
B. Adductors
C. Hip flexors
D. Hamstrings

QUESTION 2. What is one of the strongest intrinsic factors that predisposes an athlete to a groin injury/strain?

A. Strength ratio of the adduction to abduction muscle groups
B. Increased preseason practice sessions
C. Previous groin strain
D. A lack of mechanical advantage for the adductor longus

QUESTION 3. In a clinical examination, pertinent normal findings to look for may include:

A. Swelling in the groin region
B. Decreased muscle force of the adductors
C. Pain on contraction of the adductor muscle group
D. Symmetrical adductor force production of both lower extremities

QUESTION 4. A general guideline for choosing a nonsurgical treatment option consist of:

A. Avulsion of the adductor longus
B. Sports hernia
C. No bony avulsion
D. Hip fracture

QUESTION 5. An increased uptake on a bone scan or CT scan may differentiate which of the following from a diagnosis of groin strain?

A. Osteitis pubis
B. Athletic pubalgia
C. Hernia
D. Hip-joint osteoarthrosis

Answer Key

QUESTION 1. Correct answer: **B** (see Pathophysiology)

QUESTION 2. Correct answer: **C** (see Pathophysiology)

QUESTION 3. Correct answer: **D** (see Clinical Presentation)

QUESTION 4. Correct answer: **C** (see Treatment)

QUESTION 5. Correct answer: **A** (see Differential Diagnosis)

NONOPERATIVE REHABILITATION OF ADDUCTOR AND HIP JOINT STRAINS

Timothy F. Tyler, MS, PT, ATC, and Stephen J. Nicholas, MD

GUIDING PRINCIPLES OF NONOPERATIVE REHABILITATION

- Pain
- Range of motion
- Restore the adduction-to-abduction strength ratio of the injured leg
- Function

Phase I (weeks 0 to 3 to 6)

Protection

- Compression shorts or a wrap bandage may be helpful in decreasing swelling and provide support.
- If walking causes pain, limit weight bearing; crutches are considered for the first day or two after the injury.

Management of Pain and Swelling

- RICE (rest, ice, compression, elevation) is the standard protocol for mild to moderate muscle strains for the first 24 to 48 hours.
- Electrical stimulation, cold laser, or ultrasound can be useful in healing.

Techniques for Progressive Increase in Range of Motion

Therapy Techniques

- Gentle pain-free sub maximal contractions within 48 hours. Maintain pain-free available passive range of motion.

TIMELINE 24-1: **Nonoperative Rehabilitation of Adductor and Hip Joint Strains**

PHASE I (weeks 0 to 4)	PHASE II (weeks 4 to 8)
• RICE (rest, ice, compression and elevation) for first ~48 hours after injury • NSAIDs • Massage • TENS • Ultrasound • Submaximal isometric adduction with knees bent, with knees straight progressing to maximal isometric adduction, pain free • Hip passive range of motion (PROM) in pain-free range • Non weight-bearing hip progressive resistive exercises (PREs) without weight in antigravity position (all except abduction), pain-free, low load, high repetition exercise • Upper body and trunk strengthening • Contralateral LE strengthening • Flexibility program for noninvolved muscles • Bilateral balance board	• Bicycling/swimming • Sumo squats • Single limb stance • Concentric adduction with weight against gravity • Standing with involved foot on sliding board moving in frontal plane • Adduction in standing on cable column or Thera-Band • Seated adduction machine • Bilateral adduction on sliding board moving in frontal plane (i.e., bilateral adduction simultaneously) • Unilateral lunges (sagittal) with reciprocal arm movements • Multiplane trunk tilting • Balance board squats with throwbacks • General flexibility program • Involved lower extremity PROM equal to that of the uninvolved side and involved adductor strength at least 75% that of the ipsilateral abductors.

Soft Tissue Techniques

- Gentle massage to the area with ice to help decrease swelling.

Other Therapeutic Exercises

- Biking for maintaining fitness
- Upper body and trunk strengthening
- Core stability

Activation of Primary Muscles Involved

- Submaximal isometric adduction with knees bent (Figure 24-4), with knees straight progressing (Figure 24-5) to maximal isometric adduction.
- If pain free, progress to side-lying hip adduction against gravity (Figure 24-6).
- Hip passive range of motion (PROM) in pain-free range.



FIGURE 24-4. Submaximal adductor strengthening with short lever arm.



FIGURE 24-5. Submaximal adductor strengthening with long lever arm.



FIGURE 24-6. Side-lying hip adduction against gravity.

Sensorimotor Exercises

- Bilateral balance board
- Single leg stance on stable surface

TIMELINE 24-1: **Nonoperative Rehabilitation of Adductor and Hip Joint Strains** (Continued)

PHASE III (weeks 8 to 12)	PHASE IV (weeks 12+)
• Phase II exercises with increase in load, intensity, speed and volume • Standing resisted stride lengths on cable column to simulate skating • Slide board • On ice kneeling adductor pull togethers • Lunges (in all planes) • Correct or modify ice skating technique	• Heavy load isolated eccentrics of the adductors • On ice training forward/backwards/crossovers • Skating with without the puck • Skating with puck • Stickhandling, passing, shooting • Scrimmage NO contact • Scrimmage • Game play

Open and Closed Kinetic Chain Exercises

Nonweight-bearing hip progressive resistive exercises (PREs) without weight in antigravity position (all except abduction), pain-free, low load, high repetition exercises.

- Mini squats to full squats

Techniques to Increase Muscle Strength, Power, and Endurance

- Contralateral LE strengthening

Neuromuscular Dynamic Stability Exercises

- Flexibility program for noninvolved muscles

Sport-Specific Exercises

- Hockey: stick-handling while standing with the ball

Milestones for Progression to the Next Phase

- Pain-free passive range of motion
- Minimal swelling as measured by clinical palpation and observation.
- Concentric adduction against gravity without pain.
- Normal gait with full weightbearing

Phase II (weeks 3 to 6 and weeks 6 to 8)

Protection

- Compression shorts
- Hip spica

Management of Pain and Swelling

- Electrical stimulation
- Cold laser
- Ultrasound
- Ice

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Manual resistance to adductors. Providing minimal resistance to the leg proximal then moving more distally towards the ankle. Resistance should always be pain free.

Soft Tissue Techniques

- Graston technique and/or deep tissue massage. Gentle massage to the knee to milk the fluid away from the groin

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Initiate gentle PROM of adductor and hip flexors. Gentle stretching so as not to cause plastic deformation of the muscle.

Other Therapeutic Exercises

- Elliptical
- StairMaster
- Treadmill long stride walking
- Bicycling
- Swimming

Activation of Primary Muscles Involved

- Concentric adduction with weight against gravity. Start with 2 lbs and try to achieve 3 sets of 10, then move to 3 sets of 15 followed by 1 set of 30 at the same weight. If the patient can perform 1 set of 30 with that weight, add 2 lbs and go back to doing 3 sets of 10 repetitions.
- Adduction in standing on cable column or Thera-Band. Start the athlete with yellow Thera-Band and then move to red once they achieve 30 repetitions with perfect form.
- Seated adduction machine. Use a pain free resistance level so the patient can achieve 3 sets of 10.
- General flexibility program. Perform a general flexibility assessment looking for asymmetrical tightness from anterior to posterior or restrictions from involved non-involved sides.

Sensorimotor Exercises

- Single-leg stance standing on the floor, the patient is bare foot, knee slightly bent and eyes open. Perform SLS for 30 seconds. Try and achieve this 3 times. If the patient can perform easily without pain or loss of balance, progress to 1 minute for 3 sets. If patient cannot perform for 30 seconds or 1 minute, decrease time and/or add UE support. This exercise can be progressed by adding an unstable surface (BAPS, Thera-Band, stability pad etc.)
- Quick steps: Quick alternating steps over a line on the floor. Count the number of repetitions.
- Tic tock: Feet shoulder width apart and pass the ball back and forth quickly between feet.
- Lateral band walks (Figure 24-7)
- Balance board tosses: Patient in mini squat position, perform 30 tosses in a row without touching either side of board to the floor. Perform this 3 times. Progress to overhead throw and side chops while maintaining balance.

Open and Closed Kinetic Chain Exercises

- Sumo squats (Figure 24-8): Begin with 3 sets of 10, stand on the floor with pain-free and proper form, add a kettle bell for resistance.



FIGURE 24-7. Lateral band walks.



FIGURE 24-8. Sumo squats.

- Contralateral Thera-Band: Stand on the involved leg and move the noninvolved leg into different planes of motion, for example hip abduction/extension.
- Leg Press: Perform 3 sets of 10 progressing to 3 sets of 12 and 3 sets of 15 with two legs in pain-free resistance. Progress to single leg.

Neuromuscular Dynamic Stability Exercises

- Standing with involved foot on sliding board moving in frontal plane (Figure 24-9)
- Balance board squats with throwbacks: With patient in mini squat position, perform 30 tosses in a row without touching either side of the board to the floor. Perform this 3 times. Progress to overhead throw and side chops while maintaining balance.

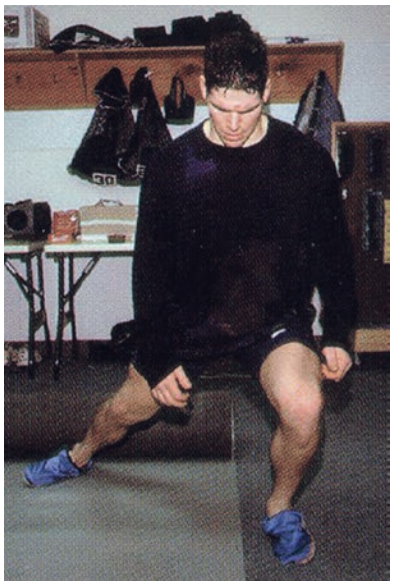


FIGURE 24-9. Standing with involved foot on sliding board moving in frontal plane.

Plyometrics

- Lateral shuffles: Maintain proper alignment in mini squat position (watch for knees diving in) shuffle side to side across the room. Begin at 50% speed pain-free and progress to 75% and then full speed.

Functional Exercises

- Lunges (forward and lateral) with reciprocal arm movements.
- Unweighted spilt jumps: Explosively jump while using the arms to assist as needed. While in mid-air switch the leg position landing softly in lunge position. Progress for maximum height and power.
- Forward/backward running drills: Begin at 50% and progress to 75% to then full speed. Therapist can add in directional changes.

Sport-Specific Exercises

- Bilateral adduction on sliding board moving in frontal plane (i.e., bilateral adduction simultaneously). Standing on sliding board slide both legs together. Perform as many as patient can pain-free.
- Skater strides (Figure 24-10): In skating position, see how many times the patient can go back and forth along the slide board. Increasing the number of reps and speed as they progress within the same timeframe.

Milestones for Progression to the Next Phase

- Involved lower extremity PROM equal to that of the uninvolved side
- Involved adductor strength at least 75% that of the ipsilateral abductors. This is determined by performing a break test using a hand held dynamometer.

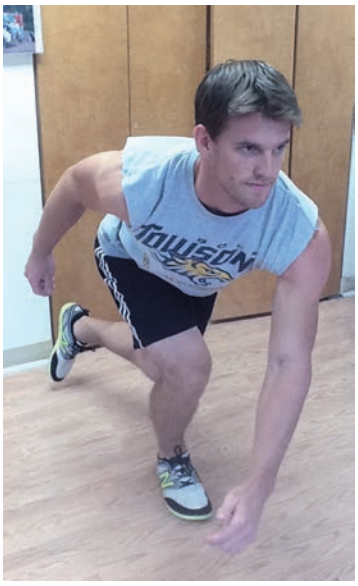


FIGURE 24-10. Skater strides.

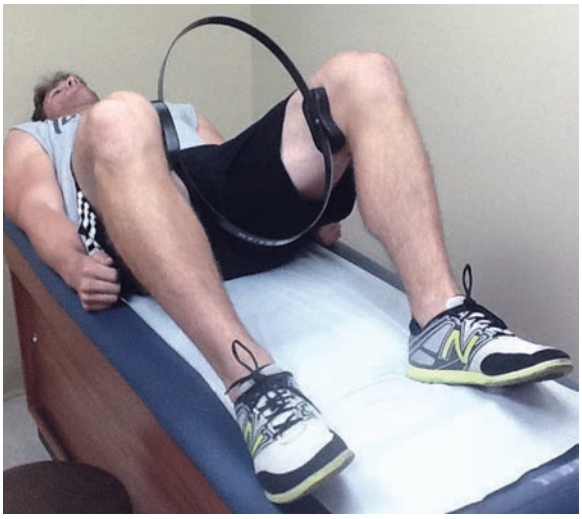


FIGURE 24-11. Ring squeezes.



FIGURE 24-12. Ring squeezes in table top.

Phase III (weeks 6 to 8 and weeks 9 to 12)

Protection

- Hip spica

Management of Pain and Swelling

- Biofreeze
- Ice
- Compression wrap

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Manual resistance to adductors

Soft Tissue Techniques

- Graston technique and/or deep tissue massage

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Progressive stretching of the adductors

Other Therapeutic Exercises

- Phase II exercises with increase in load, intensity, speed, and volume
- Core stability with/without stability ball: planks, side planks, double-leg/single-leg bridges. Use a time based approach starting at 30 seconds progressing to one minute.

Activation of Primary Muscles Involved

- Eccentric lengthened state strengthening of the adductors
- Ring squeezes (Figure 24-11)
- Ring squeezes in table top position (Figure 24-12)
- Hip adductor machine

Sensorimotor Exercises

- Slide board side to side

Open and Closed Kinetic Chain Exercises

Standing resisted stride lengths on cable column to simulate skating

Techniques to Increase Muscle Strength, Power, and Endurance

- Lunges (in all planes)

Neuromuscular Dynamic Stability Exercises

- Single-leg cable column ice skating stride
- Quick kick with Thera-Band
- Perturbation training

Plyometrics

- Bounding side to side

Functional Exercises

- Correct or modify ice skating technique

Sport-Specific Exercises

- On ice kneeling adductor pull togethers

Milestones for Progression to Advanced Sport-Specific Training and Conditioning

- Adduction strength, at least 90% to 100% of the abduction strength. This is determined by performing a break test using a hand held dynamometer.
- Involved adductor muscle strength equal to that of the contralateral side. This is determined by performing a break test using a hand held dynamometer.

Phase IV (weeks 12+)

Protection

- Hip spica
- Compression shorts

Management of Pain and Swelling

- Ice

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Contract-relax

Soft Tissue Techniques

- Massage

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Stretching of the adductors

Other Therapeutic Exercises

- Running
- Squats
- Dead lifts
- Cleans
- Snatches



FIGURE 24-13. Split squats.

Activation of Primary Muscles Involved

- Heavy load eccentrics of adductors and hip flexors

Sensorimotor Exercises

- Ice skating with drill

Open and Closed Kinetic Chain Exercises

- Split squats (Figure 24-13)

Techniques to Increase Muscle Strength, Power, and Endurance

- Timed slide board slides

Neuromuscular Dynamic Stability Exercises

- Ice single-limb stance

Plyometrics

- Box jumps

Milestones to Progress to Sport-Specific Training and Conditioning

- Pain-free range of motion
- Pain-free ice skating
- Symmetrical strength of adductors in shortened, mid range and lengthened state of the muscle. We determine this by performing a break test using a hand held dynamometer. Approximately 10° from the most shortened muscle length and 10° from the longest muscle length.
- No limiting symptoms with full speed functional drills

Criteria for Abandoning Nonoperative Treatment and Proceeding to Surgery or More Intensive Intervention

- No response in returning strength
- Grade 3 tear

Tips and Guidelines for Transitioning to Performance Enhancement

- All motion loaded and unloaded in the frontal sagittal and transverse plane should be pain free.
- During this period there should be no movement deviations or compensations.

Performance Enhancement and Beyond Rehabilitation: Training/Trainer and Optimization of Athletic Performance

- Perturbation training on and off the ice

Specific Criteria for Return to Sports Participation: Tests and Measurements

- Confidence in the lower extremity.
- 100 % recovery. Ask the patient what percent of 100% are they today, and then compare this to the uninjured side.

Evidence

Engebretsen AH, Myklebust G, Holme I, et al: Prevention of injuries among male soccer players: a prospective, randomized intervention study targeting players with previous injuries or reduced function. *Am J Sports Med* 36:1052–1060, 2008.

A total of 508 players were divided into high-risk (HR) (76%) and low-risk (LR) groups. The HR players were randomized individually into an HR intervention group or HR control group. A total of 505 injuries were reported, sustained by 56% of the players. Compliance with the training programs in the HR intervention group was poor, with only 27.5% in the ankle group, 29.2% in the knee group, 21.1% in the hamstring group, and 19.4% in the groin group defined as having carried out the minimum recommended training volume. The players with a significantly increased risk of injury were able to be identified through the use of a questionnaire, but player compliance with the training programs prescribed was low and any effect of the intervention on injury risk could not be detected. Randomized controlled trial. (Level II evidence).

Hölmich P, Uhrskou P, Ulnits L, et al: Effectiveness of active physical training as treatment for long-standing adductor-related groin pain in athletes: randomized trial. *Lancet* 353:439–443, 1999.

This randomized clinical trial compared an active training rehabilitation program (AT) with a passive rehabilitation program (PT) in the treatment of 68 athletes with long-standing groin pain. Twenty-three patients in the AT group returned to sports without groin pain while only four returned in the PT group. AT with a program aimed at improving strength and coordination of the muscles acting on the pelvis, in particular the adductor muscles, is very effective in the treatment of athletes with long-standing adductor-related groin pain. (Level I evidence).

Robinson P, Barron DA, Parsons W, et al: Adductor-related groin pain in athletes: correlation of MR imaging with clinical findings. *Skeletal Radiol* 33:451–457, 2004.

The purpose of this study was to evaluate gadolinium-enhanced MR imaging in athletes with chronic groin pain and correlate with the clinical features. MR examinations performed in 52 athletes with chronic groin pain and 6 asymptomatic control athletes were independently reviewed by two radiologists masked to the clinical details. The extent and side of anterior pubis and adductor longus enthesis abnormality on MR imaging significantly and reproducibly correlates with the athletes' current symptoms in chronic adductor-related groin pain. (Level II evidence).

Schlegel TF, Bushnell BD, Godfrey J, et al: Success of nonoperative management of adductor longus tendon ruptures in National Football League athletes. *Am J Sports Med* 37: 2009.

Adductor tendon ruptures documented by MRI were identified in 19 NFL players. Fourteen players were treated nonoperatively, and 5 players were treated with surgical repair using suture anchors, all players eventually returned to play. Mean time for return to play was 6.1 ± 3.1 weeks (range, 3 to 12 weeks) for the nonoperative group and 12.0 ± 2.5 weeks (range, 10 to 16 weeks) for the operative group ($p = .001$). Nonoperative treatment of proximal adductor tendon rupture results in a statistically significantly faster return to play than does operative treatment in athletes competing in the NFL. (Level III evidence).

Multiple-Choice Questions

QUESTION 1. Which is not an appropriate clinical guideline for progressing from Phase I to Phase II?

A. Pain-free PROM
B. Minimal swelling
C. Abduction strength
D. Pain-free concentric adduction against gravity

QUESTION 2. Which of the following should be avoided in Phase I?

A. Adductor strengthening
B. Submax isometrics
C. Ultrasound
D. Ice

QUESTION 3. What factors have been proven to put athletes at risk for adductor strains?

A. Gender
B. History of ITB friction syndrome
C. Ambient temperature
D. Poor hip adductor to abductor ratio

QUESTION 4. Which of the following is NOT a guiding principle of rehab for an adductor strain?

A. Thigh girth
B. ROM
C. Function
D. Restoring abduction to adduction strength ratio

QUESTION 5. What added protection may a sports clinician give to a player to return to play?

A. Tape
B. Thera-Band
C. Hip spica
D. Underwear

Answer Key

QUESTION 1. Correct answer: **B** (see Phase I)

QUESTION 2. Correct answer: **A** (see Phase I)

QUESTION 3. Correct answer: **D** (see Introduction, Evidence)

QUESTION 4. Correct answer: **A** (see Guiding Principles)

QUESTION 5. Correct answer: **C** (see Phase IV)

BEYOND BASIC REHABILITATION: RETURN TO HOCKEY AFTER ADDUCTOR STRAIN

Timothy F. Tyler, MS, PT, ATC, and Stephen J. Nicholas, MD

Introduction

- Groin strains are a prevalent pathology associated with ice hockey and have a high recurrence rate.
- It is particularly challenging to return to the sport because the player needs stability on a single leg on a skate blade, which requires adductor strength.
- The three mechanisms of ice hockey hip and adductor strains are (Figure 24-14*A, B, and C*):
  - Excessive ROM
  - Contact with an opposing player
  - Contact with ice

ASPECTS OF HOCKEY THAT REQUIRE SPECIAL ATTENTION IN REHABILITATION

- Balance
- Agility
- Strength
- Power
- Kinetics
- Anaerobic power
- Speed endurance and training

Phase I: Advanced Strength and Conditioning Programs

Periodization

- Linear
- Microcycles

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- Training continuum
- Flexibility/joint mobility for joint stability
- Training with hockey posture
- Sensorimotor and balance training
- Core training
- Cardiorespiratory training
- Multiplanar training activities
- Training for optimum muscle balance
- Training for optimum muscle functional strength
- Training for optimum muscle functional power
- Neuromuscular dynamic stability exercises
- Training for speed, agility, quickness (SAQ)
- Plyometric training
- Functional training
- Sport-specific training

Olympic Lifts Used in the Training Program

- Snatch
- Clean and jerk
- Power clean

Training Principles Used in the Design of the Program

- Principle of progression
- Principle of overload
- Principle of variation
- Principle of individualization
- Principles of specificity–specific adaptation to imposed demands (SAID)

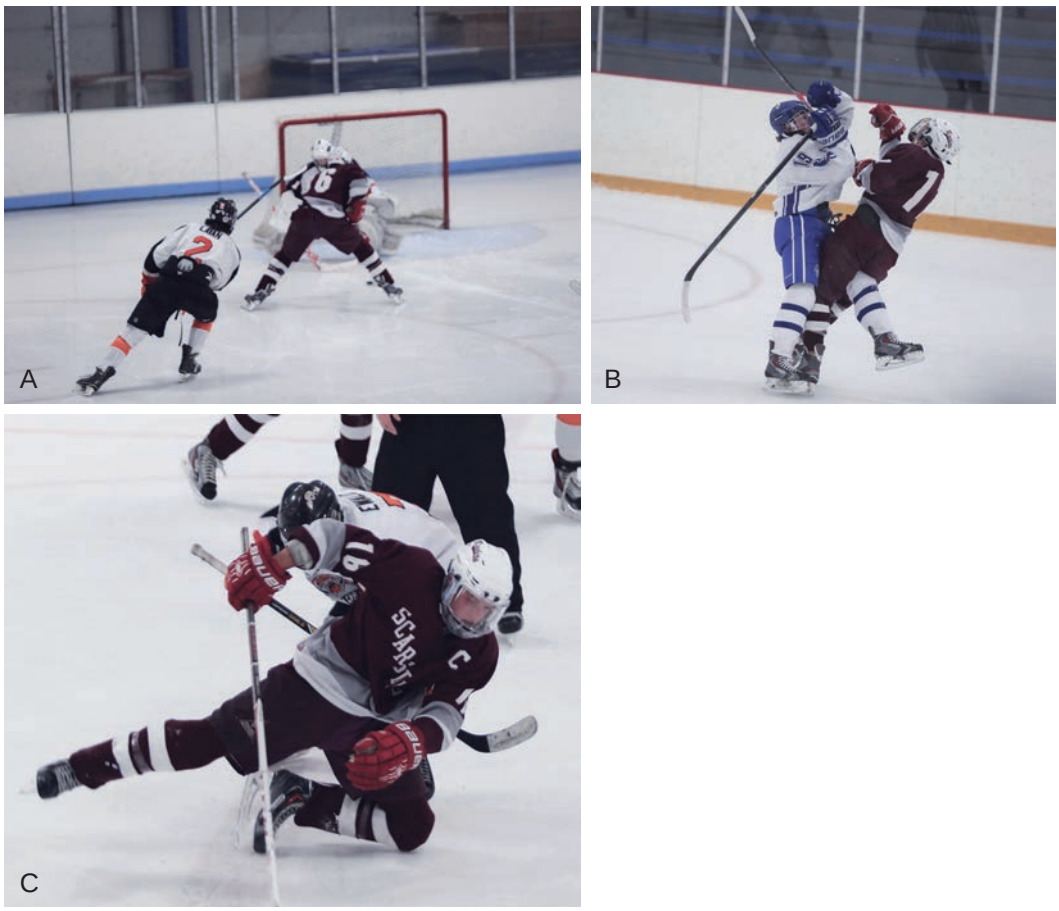


FIGURE 24-14. The three mechanisms of ice hockey hip and adductor strains. **A**, Excessive ROM. **B**, Contact with an opposing player. **C**, Contact with ice.

Application of Acute Training Variables

- High repetitions
- 5 to 14 sets
- 30 to 60 second rest interval
- Moderate intensity
- Training frequency of TIW
- Training duration of 10 to 20 minutes
- Training volume of 8 to 14 sets
- Specific exercises used in the training are sumo squats, on-ice squeezes, isometric ball squeezes.

TIMELINE 24-2: **Beyond Basic Rehabilitation: Return to Hockey after Adductor Strain**

PHASE I	PHASE II	PHASE III
Warmup	**Advanced Strengthening Program**	**Sport-Specific Training**
• Bike • Adductor stretching • Sumo squats • Side lunges • Kneeling pelvic tilts	• Bilateral adduction on sliding board moving in frontal plane (i.e. bilateral adduction simultaneously) • Unilateral lunges with reciprocal arm movements	• On-ice kneeling adductor pull togethers • Standing resisted stride lengths on cable column to simulate skating • Slide skating • Cable column crossover pulls
Strengthening Program		
• Ball squeezes (legs bent to legs straight) • Different ball sizes • Concentric adduction with weight against gravity • Adduction in standing on cable column or elastic resistance • Seated adduction machine • Standing with involved foot on sliding board moving in sagittal plane		

Phase II: Performance Enhancement Training Techniques

Periodization

- Linear
- Undulating
- Macrocycles
- Mesocycles
- Microcycles

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- Core training
- Cardiorespiratory training
- Multiplanar training activities
- Training for optimum muscle balance
- Training for optimum muscle functional strength
- Training for optimum muscle functional power
- Neuromuscular dynamic stability exercises
- Training for speed, agility, quickness (SAQ)
- Plyometric training
- Functional training on the ice
- Sport-specific training on the slide board

Olympic Lifts used in the Training Program

- Snatch
- Clean and jerk
- Power clean

Training Principles Used in the Design of the Program

- Principle of progression
- Principle of overload
- Principle of variation
- Principle of individualization
- Principles of specificity–specific adaptation to imposed demands (SAID)

Application of Acute Training Variables

- 6 to 12 repetitions
- 8 to 10 sets per body part
- Rest interval of 60 seconds
- High intensity
- Slow repetition tempo
- Training frequency of 48 hours rest for each body part
- Training duration of 6 to 10 weeks
- Training volume of no more than 30 repetitions
- Specific exercises used in the training
  - Split squats (See above: gives some guidelines to the readers regarding volume of training for the different exercises)
  - Squats
  - Lunges
  - Slide board
  - Diagonal PNF
  - Light agility program with on-ice directional changes

Application of Chronic Training Variables

- Repetition to create muscle memory.

Phase III: Sport-Specific Training

Periodization

- Linear
- Macrocycles: full year and will rest after the season is over
- Mesocycles: resistance training to balance adductor to abductor strength ratio.
- Microcycles: individual sport specific eccentric training

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- Training continuum
- Flexibility/joint mobility for joint stability
- Sport-specific on-ice training

Training Principles Used in the Design of the Program

- Principle of progression: The Delorme principle is recommended to progress resistance training.
- Principle of overload: The Oxford training principles are recommended.
- Principle of variation: Perform dry land training 2 times per week during the hockey season.
- Principle of individualization: An example of this is to emphasize the end range strength in goaltenders who are functioning often in their end ROM.

Application of Acute Training Variables

- 2 to 5 repetitions on-ice
- 2 minute rest interval
- Maximum intensity
- Repetition tempo as fast as the athlete can
- Daily training frequency
- 10 to 20 minute training duration
- High training volume
- Specific exercises used in the training
  - Forward skating
  - Backwards skating
  - Clockwise cross overs
  - Counter clockwise cross overs
  - One on ones
  - Two on ones
  - Three on twos
  - Scrimmage no contact
  - Scrimmage with checking
  - Game

Application of Chronic Training Variables

- Applied to the athlete's tolerance.

Sports Performance Testing

General Information

- General history
- Subjective questionnaires
- Medical history
- Sports injury history
- Surgical history
- Chronic conditions/medication
- Impact testing
- Eye exam

Specific Criteria for Progression to the Next Stage to Determine their Readiness for Hockey

Objective Tests

- Physiological assessments. Girth measurements to asses for atrophy.
- Body composition tests BMI, skin-fold testing.
- Movement performance testing to look for ROM and strength deficits forward and backward shuttle runs looking for asymmetrical body movement.
- Sport-specific testing: Timed slide board slides.
- Impact testing for concussion management.
- On-ice testing: Timed circles in both directions to assess single limb stance ability on skates.

Criteria for Determining Readiness for Sport

- Rate of perceived exertion

Specific Criteria for Releasing an Athlete to Unsupervised Complete Participation in Hockey

- Pain-free full ROM and strength throughout the range.
- Symmetrical adduction strength, symmetrical single-leg hop for distance. Hand held dynamometer testing in which the involved hip adductors are 80% of the hip abductors of the involved leg.
- Subjective 100% confidence of patient that they are ready to return.

Recommended Ongoing Exercises

- Standing unilateral elastic resistance, slide board, balance board.

Evidence

Tyler TF, Campbell R, Nicholas SJ, et al: The effectiveness of a preseason exercise program on the prevention of groin strains in professional ice hockey players. *Am J Sports Med* 30:680–683, 2002.

A total of 33 of 58 players from the same NHL team were identified as at risk on the basis of preseason hip adductor strength and participated in an intervention program. The program consisted of 6 weeks of exercises aimed at functional strengthening of the adductor muscles. Adductor strains were reduced by 78% compared to the previous seasons. A therapeutic intervention of strengthening the adductor muscle group appears to be an effective method for preventing adductor strains in professional ice hockey players. (Level I evidence).

Multiple-Choice Questions

QUESTION 1. Where should most sport specific training be done?

A. On ice
B. Gym
C. Training room
D. At night at home

QUESTION 2. What is a good acute training exercise for warming up?

A. Box jumps
B. Isokinetics
C. Sumo squats
D. Ultrasound

QUESTION 3. Repeated sprints should take how long to complete?

A. Each 5 to 6 minutes to complete
B. All day
C. Each takes 4 to 6 seconds
D. Each takes 45 to 60 seconds

QUESTION 4. Why is it particularly challenging to return to hockey after a groin strain?

A. Hockey players have less stability than other athletes
B. Younger people play hockey
C. Most are multisport athletes
D. The player needs stability on a single leg on a skate blade, which requires adductor strength

QUESTION 5. During speed training the training should include how many turns?

A. 4
B. 3
C. 9
D. 1

Answer Key

QUESTION 1. Correct answer: **A** (see Box 24-1)

QUESTION 2. Correct answer: **C** (see Warm-up phase of guidelines)

QUESTION 3. Correct answer: **D** (see Box 24-1)

QUESTION 4. Correct answer: **D** (see Introduction)

QUESTION 5. Correct answer: **D** (see Box 24-1)

BOX 24-1 Advanced Rehabilitation Program: On- and Off-Ice Workouts

On-Ice Workouts

ANAEROBIC POWER TRAINING

- Repeated sprints that each take 45 to 60 seconds to complete. Move goals forward to approximately in line with the end zone face-off spots and have athletes skate 3 laps as fast as they can. Rest period should be 4 to 6 times the sprint time. Players should complete 6 to 8 sets. The rest time can be dictated by how many players are in a group.
- For example, if you want a 5:1 recovery to sprint ratio and you have 18 players, divide the players into 3 groups of 6 with each group stationed at different points around the ice. The first players in each group complete their first set, then the 2nd players go and so on until all 6 players have completed their first set of 3 laps. Then the first 3 players start their 2nd set.
- Direction should be reversed between each set and the goals should be moved to spread the wear on the ice.
- The distance can be fixed by tying a rope between both goals. When the goals are moved, to spread the wear on the ice, make sure the rope remains taught.
- Regardless of how the workout is executed the goal is to have players go all out for 45 to 60 seconds and give them 4 to 6 minutes recovery and repeat 6 to 8 times.
- The distance will depend on the time after injury of the athlete. The shorter the recovery time the slower the subsequent sets.
- The traditional mentality is to have short recovery times so everyone is exhausted for the last couple of sets and crawl over the finish line (no pain no gain mentality). Training adaptations will be better if there is only a small decline in speed from first to last sets.

SPEED ENDURANCE TRAINING

- Repeated sprints that each take 20 to 30 seconds to complete. Figure of 8 sprints performed across the width of the ice, where players start in the middle and have to complete 3 laps (i.e. cross their starting point 6 times).
- The recovery to sprint ratio should be the same or similar to the anaerobic power training i.e. 4:1, 5:1, or 6:1.
- This test is more technically demanding than anaerobic power training because skating ability during turns is critical. Thus this tests a combination of skating ability and fitness.
- The practical issue in doing this test is wear on the ice. Actual distance can be manipulated to match the fitness of the players to stay within the 20 to 30 second time requirements.

SPEED TRAINING

- All out sprint with only 1 turn. The goal is to test instantaneous power.
- For example, start on goal line, sprint to opposite goal line and back to blue line at end where you started (292 foot sprint).
- This should take approximately the same time as the figure of 8 test, but should only be repeated a max of 6 times, with the same 4 to 6:1 recovery:sprint ratio.

Off-Ice Workouts

AEROBIC POWER

- On track 200 meters in 45 second, 200 meters in 90 seconds, repeat 10 to 12 times. This workout is designed for athletes with a VO_2 max of 50 ml/kg/min.
- If you want an accurate measure of their VO_2 max have them run 8 laps (2 miles) and get an accurate time for their max effort. A VO_2 max of 50 ml/kg/min equates to 2 miles in 14 min.

ANAEROBIC POWER

- 30 meter sprint every 30 seconds repeated 6 times, 2 minute recovery, repeat 6 times.
- Players can do alternating 20 sit-ups or pushups during 2 minute recovery.
- In any of these sprint workouts (on-ice or off-ice) it is essential to provide sufficient recovery so that the later sprints are not performed at walking speed.
- Some decrement is expected, but if it is no longer a sprint, that is, they are too fatigued to go fast, then the exercise is not going to be beneficial.
- The key to training the targeted energy systems is quality of the sprint.

Strength workouts

SQUATS*

1. Single-leg split squats with rear leg held back and parallel to ground (2 × 15 or 20)
2. Single-leg split squats with rear leg back and up on bench (approx. 3 feet high) (2 × 15 or 20)
3. Walking split squats; also called lunge walking (20 repetitions)
4. Split squat plyometric jumps; also called lunge jumping (2 × 15 or 20)

JUMPS

1. Lateral jumps: single leg lateral jumps across markings 2 feet apart. Jump for 10 seconds (count repetitions). Do 4 sets each leg, alternating between legs.
2. Skater jumps: lateral jumps across a 5 foot distance (6 feet for adults). Take off on 1 leg and land on the other leg. Do 10 repetitions, rest 1 minute, do 3 sets.

OTHER

Sit-ups and pushups as needed.

*Do numbers 1 and 2 on one day and numbers 3 and 4 on another day

NONOPERATIVE REHABILITATION OF HAMSTRING STRAINS AND CONTUSIONS

Marc Sherry, PT, DPT, LAT, CSCS, PES, Bryan C. Heiderscheit, PT, PhD, and William Clancy, MD, PhD

GUIDING PRINCIPLES OF NONOPERATIVE REHABILITATION

- Excessive or aggressive stretching of the injured hamstrings should be avoided, as this can result in a dense scar formation in the area of injury prohibiting muscle regeneration. However, early mobilization and movement, with pain defining the range of motion limit, is safe and effective for return to sport with minimal chance for injury recurrence.
- Rehabilitation interventions should focus on progressive agility, trunk stabilization, eccentric strengthening and eliminating muscle imbalances.
- Specific evaluation of strength, mobility and apprehension are key indicators for return to sport readiness.

Phase I: Acute (weeks 0 to 4)

Phase I starts as soon as possible after the injury and continues for 5 to 25 days depending on the severity of injury.

Protection

- Crutches may be used in moderate to severe injuries.
- In mild to moderate injuries athletes should be able to shorten their normal stride length to ambulate pain free.

Management of Pain and Swelling

- Modification of activity, particularly avoiding tension on the hamstring during the acute phase
- Compression thigh wraps for moderate to severe injuries to help decrease swelling
- Slight elevation above the heart for moderate to severe injuries to help decrease swelling
  Note: the elevation should not be so great as to stretch the injured hamstrings during this time.
- Cryotherapy
- Use of NSAIDs for this type of injury remains controversial

Therapeutic Exercises

- Stationary biking
- Progressive agility and trunk stabilization (PATS), Phase I
  - Low- to moderate-intensity side stepping, 3 times 1 minute
  - Low- to moderate-intensity grapevine stepping (lateral stepping with the trail leg going over the lead leg and then under the lead leg), both directions, 3 times 1 minute (Figure 24-15)
  - Low- to moderate-intensity steps forward and backward over a tape line while moving sideways, 2 times 1 minute (Figure 24-16)
  - Single-leg stand, progressing from eyes open to eyes closed, 4 times 20 seconds (Figure 24-17)

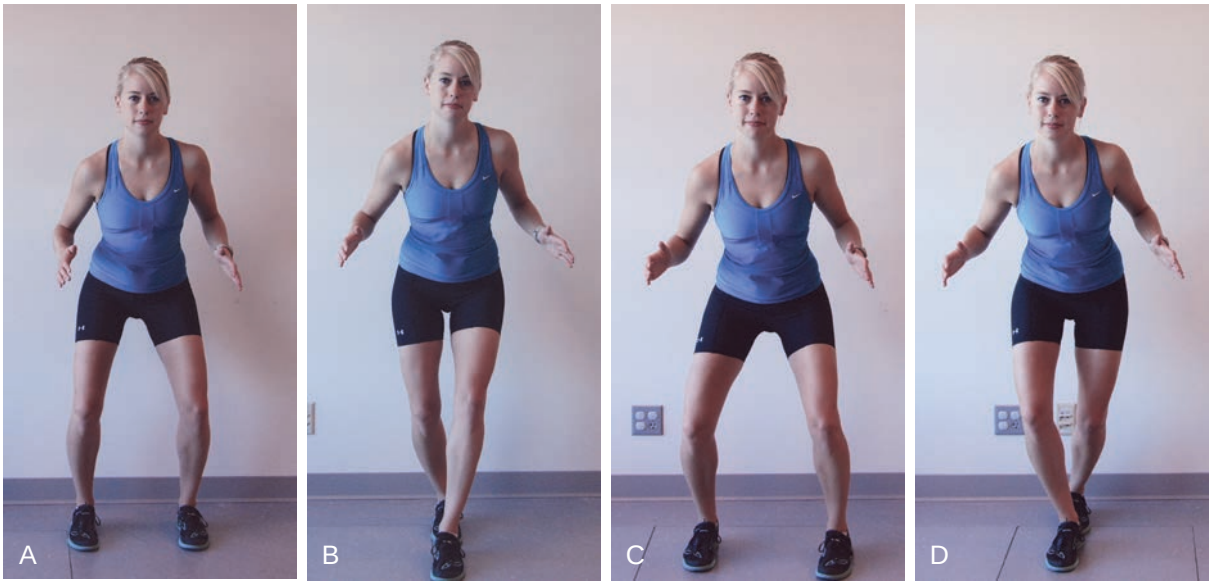


FIGURE 24-15. Grapevine stepping.

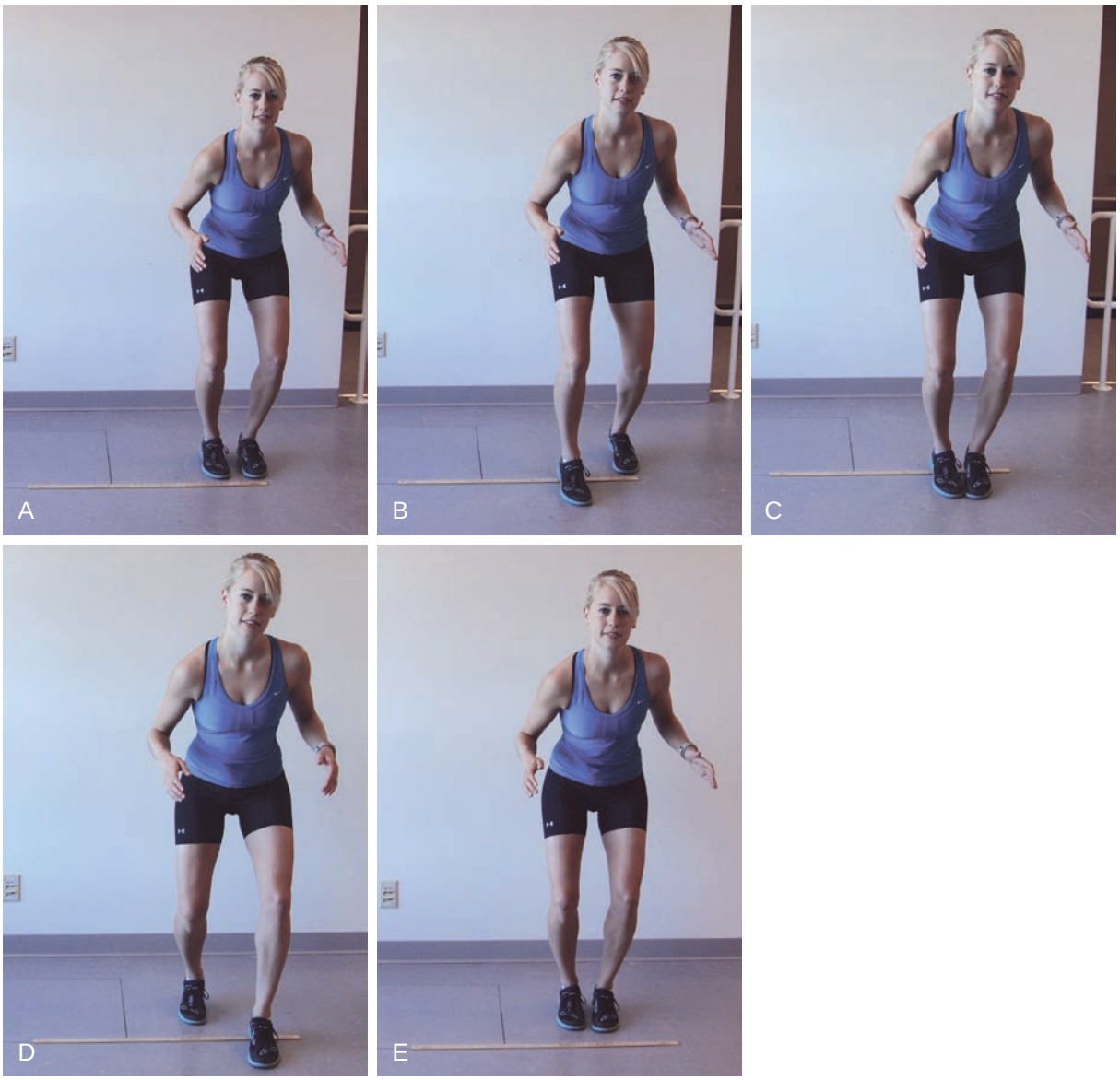


FIGURE 24-16. Forward-backward stepping over a line while moving sideways.

- Prone abdominal body bridge (performed by using abdominal and hip muscles to hold the body in a face down straight plank position with the elbows and feet being the only point of contact), 4 times 20 seconds (Figure 24-18)
- Supine extension bridge (performed by using abdominal and hip muscles to hold the body in a supine hook lying position with the head, upper back, arms and feet being the points of contact), 4 times 20 second (Figure 24-19)
- Side bridge (performed by using abdominal and hip muscles to hold the body in a side-lying plank position with the lower elbow and feet being the only point of contact), four times 20 seconds on each side (Figure 24-20)

Activation of Primary Muscles Involved

- Core muscles of the hip and pelvis, hip abductors and adductors, medial and lateral hamstrings

Sensorimotor Exercises

- Single leg stand, progressing from eyes open to eyes closed

Open and Closed Kinetic Chain Exercises

- Progress agility and trunk stabilization; see above

Techniques to Increase Muscle Strength, Power, and Endurance

- Progress agility and trunk stabilization; see above

Neuromuscular Dynamic Stability Exercises

- Progress agility and trunk stabilization; see above

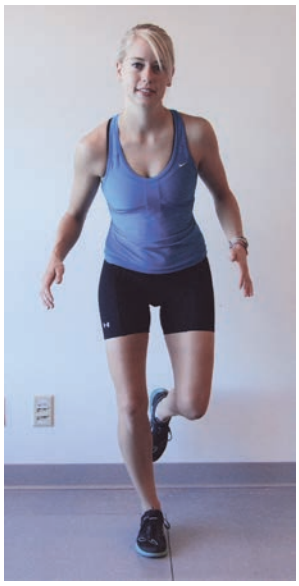


FIGURE 24-17. Single leg standing, progress from eyes open to eyes closed.



FIGURE 24-18. Prone body bridge.



FIGURE 24-19. Supine extension bridge.

Functional Exercises

- Progress agility and trunk stabilization; see above

Milestones for Progression to the Next Phase

- Walk with a normal gait pattern without pain.
- Do a knee to waist height march in place without pain.

TIMELINE 24-3: **Nonoperative Rehabilitation of Hamstring Strains and Contusions**

PHASE I (weeks 0 to 4)	PHASE II (weeks 2 to 8)	PHASE III (starting weeks 4 to 8 postinjury and continuing until return to sport)
Week 1 • Crutches as needed to normalize gait • Begin PATS Phase I • Avoid stretching • Ice and compression wrap to control pain and swelling	• PATS Phase III • Allow gentle hamstring stretching if needed • Neuromobilization techniques • Eccentric strengthening • End-range strengthening • Soft tissue and manual therapy techniques for indirect mobility impairments • Medium-to-high velocity sport-specific and functional drills and skills • Cardiovascular conditioning • Ice as needed	• PATS Phase III (cont) • Lower extremity dynamic mobility drills, including A and B skips • Neuromobilization techniques • End-range eccentric strengthening • Soft tissue and manual therapy techniques for indirect mobility impairments • High-velocity sport-specific and functional drills and skills • Single-leg balance exercises and perturbation type exercises • Sport-specific conditioning
Week 2 • Crutches as needed to normalize gait; DC crutches • PATS Phases I–II • Avoid stretching • Ice and compression wrap to control pain and swelling		
Week 3 • DC crutches • PATS Phases II–III • Avoid stretching • Neuromobilization techniques • Eccentric strengthening • End-range strengthening • Soft tissue and manual therapy techniques for indirect mobility impairments • Low-velocity sport-specific and functional drills and skills • Ice to control pain and swelling		



FIGURE 24-20. Side bridge.

- Have at least 4+/5 strength with one repetition for prone knee flexion at 90° of flexion without pain.

Phase II: Subacute (weeks 2 to 6)

Phase II starts after Phase I milestones are met and continues for 7 to 28 days depending on the severity of injury.

Management of Pain and Swelling

- Ice as needed for postrehabilitation soreness

Manual Therapy Techniques

- During this time if the individual has indirect joint mobility or flexibility limitations, which may have contributed to their injury or the recovery of it, the appropriate manual therapy interventions should be employed. Examples:
  - Restricted ankle dorsiflexion secondary to decreased posterior talar glide (Figure 24-21)
  - Restricted spinal mobility, such as thoracic spine hypomobility limiting upper body rotation and causing increased lumbar lordosis and anterior pelvic tilt
  - Sacroiliac joint restrictions affecting pelvic mobility (Figure 24-22)



FIGURE 24-21. Talar glide to facilitate ankle dorsiflexion.



FIGURE 24-22. Sacroiliac manipulation.

Soft Tissue Techniques

- Manual or self-directed (the Stick, foam roller, etc.) soft tissue mobilization may be gently initiated in this phase for moderate to severe injuries when there is a concern for excessive scar tissue formation (Figure 24-23).

Stretching and Flexibility Techniques for the Musculotendinous Unit

- During this time, isolated and/or aggressive hamstring stretching should be avoided.
- If the individual has indirect mobility or flexibility limitations, which may have contributed to the injury or the recovery of it, corrective therapeutic interventions should be prescribed.
  - Examples include restricted ankle dorsiflexion, restricted spinal mobility or hip flexor tightness.

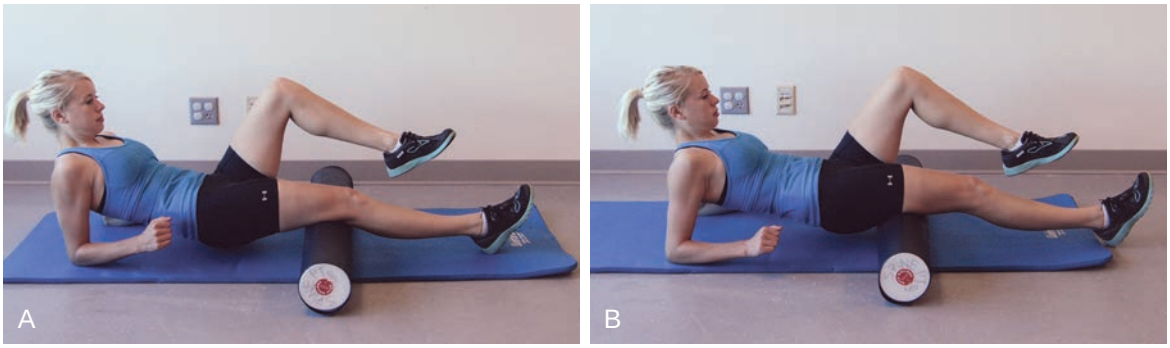


FIGURE 24-23. Foam rolling to hamstrings.

Other Therapeutic Exercises

- Progressive agility and trunk stabilization (PATS), Phase II
  - Moderate to high-intensity side stepping, 3 times 1 minute
  - Moderate– to high-intensity grapevine stepping, 3 times 1 minute
  - Moderate- to high-intensity steps forward and backward while moving sideways, 2 times 1 minute
  - Single leg stand windmill touches (performed by standing on one leg, then rotating the trunk and flexing the hips to bring the hand down in front of the lower leg), 4 times 20 seconds of repetitive alternate hand touches (Figure 24-24)
  - Pushup stabilization with trunk rotation (performed by starting at the top of a full pushup, then maintain this position with one hand while rotating the chest toward the side of the hand that is being lifted to point toward the ceiling, pause and return to the starting position), 2 times 15 reps on each side. (Figure 24-25)
  - Fast feet in place (performed by jogging in place with increasing velocity, picking the foot only a few inches off the ground), 4 times 20 seconds
  - High-to-low and low-to-high wood chops with Thera-Band, 2 × 15 to the right and left of each (Figures 2-26 and 24-27)
- Neuromobilization techniques may be used if the injured athlete demonstrates any sign of adverse lower limb tension as a result of the injury or recovery process. Care should be taken to tension the nerve without overtensioning the injured hamstring, thus limiting the hip flexion component of the neural mobilization techniques (Figure 24-28).

Activation of Primary Muscles Involved

- Core muscles of the hip and pelvis, hip abductors and adductors, medial and lateral hamstrings

Sensorimotor Exercises

- In addition to the balance exercises listed in the PATS program, balance board and unstable surface balance training are appropriate for this phase.

Open and Closed Kinetic Chain Exercises

- See Phase II PATS above.



FIGURE 24-24. Single-leg stand windmill touches.

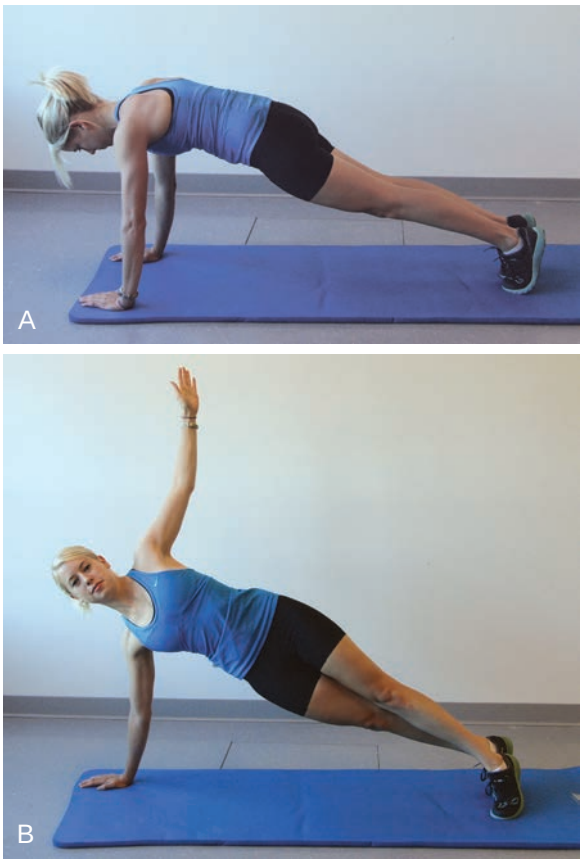


FIGURE 24-25. Pushup stabilization with trunk rotation.

Techniques to Increase Muscle Strength, Power, and Endurance

- Sub-maximal eccentric strengthening exercises near mid-length of the muscle are initiated as part of functional movement patterns rather than through exercises isolating the hamstring.

Neuromuscular Dynamic Stability Exercises

- See Phase II PATS above.

Plyometrics

- Begin initiating plyometric exercises near mid-length of the muscle. These exercises are initiated as part of functional movement patterns rather than through exercises isolating the hamstring.

Functional Exercises

- See Phase II PATS above.

Sport-Specific Exercises

- Symptom-free practice and skill-related drills without high-speed maneuvers.

Milestones for Progression to the Next Phase

- Ability to jog without pain
- Have 5/5 strength for prone knee flexion at 30° of flexion without pain.

Phase III: Early Functional (weeks 4 to 8 and beyond)

Management of Pain and Swelling

- Ice as needed for postrehabilitation or practice soreness



FIGURE 24-26. High to low wood chops.



FIGURE 24-27. Low to high wood chops.

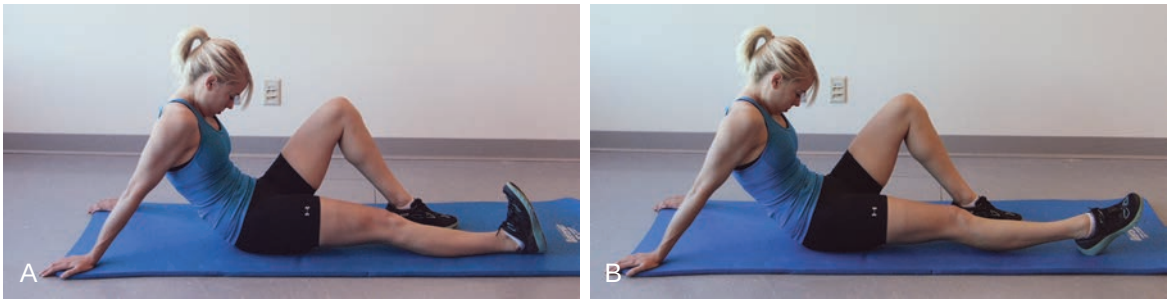


FIGURE 24-28. Neural mobilization.

Manual Therapy Techniques

- Continue during this time working on indirect joint mobility or flexibility limitations, which may have contributed to their injury or the recovery of it, the appropriate manual therapy interventions should be employed. Examples:
  - Restricted ankle dorsiflexion secondary to decreased posterior talar glide
  - Restricted spinal mobility, such as thoracic spine hypomobility limiting upper body rotation and causing increased lumbar lordosis and anterior pelvic tilt.
  - Sacroiliac joint restrictions affecting pelvic mobility

Soft Tissue Techniques

- Manual, augmented (Graston, ASTYM) or self directed (the Stick, foam roller, etc.) soft tissue mobilization may be more aggressively used in this phase for moderate to severe injuries when there is a concern for excessive scar tissue formation.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- During this phase if the athlete has nearly recovered hamstring strength, yet still has limitations in flexibility, then it would be appropriate to include dynamic hamstring stretches.
- The individual should continue to work on indirect flexibility limitations, which may have contributed to the injury or the recovery of it, and they should be given corrective therapeutic interventions.
- Examples would include restricted ankle dorsiflexion, restricted spinal mobility or hip flexor tightness.

Other Therapeutic Exercises

- Dynamic agility drills: Side shuffle, cariocas, boxer shuffles (Figure 24-29), A skips (Figure 24-30) and B skips (Figure 24-31), forward and backward running
- Dynamic core stabilization: Rotating body bridge with dumbbells (Figure 24-32), physioball pushup rotations (Figure 24-33), physio ball bridges with single-leg hold (Figure 24-34)

Activation of Primary Muscles Involved

- Working toward maximal eccentric strengthening exercises near end-length of the muscle are included as part of functional movement patterns. Functional exercises begin to focus on power by being more explosive and reactive.

Sensorimotor Exercises

- This phase should include single-leg balance exercises, especially those involving core control and hamstring activation in a lengthened position. Examples include

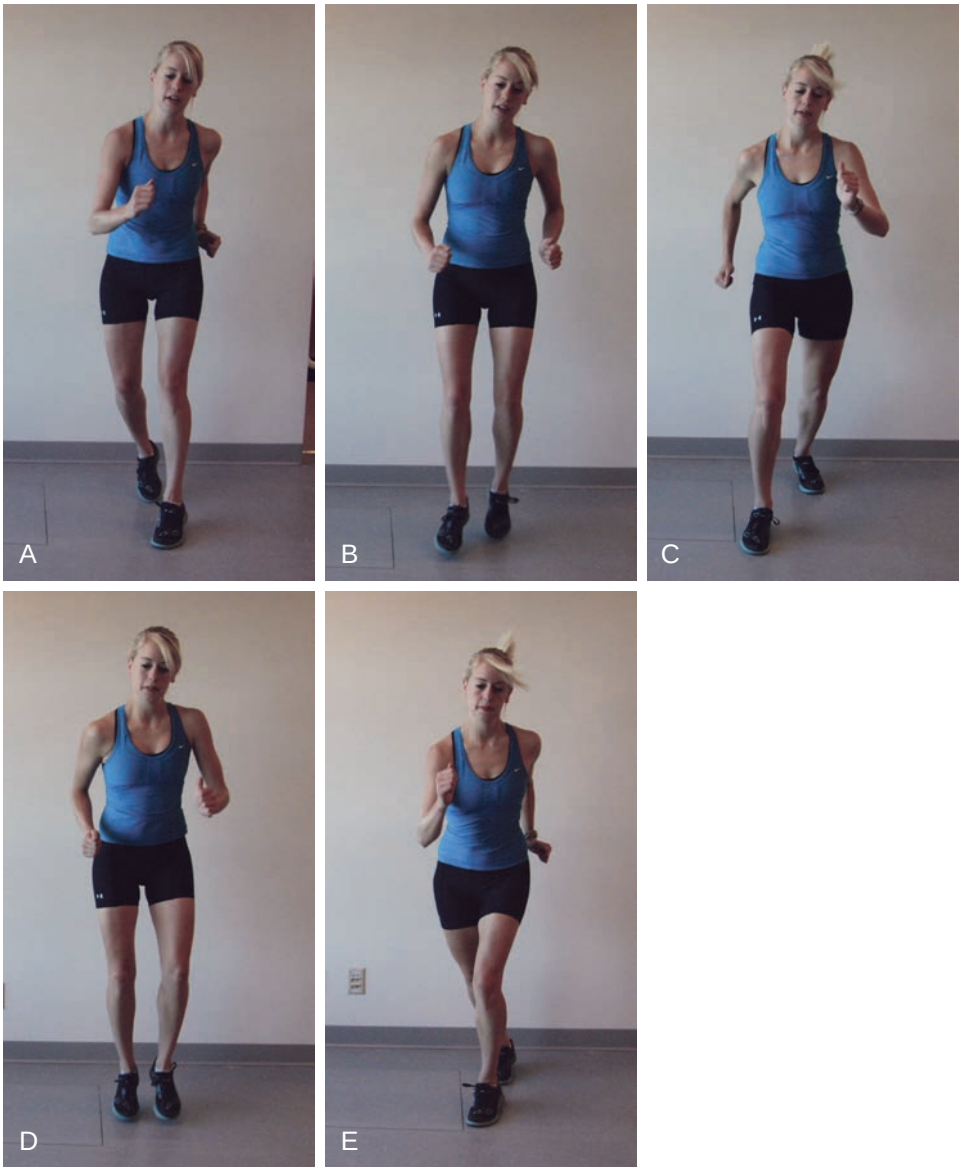


FIGURE 24-29. Boxer shuffles.

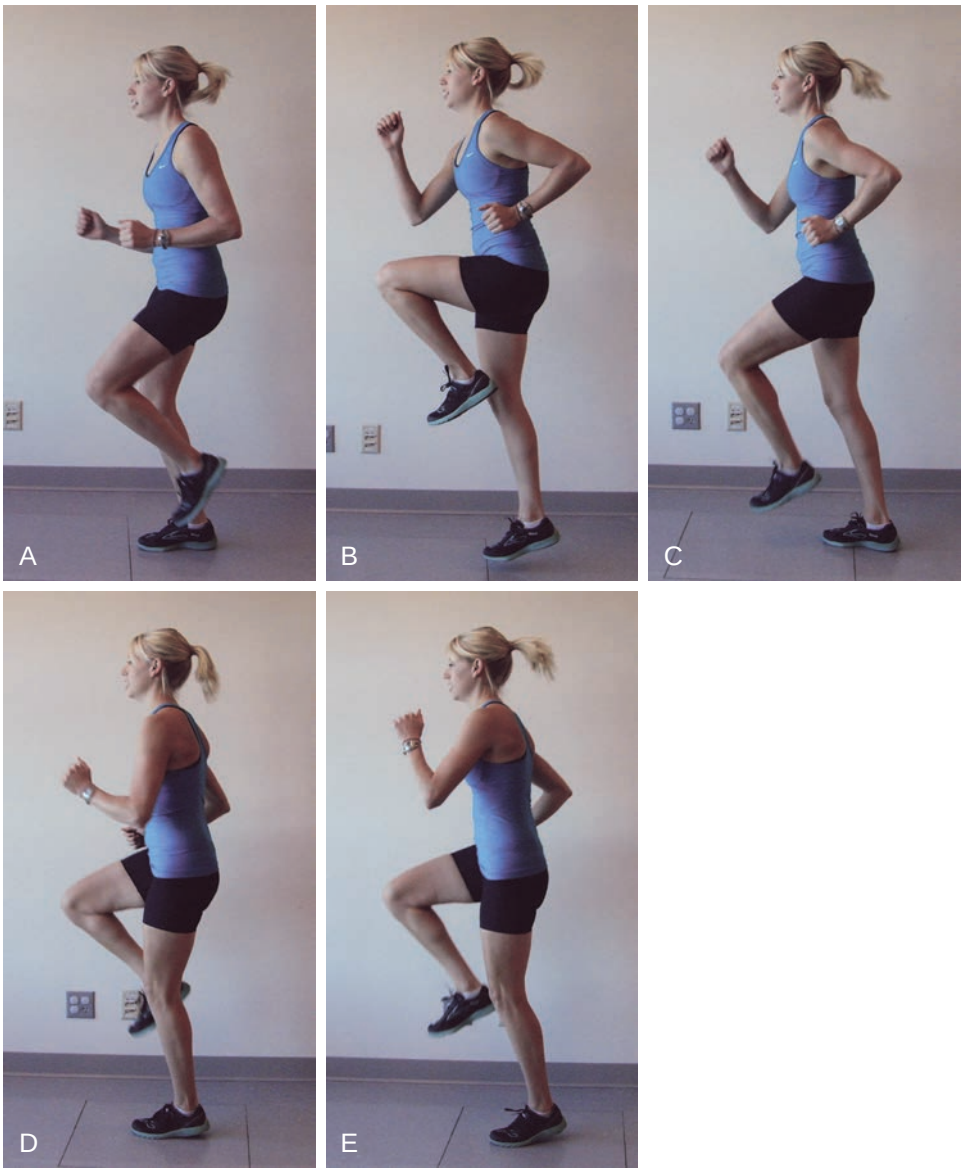


FIGURE 24-30. A skips.

single-leg deadlifts, single-leg dumbbell hang cleans, single-leg windmill touches with dumbbells, and repetitive hop for distance.

Open and Closed Kinetic Chain Exercises

- The transition from open to closed chain movement is important in this phase. Specific exercises that can work on this include B skips, repetitive hopping, alternating leg windmill touches with dumbbell reach and alternating short arc bridge curl on a physio ball.

Techniques to Increase Muscle Strength, Power, and Endurance

- Olympic Lifts
- Snatches
  - Clean and jerk
  - Power clean

Neuromuscular Dynamic Stability Exercises

- Single-leg balance exercises, especially those involving core control and hamstring activation in a lengthened position.
- Examples include the following:
  - Single-leg deadlifts
  - Single-leg dumbbell hang cleans
  - Single-leg windmill touches with dumbbells
  - Repetitive hop for distance

Plyometrics

- Plyometrics are used in this phase to help increase power; focus should be in single-leg activities to prevent overcompensating with the uninvolved leg.

Functional Exercises

- See exercises above.

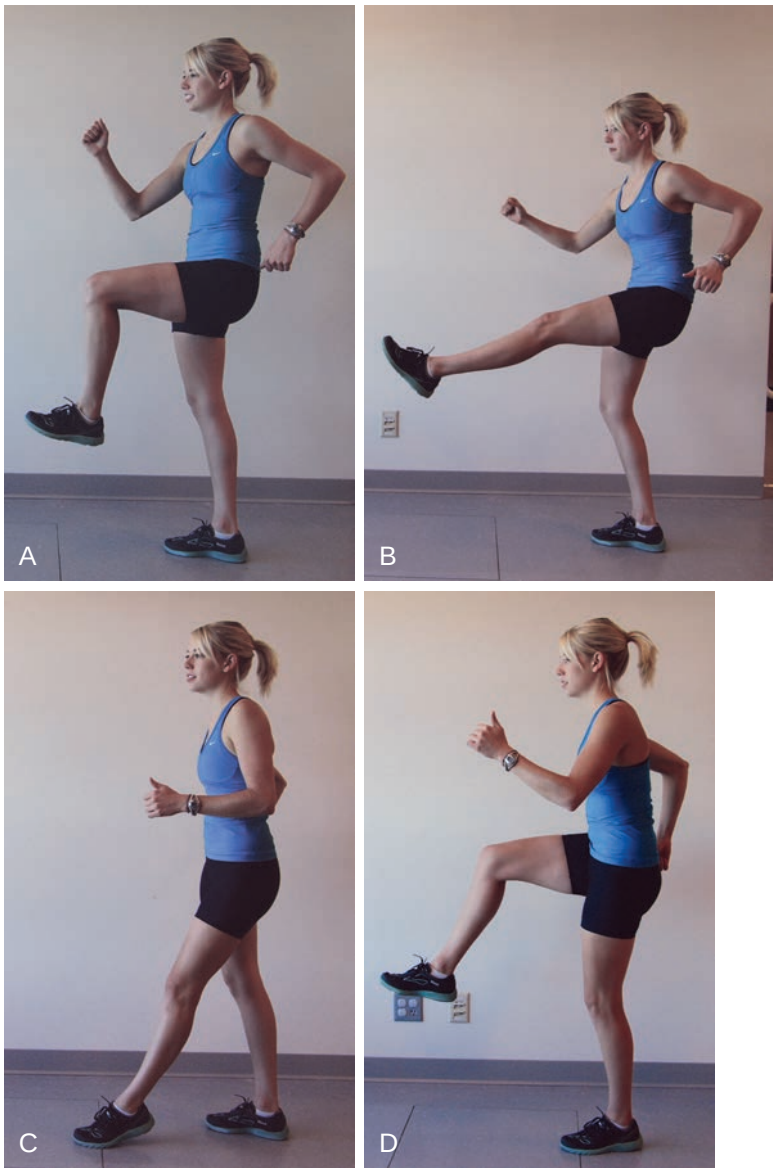


FIGURE 24-31. B skips.

Sport-Specific Exercises

- Symptom-free practice and skill-related drills building up to high-speed maneuvers.
- Running drills that incorporate change of direction as well as change of head and body position are potentially very important during this phase.
- These drills will challenge core control and also train the hamstring activation patterns in various positions and lengths.

Milestones for Progression to Return to Sport

- No apprehension or fear by the athlete. This can be measured and compared to the other side with Asking's active hamstring test.
- Full strength:
  - 5/5 strength on manual muscle testing of the hamstrings in prone at 15° of knee flexion. This should be done with 4 consecutive repetitions with the tibia in external rotation, neutral and internal rotation and then compared with the other side.
  - Less than 5% bilateral deficit in eccentric hamstrings (30°/second): concentric quadriceps (240°/second) ratio during isokinetic testing.
  - Bilateral symmetry in knee flexion angle of peak isokinetic concentric knee flexion torque at 60°/second
- Good control of dynamic single-leg balance and support movements.
- Replication of sport-specific movements near maximal speed without pain or apprehension (e.g., incremental sprint test for running athletes)
- If patient is not making consistent improvement in strength or progression toward the milestones listed above by 12 to 14 weeks, they should be reevaluated by the physician. There are not standard surgical options or time-frames for this injury but adjuncts to rehabilitation, such as PRP or dry needling, may be considered.

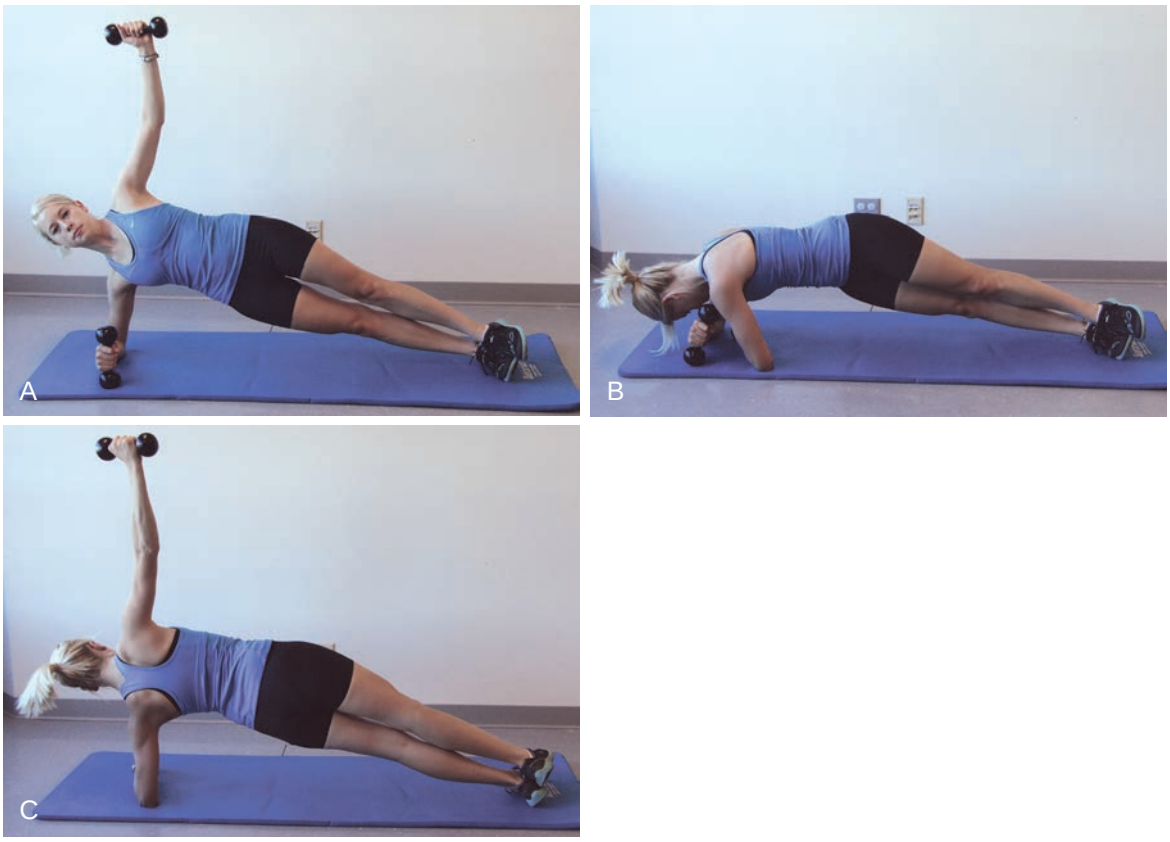


FIGURE 24-32. Rotating body bridge with dumbbells.

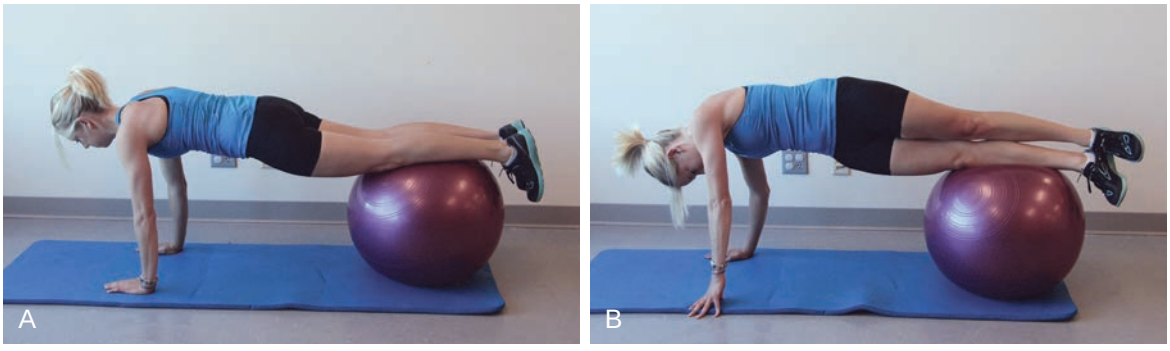


FIGURE 24-33. Physio ball pushup rotations.



FIGURE 24-34. Physio ball bridges with single-leg hold.

Performance Enhancement and Prevention of Reinjury

- Once the athlete has met milestones for return to sport, it is suggested they continue a program for performance enhancement and prevention of reinjury for the rest of that season and following off-season. The physician or physical therapist should reevaluate after the season and prior to the next season to screen for potential muscle imbalances, compensations, or weaknesses that have developed and subsequently make that athlete at higher risk for reinjury.

- Program components should include:
  - Single-leg balance exercises and perturbation type exercises
  - Dynamic agility drills
  - Eccentric hamstring strengthening, especially in a lengthened position
  - Core and trunk stabilization exercises

Specific Criteria for Return to Sports Participation: Tests and Measurements

- Pain free to palpation over the site of muscle strain
- Full concentric and eccentric strength of the hamstrings (as compared to the uninjured side) tested in a lengthened position. This can be done with an isokinetic dynometer, a mobile force sensor, or estimated with manual muscle testing.
- Full concentric and eccentric muscular endurance of the hamstrings (as compared to the uninjured side) tested in a lengthened position. This can be done with an isokinetic dynometer, a mobile force sensor, or estimated with repetition manual muscle testing.
- No fear or kiniesophobia, as measured by the hamstring active test (H Test) or modified hamstring active test.
- No pain or fear with a progressive sprint test of at least 30 yards (70% to 80% to 90% to 95% speed intervals).

Evidence

Askling CM, Nilsson J, Thorstensson A: A new hamstring test to complement the common clinical examination before return to sport after injury. *Knee Surg Sports Traumatol Arthrosc* 18:1798–1803, 2010.

Eleven healthy subjects (average age, 28 years) were tested on repeated occasions, and 11 athletes (average age, 21 years) with MRI-verified acute hamstring strain were tested when common clinical examination revealed no signs of remaining injury. Flexibility (highest range of motion of three consecutive trials) was calculated during active ballistic hip flexions and conventional passive slow hip-flexions in a supine position. A VAS-scale (0-100) was used to estimate experience of insecurity during active tests. No significant test-retest differences were observed. Active flexibility was greater (23%) than passive flexibility. In the athletes, the injured leg showed smaller (8%) active, but not passive, flexibility than the uninjured leg. Average insecurity estimation was 52 (range 28-98) for the injured and 0 for the uninjured leg, respectively. The authors report that in their own clinical experience they have used the feeling of insecurity as a guide for return to play, and in doing so they have not experienced reinjuries during the first 4 weeks. Therefore, they recommend that if an athlete has insecurity, the test should be repeated in 2 weeks, and return to sport should not be allowed until no insecurity is present. (Level III and Level V evidence).

Cameron ML, Adams RD, Maher CG, et al: Effect of the Ham-Sprint Drills training programme on lower limb neuromuscular control in Australian football players. *J Sci Med Sport* 12:24–30, 2007.

This randomized controlled trial of 29 footballers from one professional Australian Football League club compared drills specific to the improvement of running technique, coordination, and hamstring function to normal training. The training group showed significant improvement in lower limb neuromuscular control with movements similar to the late-swing, early stance phase of running. (Level I evidence).

Chumanov ES, Heiderscheit BC, Thelen DG: The effect of speed and influence of individual muscles on hamstring mechanics during the swing phase of sprinting. *J Biomech* 40:3555–3562, 2007.

The purpose of this study was to characterize the effect of speed and influence of individual muscles on hamstring stretch, loading, and work during the swing phase of sprinting at speeds ranging from 80% to 100% of maximum speed. Swing phase simulations were used to characterize the effects of speed on the peak stretch, maximum force, and negative work of the biceps femoris long head (BF), the most often injured hamstring muscle. Perturbations of the double float simulations were used to assess the influence of individual muscles on BF stretch. Peak hamstring musculotendon stretch occurred at approximately 90% of the gait cycle (late swing) and was independent of speed. Peak hamstring force and negative musculotendon work increased significantly with speed ($p<0.05$). Muscles in the lumbo-pelvic region had greater influence on hamstring stretch than muscles acting about the knee and ankle, with the hip flexors were found to induce the most hamstring stretch in the opposite limb. They concluded that hamstring strain injury during sprinting may be related to the performance of large amounts of negative work over repeated strides and/or resulting from a perturbation in pelvic muscle coordination that induces excessive hamstring stretch in a single stride. (Level II evidence).

Croisier JL, Ganteaume S, Binet J, et al: Strength imbalances and prevention of hamstring injury in professional soccer players: a prospective study. *Am J Sports Med* 36:1469–1475, 2008.

This prospective cohort study of professional soccer players determined whether strength variables could be predictors of subsequent hamstring strain and if normalization of strength imbalances could reduce the incidence of hamstring injury. The rate of muscle injury was significantly increased in subjects with untreated strength imbalances; normalizing the isokinetic parameters reduced the risk factor for injury to that observed in players without imbalances. (Level II evidence).

Kraemer R, Knobloch K: A soccer-specific balance training program for hamstring muscle and patellar and achilles tendon injuries: an intervention study in premier league female soccer. *Am J Sports Med* 37:1384–1393, 2009.

This prospective cohort study of 24 elite female soccer players determined whether proprioceptive training can reduce the incidence of hamstring muscle injuries. Soccer-specific balance training reduced noncontact hamstring injuries with a dose-effect relationship between duration of balance training and injury incidence present. (Level III evidence).

Sherry MA, Best TM: A comparison of two rehabilitation programs in the treatment of acute hamstring strains. *J Phys Ther Orthop Sports* 34:116–125, 2004.

This randomized controlled trial of 24 athletes with an acute hamstring strain compared rehabilitation programs

comprised of static stretching and isolated progressive hamstring resistance exercises or progressive agility and trunk stabilization exercises. Seventy percent (70%) of the athletes who completed the hamstring stretching and strengthening program, as compared to only 7.7% of the athletes who completed the progressive agility and trunk stabilization program, suffered a recurrent hamstring strain during a 1-year period. (Level I evidence).

Sole G, Milosavljevic S, Nicholson HD, et al: Selective strength loss and decreased muscle activity in hamstring injury. *J Orthop Sports Phys Ther* 41:354–363, 2011.

This cross-sectional laboratory study compared muscle isokinetic torque patterns and EMG activity in 15 individuals without hamstring injury and 15 individuals who had sustained a hamstring injury within the past year but had returned to at least partial sports training. Eccentric flexor torque was significantly less in the lengthened range of in the hamstring injured limb in comparison to the uninjured limb, despite no significant differences in absolute peak torque throughout the range. Differences were also found between groups in EMG amplitudes during eccentric flexor contractions, indicating neurophysiological factors may contribute to the changes in torque. (Level II evidence).

Sole G, Milosavljevic S, Nicholson H, et al: Altered muscle activation following hamstring injuries. *Br J Sports Med* 46:118–123, 2012.

In this study, 16 participants with a hamstring injury and 18 control participants participated. The EMG activity of gluteal, quadriceps, and hamstring muscles was recorded during a movement from double- to single-leg movement using surface electrodes. The EMG onsets of biceps femoris and medial hamstrings were significantly earlier for the HG injured and the uninjured sides in preparation for single-leg standing when compared with the CG average. There were no differences in onsets for the gluteal and quadriceps muscles when comparing the injured or uninjured legs of the HG to the bilateral average of the CG. This earlier onset of the injured and the uninjured hamstrings in preparation for single-leg stance of the HG in comparison with the CG suggests an alteration in the motor control of these muscles and thus neuromuscular control following a hamstring injury may be an important consideration in the rehabilitation of hamstring injuries. (Level II evidence).

Gabbe BJ, Bennell KL, Finch CF, et al: Predictors of hamstring injury at the elite level of Australian football. *Scand J Med Sci Sports* 16:7–13, 2006.

A prospective cohort of 222 players underwent baseline measurement in the form of a self-report questionnaire and a musculo-skeletal screen during the preseason period of the 2002 Australian football season. Injury surveillance and exposure data were collected for the full season. Logistic regression analyses were used to identify independent predictors of hamstring injury in this group of players. A total of 31 players sustained a hamstring injury. A past history (previous 12 months) of hamstring injury and increasing age were found to be independent predictors of hamstring injury. Restricted ankle dorsiflexion range of movement showed trends toward predicting injury and thus also warrants consideration in the development of prevention programs for hamstring injury. (Level I evidence).

Warren P, Gabbe BJ, Schneider-Kolsky M, et al: Clinical predictors of time to return to competition and of recurrence following hamstring strain in elite Australian footballers. *Br J Sports Med* 44:415–419, 2010.

A total of 59 Aussie football players who suffered a hamstring strain underwent a clinical assessment by a physiotherapist and questionnaire. This study found players taking more than 1 day to walk pain free were significantly more likely (p=0.018) to take longer than 3 weeks to return to competition (adjusted odds ratio 4.0; 95% CI 1.3 to 12.6). Nine players (15.2%) experienced an injury recurrence, all involving the biceps femoris. Recurrence was more likely in players who reported a hamstring injury in the past 12 months (adjusted odds ratio 19.6; 95% CI 1.5 to 261.0; p=0.025). Time to walk pain free and previous hamstring injury are predictors of time to return to competition and recurrence, respectively. (Level III evidence).

Multiple-Choice Questions

QUESTION 1. Which of the following should be avoided in Phase I of the hamstring injury rehabilitation program?

A. Core stabilization
B. Agility drills
C. Aggressive stretching
D. Icing

QUESTION 2. Which statement most accurately describes the hamstring active test?

A. It is more sensitive when done in standing instead of supine
B. The injured leg shows smaller passive, but not active, flexibility than the uninjured leg
C. This test should only be used after the athlete has returned to sport.
D. Apprehension or insecurity is the most important clinical measure from the test in regards to return to sport.

QUESTION 3. Which factor is important to incorporate in to hamstring rehabilitation?

A. Eccentric strengthening
B. Neuromuscular control
C. End-range hamstring strengthening
D. Core strengthening
E. All of the above

QUESTION 4. Which best describes the progression of agility exercises in the PATS program

A. Start with slow, small movements in the frontal plane progressing to faster, then bigger, then transverse and sagittal plane movements.
B. Start with slow, large movements in the frontal plane progressing to faster, then smaller, then transverse and sagittal plane movements.
C. Start with slow, small movements in the sagittal plane progressing to faster, then bigger, then transverse and frontal plane movements.
D. Start with fast, small movements in the frontal plane progressing to slower heavier resistance in the transverse and sagittal plane movements.

QUESTION 5. The most appropriate criteria for return to sport includes:

A. More passive than active motion in the injured leg on the hamstring active test, 5/5 end range strength on repeated hamstring manual muscle testing, confidence with sport-specific movements
B. No insecurity on the hamstring active test, 5/5 end range strength on repeated hamstring manual muscle testing, confidence with sport-specific movements
C. More active than passive motion in the injured leg on the hamstring active test, 5/5 end range strength on repeated hamstring manual muscle testing, confidence with sport-specific movements
D. No insecurity on the hamstring active test, 5/5 strength on hamstring manual muscle testing at 90° knee flexion, confidence with sport-specific movements

Answer Key

QUESTION 1. Correct answer: **C** (see Phase I).

QUESTION 2. Correct answer: **D** (see Askling, 2010).

QUESTION 3. Correct answer: **E** (see Annotated Evidence).

QUESTION 4. Correct answer: **A** (see Sherry, 2004).

QUESTION 5. Correct answer: **B** (see Phase III).

BEYOND BASIC REHABILITATION: RETURN TO SPRINTING ACTIVITIES AFTER HAMSTRING STRAIN

Bryan Heiderscheit, PT, PhD, Marc Sherry, PT, DPT, LAT, CSCS, and William Clancy, MD

Introduction

ASPECTS OF SPRINTING THAT REQUIRE SPECIAL ATTENTION IN REHABILITATION

- During the terminal swing phase of running, the hamstring muscles are active while elongating, resulting in substantial eccentric loading.
- The mechanical energy absorbed by the hamstrings during this eccentric loading exponentially increases with running speed.
- Hamstring injury during running is most likely to occur during the terminal swing phase.

Hamstring injuries are very common during high-speed running, particularly sprinting. This injury remains challenging as up to 30% of individuals will experience an injury recurrence upon returning to sport despite completing a formalized rehabilitation program.

The return to running program is given in Box 24-2.

Literature

- Persistent strength deficits, in particular eccentric hamstring strength, have been found to increase the risk of running-related reinjury to the hamstring muscles.[1]
- In addition, inaccuracies in perceiving running-like leg movements have been associated with an increased risk for hamstring strain injury.[2]
- Finally, individuals with a prior hamstring strain often show altered recruitment of the hamstring muscles, potentially affecting the neuromuscular coordination needed to sprint safely.[3]

Advanced Strength and Conditioning Programs

Periodization

- The program is progressed in a linear manner over time.

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- Training continuum
- Flexibility/joint mobility for joint stability
- Training with optimum posture
- Sensorimotor and balance training
- Core training
- Cardiorespiratory training
- Multiplanar training activities
- Training for optimum muscle balance
- Training for optimum muscle functional strength
- Training for optimum muscle functional power
- Neuromuscular dynamic stability exercises
- Training for speed, agility, quickness (SAQ)
- Plyometric training
- Functional training
- Sport-specific training

BOX 24-2 Return to Sprinting Program

This program is designed for individuals who have recently completed rehabilitation for a hamstring strain injury and are now returning to a sport that involves sprinting. Because the greatest risk for reinjury is present during the initial 2 weeks of returning to sport, it is important that this transition be made gradually and progressively. As such, the program is divided into 3 phases, each lasting 2 weeks:

- The initial 2 weeks are focused on the persistent neuromuscular deficits that may remain such as reduced hamstring recruitment, endurance, and ease of movement. The exercises are a continuation of those performed during rehabilitation but with greater speed and intensity.
- During weeks 3 and 4, sport-specific movements with challenging body posture are initiated as are aggressive eccentric training of the hamstrings.
- Finally, weeks 5 and 6 are designed to simulate competition but in a slightly more controlled manner. These exercises are designed to be performed as a stand-alone program. If the individual is also participating in an organized practice or training program, the volume involved with this program should be reduced to avoid overtraining.
- In addition, the strength training aspects should be performed after practice as the gains from eccentric training are better when the muscle is fatigued.

Weeks 1 to 2

GOALS:

1. Promote residual healing
2. Promote full range ease of movement
3. Facilitate hamstring muscle recruitment
4. Promote neuromuscular endurance

EXERCISES/DRILLS:

Dynamic warmup

1. Leg cycling drill, 3 × 10 each leg
2. High knee marching, 3 × 30 meters, jog back to start between repetitions
3. Heel kicks, 3 × 30 meters, jog back to start between repetitions
4. Quick carioca, 2 × 30 meters each direction
5. Cross-over skip, 2 × 30 meters each direction
6. A and B skips, 3 × 30 meters, jog back to start between repetitions A and B skips are a hurdle drill to work on the drive of the lead leg up to the hurdle. The A consists of the initial drive up and the B consists of the extension when the height of the hurdle trajectory is reached.
7. Forward-backward accelerations (20 meters), 3 × 1 minute

Running

8. Falling starts, 3 × 40 meters, walk back to start between repetitions
9. 3-point start, 3 × 40 meters, walk back to start between repetitions
10. Sprinting (70% to 90% intensity), 4 × 60 meters, walk back to start between repetitions

Strength and endurance

11. Rotating body bridge with dumbbells, 5 second hold each side, 2 × 15
12. Supine single-limb chair-bridge, 3 × 15, fast speed
13. Single-limb balance windmill touches with dumbbells, 4 × 10 per arm each leg
14. Prone hip extension off the edge of bed or table for full ROM with ankle weight, start at the top then drop and catch the leg, 2 × 20
15. Lunge walk with trunk rotation, opposite hand dumbbell toe touch and T-lift, 2 × 15 steps per limb (Figure 24-35)

Weeks 3 to 4

GOALS:

1. Promote residual healing
2. Facilitate hamstring muscle hypertrophy with eccentric focus
3. Facilitate symmetrical sprinting mechanics

EXERCISES/DRILLS:

Dynamic warmup

1. Leg cycling drill, 3 × 10 each leg, jog back to start between repetitions
2. High knee marching, 3 × 30 meters, jog back to start between repetitions
3. Heel kicks, 3 × 30 meters, jog back to start between repetitions
4. Quick carioca, 2 × 30 meters each direction
5. Cross-over skip, 2 × 30 meters each direction
6. A and B skips, 3 × 30 meters, jog back to start between repetitions
7. Forward-backward accelerations (20 meters), 3 × 1 minute

BOX 24-2 Return to Sprinting Program *(Continued)*



FIGURE 24-35. Lunge walk with trunk rotation, opposite hand dumbbell toe touch, and T-lift.

Running

8. 3-point start, 3 × 40 meters, walk back to start between repetitions
9. Squat jump and go, 3 × 40 meters, walk back to start between repetitions
10. Sprinting (80% to 95% intensity), 4 × 80 meters, walk back to start between repetitions
11. Sports-specific movements with changing body posture and head positions

Strength

12. Nordic hamstring drop-curl progression (Figures 24-36 and 24-37)
    a. 3 × 8–12, drop and return
    b. Can initially use physio ball to reduce range of motion and bands/cables to reduce load
13. Rotating body bridge with dumbbells, 5 second hold each side, 2 × 15
14. Backward weight throw standing on 2 legs, 2 × 15 (Figure 24-38)

Weeks 5 to 6

GOALS:

1. Facilitate hamstring muscle hypertrophy with eccentric focus and end-range strength
2. Facilitate symmetrical sprinting mechanics

EXERCISES/DRILLS:

Dynamic warmup

1. Leg cycling drill, 3 × 10 meters each leg, jog back to start between repetitions
2. High knee marching, 3 × 30 meters, jog back to start between repetitions
3. Heel kicks, 3 × 30 meters, jog back to start between repetitions
4. Quick carioca, 2 × 30 meters each direction
5. Cross-over skip, 2 × 30 meters each direction
6. A and B skips, 3 × 30 meters, jog back to start between repetitions
7. Forward-backward accelerations (20 meters), 3 × 1 minute

Continued on following page

BOX 24-2 Return to Sprinting Program *(Continued)*







FIGURE 24-36. Nordic hamstring curls.

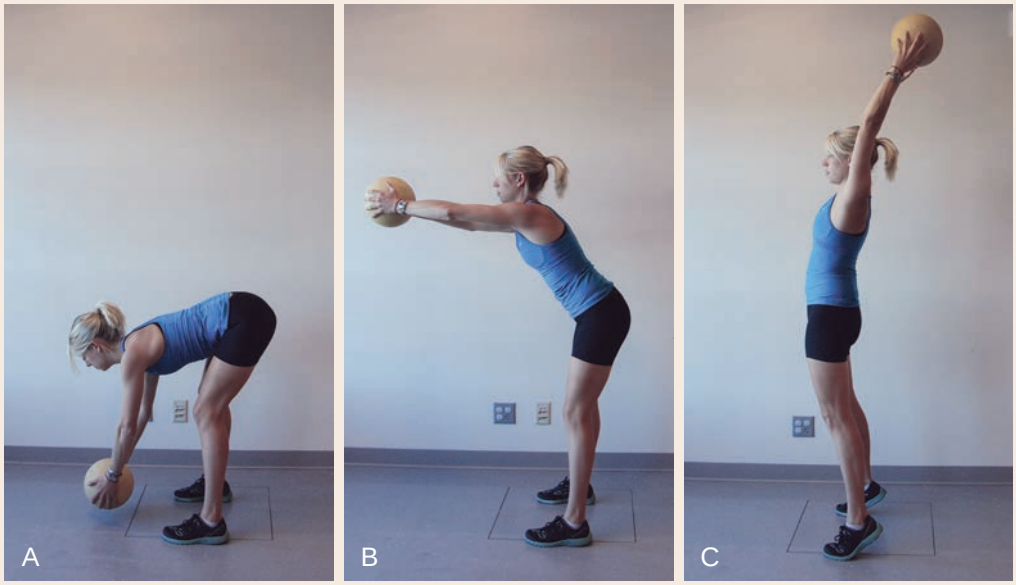






FIGURE 24-37. Nordic hamstring curls with elastic band assistance.

BOX 24-2 Return to Sprinting Program *(Continued)*



Running

8. Squat jump and go, 3 × 40 meters, walk back to start between repetitions
9. Straight leg running, 3 × 20 meters, walk back to start between repetitions
10. Sprinting (85% to 100% intensity), 4 × 100 meters, walk back to start between repetitions
11. Sports-specific movements with changing body posture

Strength

12. Nordic hamstring drop-curl progression
    a. 3 × 12 reps drop and return with increased drop speed
13. Rotating body bridge with dumbbells, 5 second hold each side, 2 × 15
14. Backward weight throw standing on 1 leg, 2 × 15

TIMELINE 24-4: **Beyond Basic Rehabilitation: Return to Sprinting Activities After Hamstring Strain**

PHASE I (weeks 1 to 2)	PHASE II (weeks 3 to 4)	PHASE III (weeks 5 to 6)
• Leg cycling drill • High knee marching • Heel kicks • Quick carioca • Cross-over skip • A and B skips • Forward-backward accelerations • Falling starts • Three-point start • Sprinting (70%–90%) • Rotating body bridge with dumbbells • Supine single-limb chair-bridge • Single-limb balance windmill touches with dumbbells • Prone hip extension off the edge of bed or table for full ROM with ankle weight • Lunge walk with trunk rotation, opposite hand dumbbell toe touch and T-lift	• Leg cycling drill • High knee marching • Heel kicks • Quick carioca • Cross-over skip • A and B skips • Forward-backward accelerations • Three-point start • Squat jump and go • Sprinting (80%–95%) • Sports-specific movements with changing body posture • Nordic hamstring drop-curl progression • Rotating body bridge with dumbbells • Backward weight throw standing on two legs	• Leg cycling drill • High knee marching • Heel kicks • Quick carioca • Cross-over skip • A and B skips • Forward-backward accelerations • Squat jump and go • Straight leg running • Sprinting (85%–100%) • Sports-specific movements with changing body posture • Nordic hamstring drop-curl progression • Rotating body bridge with dumbbells • Backward weight throw standing on one leg

Training Principles Used in the Design of the Program

- Principle of progression
- Principle of overload
- Principle of variation
- Principle of individualization
- Principles of specificity; specific adaptation to imposed demands (SAID)

Sports Performance Testing

General Information

- General history
- Medical history
- Sports injury history
- Surgical history
- Chronic conditions/medication

Subjective Questions

- Perceived ease of movement throughout full hip/knee range of motion
- Minimal self-reported insecurity of movement with active straight leg raise

Objective Tests

- Dynamic muscle performance testing
  - Isokinetic testing performed at time of return to sport and 6 weeks later
    - Concentric strength of the quadriceps and hamstrings at 60°/second and 240°/second
    - Eccentric strength of the hamstrings at 0°/second
    - Less than 5% bilateral asymmetry in hamstring to quadriceps peak torque ratio (H_{ECC30}: Q_{CON240})
- Movement performance testing
  - Nordic drops (assessing during each training session)
    - assessing depth of drop and ability to return
- Sport-specific testing
  - Straight line sprinting (assessing during each training session)
    - Bilateral symmetry in heel height during swing phase
    - Bilateral symmetry in foot-ground contact pattern
  - Sprinting with changing body posture specific to sport
    - Appropriate pelvic motion but not excessive
    - Able to bend forward at hips without excessive lumbar motion

Specific Criteria for Progression to the Next Stage to Determine Readiness for Sprinting

- Time criteria only, as the player is no longer injured and is back to sport

Recommended Ongoing Exercises

- The program should be repeated as part of each year's preseason training.
- The core stabilization exercises should be completed indefinitely.

Evidence

Askling C, Karlsson J, Thorstensson A: Hamstring injury occurrence in elite soccer players after preseason strength training with eccentric overload. *Scand J Med Sci Sport* 13:244–250, 2003.

This randomized controlled trial of 30 premier-league soccer players compared preseason strength training with emphasis on eccentric overload to a normal preseason training. The training group showed a decreased incidence of hamstring strain injuries over the subsequent 10 months with an increase in strength and speed. (Level I evidence).

Brooks JH, Fuller CW, Kemp SP, et al: Incidence, risk, and prevention of hamstring muscle injuries in professional rugby union. *Am J Sports Med* 34:1297–1306, 2006.

This prospective cohort study defined the incidence, severity, and risk factors associated with hamstring strain injuries in professional rugby, as well as whether hamstring strengthening and stretching exercises reduce the incidence and severity of these injuries. Running accounted for the majority of hamstring injuries but kicking resulted in the most severe. Nordic hamstring exercises reduced the incidence and severity of injury during practice and competition. (Level III evidence).

Cameron ML, Adams RD, Maher CG, et al: Effect of the Ham-Sprint Drills training programme on lower limb neuromuscular control in Australian football players. *J Sci Med Sport* 12:24–30, 2007.

This randomized controlled trial of 29 footballers from one professional Australian Football League club compared drills specific to the improvement of running technique, coordination and hamstring function to normal training. The training group showed significant improvement in lower limb neuromuscular control with movements similar to the late-swing, early stance phase of running. (Level 1 evidence).

Croisier JL, Ganteaume S, Binet J, et al: Strength imbalances and prevention of hamstring injury in professional soccer players: a prospective study. *Am J Sports Med* 36:1469–1475, 2008.

This prospective cohort study of professional soccer players determined whether strength variables could be predictors of subsequent hamstring strain and if normalization of strength imbalances could reduce the incidence of hamstring injury. The rate of muscle injury was significantly increased in subjects with untreated strength imbalances; normalizing the isokinetic parameters reduced the risk factor for injury to that observed in players without imbalances. (Level I evidence).

Engebretsen AH, Myklebust G, Holme I, et al: Intrinsic risk factors for hamstring injuries among male soccer players: a prospective cohort study. *Am J Sports Med* 38:1147–1153, 2010.

This cohort study of 508 players from 31 amateur teams determined whether previous hamstring injuries, reduced function scores, abnormalities on a clinical examination, high maximum sprint speed, poor hamstring strength, or low hamstring/quadriceps ratio can predict increased risk of new hamstring injuries. Previous acute hamstring injury was found to be the most important risk factor for new injury, with previously injured players having more than twice as high a risk of sustaining a new hamstring injury. (Level II evidence).

Kraemer R, Knobloch K: A soccer-specific balance training program for hamstring muscle and patellar and achilles tendon

injuries: an intervention study in premier league female soccer. *Am J Sports Med* 37:1384–1393, 2009.

This prospective cohort study of 24 elite female soccer players determined whether proprioceptive training can reduce the incidence of hamstring muscle injuries. Soccer-specific balance training reduced noncontact hamstring injuries with a dose-effect relationship between duration of balance training and injury incidence present. (Level III evidence).

Sherry MA, Best TM: A comparison of 2 rehabilitation programs in the treatment of acute hamstring strains. *J Orthop Sports Phys Ther* 34:116–125, 2004.

This randomized controlled trial of 24 athletes with an acute hamstring strain compared rehabilitation programs comprised of static stretching and isolated progressive hamstring resistance exercises or progressive agility and trunk stabilization exercises. Seventy percent (70%) of the athletes who completed the hamstring stretching and strengthening program, as compared to only 7.7% of the athletes who completed the progressive agility and trunk stabilization program, suffered a recurrent hamstring strain during a 1-year period. (Level I evidence).

Verrall GM, Slavotinek JP, Barnes PG: The effect of sports-specific training on reducing the incidence of hamstring injuries in professional Australian Rules football players. *Br J Sports Med* 39:363–368, 2005.

This prospective cohort study of one team of Australian Rule football players assessed the effect of a sport-specific intervention program on the incidence and consequence of hamstring strain injuries. During the 2 years with the intervention, a decreased incidence of hamstring injuries was observed, as well as fewer games missed caused by this injury. (Level III evidence).

REFERENCES

1. Croisier JL, Ganteaume S, Binet J, et al: Strength imbalances and prevention of hamstring injury in professional soccer players: a prospective study. *Am J Sports Med* 36:1469–1475, 2008.
2. Cameron ML, Adams RD, Maher CG, et al: Effect of the HamSprint Drills training programme on lower limb neuromuscular control in Australian football players. *J Sci Med Sport* 12:24–30, 2007.
3. Sole G, Milosavljevic S, Nicholson HD, et al: Selective strength loss and decreased muscle activity in hamstring injury. *J Orthop Sports Phys Ther* 41:354–363, 2011.

Multiple-Choice Questions

Question 1. During sprinting, the hamstring muscles are at the great risk for reinjury at:

A. Midstance
B. Push-off
C. Initial swing
D. Terminal swing

Question 2. After returning to sport following a hamstring strain injury, what neuromuscular deficit has not been identified?

A. Muscle weakness
B. Altered proprioception
C. Increased stiffness
D. Altered recruitment

Question 3. Because of the residual evidence of muscle injury that is common at the time of return to sport, what type of exercise is delayed until week 3?

A. High-speed running/sprinting
B. Eccentric strength training
C. Progressive agility
D. Trunk stabilization

Question 4. Which of the following is not part of the sports performance testing for return to sprinting activities following a hamstring strain injury?

A. Isokinetic strength testing
B. Sprinting mechanics
C. Nordic drops
D. Passive straight leg raise

Question 5. Based on the Engebretsen et al. (2010) study, what is the single biggest risk factor for incurring another hamstring strain injury?

A. A previous hamstring injury
B. Straight leg raise less than 60°
C. Hamstring strength bilateral difference of 15%
D. Athlete perception of reduced performance

Answer Key

QUESTION 1. Correct answer: **D** (see Introduction)

QUESTION 2. Correct answer: **C** (see Introduction)

QUESTION 3. Correct answer: **B** (see Box 24-2).

QUESTION 4. Correct answer: **D** (see Sports Performance Testing).

QUESTION 5. Correct answer: **A** (see Evidence).

POSTOPERATIVE REHABILITATION AFTER REPAIR OF PROXIMAL HAMSTRING AVULSION

Matthew Joseph Salzler, MD, Steve Brian Behrens, MD, and James P. Bradley, MD

Indications for Surgical Treatment

- All three hamstring origins avulsed
- Sciatic nerve symptoms secondary to hamstring avulsion
- Two hamstring origins avulsed with >2 cm of retraction
- One or two hamstring origin chronic avulsion with <2 cm of retraction with persistent pain, despite adequate nonoperative management

Brief Summary of Surgical Treatment

Major Surgical Steps

- General anesthesia with patient in prone position and table flexed ~30° at the waist (Figure 24-39)
- Transverse infragluteal incision, retract gluteus maximus proximally (Figure 24-40)
- Protect sciatic nerve
- Longitudinally incise hamstring fascia, mobilize hamstring origins
- Prepare ischial tuberosity and proximal hamstrings (Figure 24-41)
- Place five 2.8 to 3.0 mm PLDLA/calcium phosphate suture anchors loaded with high-strength nonabsorbable sutures in an X configuration (Figure 24-42)
- Pass sutures through tendons in horizontal mattress fashion and tie down securely (Figure 24-43); we prefer horizontal mattress sutures through the tendon over a whipstitch to prevent tendon bunching
- Careful multilayered wound closure covered with a waterproof dressing
- Postop precautions: Touchdown weight bearing with knee immobilizer locked at 40°
- Complications: Wound dehiscence, sitting discomfort, posterior thigh/foot numbness

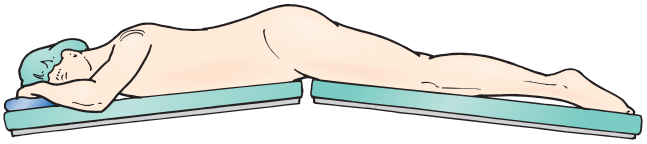


FIGURE 24-39. Illustration of flexed operative table (approximately 20°) for hamstring repair. *(Reproduced with permission from Pombo M, Bradley JP. Proximal hamstring avulsion injuries: A technique note on surgical repairs. Sports Health 1:261–264, 2009.)*

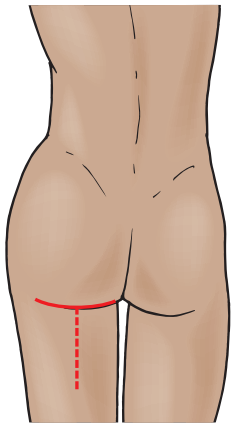


FIGURE 24-40. Illustration of transverse infragluteal incision. *(Reproduced with permission from Pombo M, Bradley JP. Proximal hamstring avulsion injuries: A technique note on surgical repairs. Sports Health 1:261–264, 2009.)*

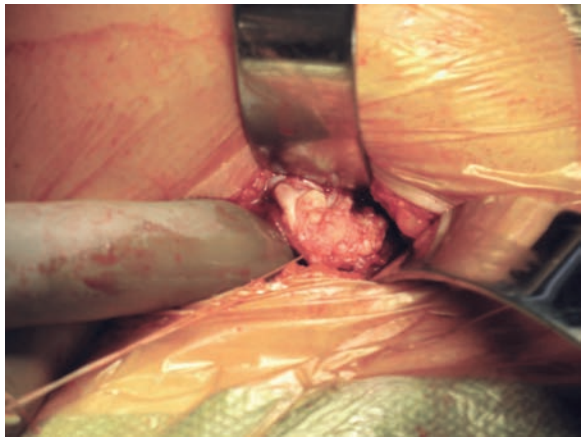


FIGURE 24-41. Intraoperative photograph of mobilized and debrided proximal hamstring tendon. *(Reproduced with permission from Pombo M, Bradley JP. Proximal hamstring avulsion injuries: A technique note on surgical repairs. Sports Health 1:261–264, 2009.)*

Factors that may Affect Rehabilitation

Anesthetic

- Avoid regional and spinal anesthesia; impairs assessment of sciatic nerve postoperatively

Surgical

- Number of hamstring tendons repaired, chronicity, and amount of retraction
  - Greater number of tendons avulsed, more retraction, and longer time of retraction all potentially increase tension on the repair. If concerned for strength of repair or tension on repair, consider a slower and more conservative protocol.

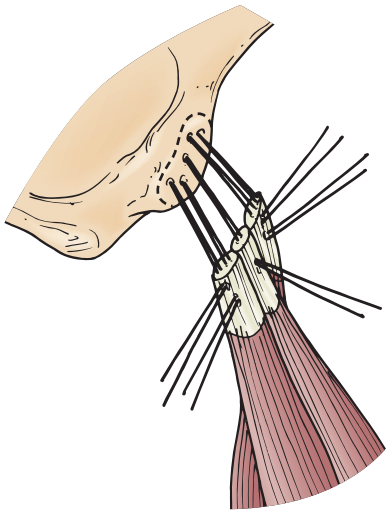


FIGURE 24-42. Illustration of suture anchors in an X configuration with sutures through the proximal tendon in a horizontal mattress fashion. *(Reproduced with permission from Pombo M, Bradley JP. Proximal hamstring avulsion injuries: A technique note on surgical repairs. Sports Health 1:261–264, 2009.)*

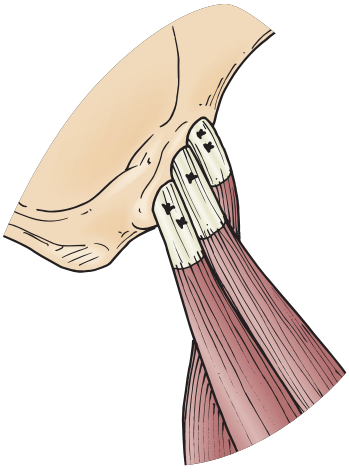


FIGURE 24-43. Illustration of repaired tendon after tying of sutures. *(Reproduced with permission from Pombo M, Bradley JP. Proximal hamstring avulsion injuries: A technique note on surgical repairs. Sports Health 1:261–264, 2009.)*

Before Surgery: Overview of Goals, Milestones, and Guidelines

GUIDING PRINCIPLES OF POSTOPERATIVE REHABILITATION

- Understand the anatomic structures involved and their rate of healing
- Understand position and activities that stress the repair
- Proper selection of therapy and ROM at the appropriate phase of healing

Phase I: Immediate Postoperative Period (days 0 to 14)

Clinical Pearls

If there are concerns about the strength of the repair, tension on the repair, or the patient's compliance, consider a more conservative rehabilitation protocol. This would involve utilizing a hip abduction brace instead of a hinged knee brace and potentially delaying the phases of rehab by 1 to 2 weeks.

Goals

- Allow for wound healing; dehiscence is a disastrous complication
- Protect the repaired structures
- Minimize the effects of immobilization
- Decrease pain and inflammation

Protection

- Toe-touch weight bearing on crutches at all times
- Avoid the "7" position (hips flexed and knees extended straight (Figure 24-44)
- Hinged knee brace locked at 40° to be removed briefly only for bathing/dressing and minimize hip flexion when out of brace (Figure 24-45.)
- Hip flexion brace locked in full extension if concerned about the strength of the repair or about patient compliance (Figure 24-46)

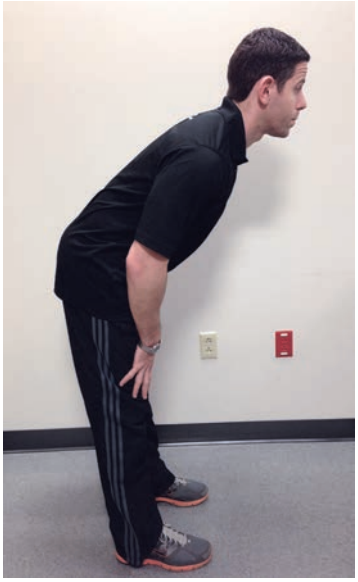


FIGURE 24-44. Photograph of the "7" position (hips flexed and knees extended straight) to be avoided.

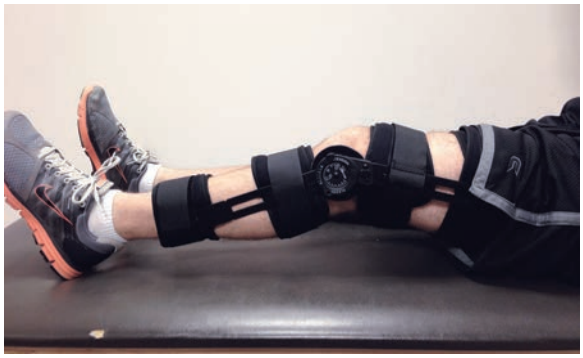


FIGURE 24-45. Photograph of a hinged knee brace locked at 40°.



FIGURE 24-46. Photograph of a hip flexion brace locked in full extension.

Management of Pain and Swelling

- Oral pain medications
- Therapeutic modalities for pain and inflammation to include TENS, E-Stim, and ice/continuous cryotherapy
- Patient education: Find a "position of comfort" that relaxes the repair with the hips extended and knee flexed
- Light desensitization massage of the incision may reduce the occurrence of hypersensitivity

Techniques for Progressive Increase in Range of Motion

- Ankle ROM only

Other Therapeutic Exercises

- Ankle pumps should be performed 20 to 30 times per hour
- Quad sets should be performed for 10 to 15 minutes, 3 times a day
- Any additional therapeutic exercises should be avoided to prevent stressing the repair

Milestones for Progression to the Next Phase

- Adequate wound healing
- No evidence of failure of repair (palpable gap at repair site)

Phase II (weeks 3 to 6)

Goals

- Protect the repaired structures
- Minimize the effects of immobilization
- No marked pain at area of repair
- Progress towards normal gait pattern

Protection

- Continue with crutches for 6 weeks postop
- Continue with knee brace locked at 40 degrees for full 4 weeks; okay to remove for PT

TIMELINE 24-5: **Postoperative Rehabilitation After Repair of Proximal Hamstring Avulsion**

PHASE I (weeks 0 to 2)	PHASE II (weeks 3 to 6)	PHASE III (weeks 6 to 10)
• Hinged knee brace locked at 40° (or hip flexion brace locked in full extension) • PT modalities • TDWB on crutches • Ankle ROM only • Ankle pumps and quad sets	• Hinged knee brace locked at 40° (or hip flexion brace locked in full extension) • PT modalities • TDWB on crutches: increase WB by 25% body weight every week • PROM – knee flexion in prone position • Wk 4 – PROM of hip extension • Wk 4 – gentle AROM/AAROM avoiding hip flexion & terminal knee extension • Ankle pumps and quad sets	• DC hinged knee brace • Wean off crutches when normal gait pattern established • PT modalities as needed • PROM – avoid combined hip flexion/knee extension • TBS/TAS activities as recommended & tolerated • TLS – gluteus medius/maximus PREs • OKC standing hamstring curls • CKC quarter depth squats and heel raises

- At 4 weeks, brace can be unlocked as tolerated
- Begin partial weight bearing at 25% of body weight increasing by 25% every week over next 4 weeks

Management of Pain and Swelling

- Continue with oral pain medications
- Continue therapeutic modalities including TENS, E-Stim, and cryotherapy
- Continue with cryotherapy as needed

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Avoid hip flexion and 40° of terminal knee extension up to 4 weeks
- At 2 weeks, PROM flexion of the knee in the prone position should be initiated to prevent knee stiffness
- Ankle and lumbar spine ROM is encouraged

Soft Tissue Techniques

- Scar mobilization to surgical incision once closed.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- At 4 weeks, PROM of hip extension and knee flexion is initiated with cessation of ROM with any discomfort

Other Therapeutic Exercises

- Continue with ankle pumps and quad sets
- Persistent limitation of activity beyond ADLs to protect repair for 4 to 6 weeks

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Initiate gentle isotonic AAROM/AROM at week 4 with avoidance of hip flexion and terminal knee extension

Milestones for Progression to the Next Phase

- No evidence of failure of repair
- Pain tolerable with limited PROM

Phase III (weeks 6 to 10)

Clinical Pearl

Flexibility exercises remain contraindicated at this point to protect the repair. Tightness and/or cramping is not uncommon, and, if experienced, gentle stretching with hip and knee flexion as tolerated can be initiated (Figure 24-47)



FIGURE 24-47. Photograph of "knee-to-chest" stretch with hip and knee flexion.

Goals

- Protect repaired structures
- Normal gait pattern
- Return of pain-free ADLs at home
- Limited pain with gentle strengthening

TIMELINE 24-5: **Postoperative Rehabilitation After Repair of Proximal Hamstring Avulsion** (Continued)

PHASE IV (weeks 10 to 14)	PHASE V (weeks 14 to 24)	PHASE VI (weeks 24 to 52)
• PT modalities as needed • PROM – avoid combined hip flexion/knee extension • TBS/TAS activities as recommended & tolerated • TLS – gluteus medius/maximus PREs • OKC standing hamstring curls • CKC half-depth squats and heel raises • CKC leg press PREs • NMS half-depth multidirectional step lunges • Double leg Swiss ball curls	• PT modalities as needed • PROM – full as tolerated (limited goals relative to contralateral side) • TBS/TAS/TLS activities as recommended and tolerated • OKC standing hamstring curls • CKC full depth squats and heel raises • CKC leg press, Romanian dead lifts—PREs • NMS full depth multidirectional step lunges • Plyometrics jumping rope • Single leg Swiss ball curls	• PROM – full as tolerated (limited goals relative to contralateral side) • TBS/TAS/TLS activities as recommended & tolerated • OKC standing hamstring curls • CKC full-depth squats and heel raises • CKC leg press, Romanian dead lifts – PREs • NMS single-leg stance, movement on unstable surfaces • Plyometrics sport-specific high intensity exercises • Plyometrics agility drills, side to side and box jumps • Single-leg Swiss ball curls • Sport-specific exercises initiated and progressed

Protection

- Crutches can be weaned off once a normal gait pattern is reestablished
- Knee brace discontinued

Management of Pain and Swelling

- Oral analgesic use is continued as needed
- NSAID therapy may be prescribed for persistent pain
- TENS and E-Stim for pain control PRN
- Cryotherapy is used posttherapy to mitigate postexercise inflammation and soreness

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- ROM Precautions: Avoid combined hip flexion/knee extension
- Knee PROM: techniques used to improve knee flexion and extension within limits of comfort

Soft Tissue Techniques

- Light desensitization massage to surgical incision and posterior hip.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Gentle isolated knee stretches within limits of comfort
- Avoid combined hip flexion/knee extension stretches

Other Therapeutic Exercises

- Cardiovascular: aquatic walking and an upper body ergometer with gel seat cushioning may be initiated with resistance as tolerated.
- Upper body strengthening is initiated with closed and open chain exercises.
- Initiate core pelvic strength training with avoidance of hip flexion.
- Gluteus maximus strength exercises begin and progress from the prone to supine position
- Gluteus medius strengthening is initiated in the side lying position and progresses to the upright position

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Increasing resistance in isotonics in limited range-of-motion; continued avoidance of terminal range of knee extension

Sensorimotor Exercises

- Gait training without crutches is continued
- Step-down exercises are initiated using progressively higher steps

Open and Closed Kinetic Chain Exercises

- Emphasis of CKC isotonics with initiation of OKC exercises



FIGURE 24-48. Photograph of standing hamstring curl.

- CKC: Quarter-depth squats and heel raises progress from bilateral to unilateral status
- OKC: Standing hamstring curls are initiated with hip joint held in neutral and lower leg moving against gravity in pain free arc. Resistance is increased a pound at a time as tolerated with emphasis on high reps and frequency (Figure 24-48)
- Initiate unilateral leg press activities with light resistance and increase as the operative leg tolerates. (Starting hip position should be below 90° and pain free)

Techniques to Increase Muscle Strength, Power, and Endurance

- Machine hamstring curls initiated with 8 to 10 lb at high reps once a full and pain-free knee flexion arc is obtained.

Milestones for Progression to the Next Phase

- Restoration of normal gait pattern
- Return to complete home ADLs without pain

Phase IV (weeks 10 to 14)

Clinical Pearl

Patients may have discomfort while sitting during ADLs and seated exercises. Upright exercises may avoid the sensitive area and a gel seat pad with/without an incision protecting cutout can mitigate the discomfort.

Goals

- Return to unrestricted pain free ADLs at home and at work (excluding heavy labor)
- Performance of nonimpact cardiovascular exercise
- Transition hamstring strengthening from machines to exercises combining strength and balance

Management of Pain and Swelling

- Oral NSAIDs may be continued. If pain continues to be a limiting factor to progression, the patient should return to the surgeon for reassessment.
- TENS, E-Stim, and cryotherapy for pain control PRN
- Cryotherapy is used posttherapy to mitigate postexercise inflammation and soreness

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- ROM precautions: Avoid combined hip flexion/knee extension
- Knee PROM: Techniques used to improve knee flexion and extension within limits of comfort
- Hip PROM: Techniques used to improve hip flexion and extension within limits of comfort

Soft Tissue Techniques

- Light desensitization massage to surgical incision and posterior hip

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Gentle hip and knee stretches within limits of comfort
- Avoid combined hip flexion/knee extension stretches

Other Therapeutic Exercises

- Cardiovascular: Progression to three to five nonimpact aerobic sessions weekly lasting 30 minutes including upper body ergometer, aquatic walking, elliptical, or stationary cycling.
- Continuation of core pelvic and upper body strengthening
- Continued focus on strengthening the hip stabilizers including the gluteus medius and maximus

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Increasing resistance in isotonics with progression to full range of motion

Sensorimotor Exercises

- Continuation of step-down exercises

Open and Closed Kinetic Chain Exercises

- Continuation of CKC and OKC exercises
- CKC: Unilateral half-depth squats and heel raises progress
- CKC: Leg press activities with increasing resistance, reps, and frequency
- OKC: Continued standing hamstring curls with increasing resistance, reps, and frequency

Techniques to Increase Muscle Strength, Power, and Endurance

- Machine hamstring curls with increasing resistance

Neuromuscular Dynamic Stability Exercises

- Half-depth squats with progression to half depth walking lunges is initiated
- Progression to half-depth multidirectional step lunges

Functional Exercises

- Initiation of double leg Swiss ball curl (Figure 24-49 *A*,*B*)

Milestones for Progression to the Next Phase

- Pain free participation in ADLs at home and at work (excluding heavy labor)
- Performance of nonimpact cardiovascular exercise
- Tolerance of strength and balance exercises

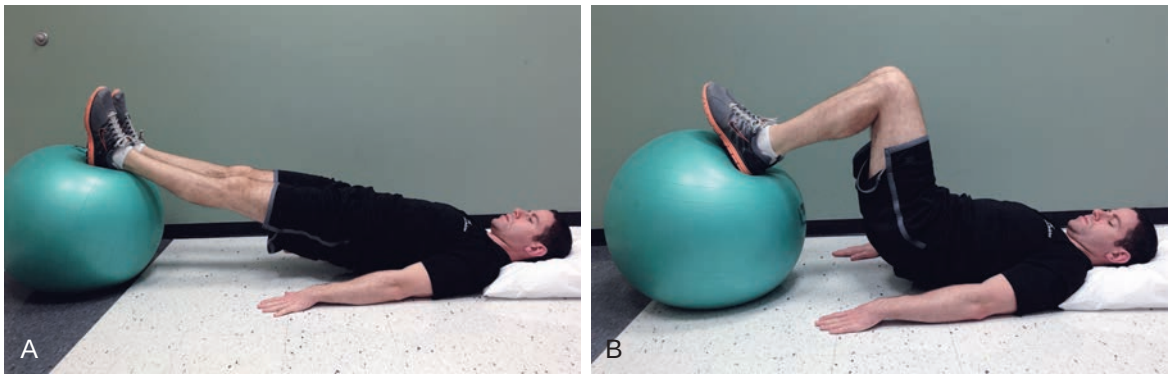


FIGURE 24-49. Photographs of a double-leg Swiss ball curl.

Phase V (weeks 14 to 24)

Clinical Pearl

Hamstring flexibility exercises are initiated in this Phase. The goal of hamstring flexibility is **not** to match the contralateral side; the goal is to alleviate cramping and allow enough flexibility for return to sport.

Goals

- Complete return to work, including heavy labor
- Hamstring strength 75% of contralateral side
- Successful initiation of light jogging

Management of Pain and Swelling

- Oral NSAIDs may be continued. If pain continues to be a limiting factor to progression, the patient should return to the surgeon for reassessment.
- TENS, E-Stim, and cryotherapy for pain control PRN
- Cryotherapy is used posttherapy to mitigate postexercise inflammation and soreness

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- ROM precautions: Within limits of comfort
- PROM: Gentle initiation of hip flexion/knee extension stretching may be initiated; flexibility should remain limited relative to the contralateral side.

Soft Tissue Techniques

- Desensitization massage to surgical incision and posterior hip

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Initiation of gentle combined hip flexion/knee extension stretches within limits of comfort

Other Therapeutic Exercises

- Cardiovascular: Continuation of prior aerobic exercise with the slow introduction of jogging on soft surfaces with avoidance of a treadmill.
- Continuation of core pelvic and upper body strengthening
- Continued focus on strengthening the hip stabilizers including the gluteus medius and maximus

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Increasing resistance in isotonics with progression to full range of motion

Sensorimotor Exercises

- Continuation of step-down exercises

Open and Closed Kinetic Chain Exercises

- CKC: Unilateral full depth squats and heel raises progress
- CKC: Leg press activities with increasing resistance, reps, and frequency
- CKC: Initiation of Romanian dead lifts
- OKC: Continued standing hamstring curls with increasing resistance, reps, and frequency
- OKC: Initiation of resisted inclined hip extensions

Techniques to Increase Muscle Strength, Power, and Endurance

- Machine hamstring curls with increasing resistance

Neuromuscular Dynamic Stability Exercises

- Progression from half- to full-depth squats
- Progression from half- to full-depth multidirectional step lunges

Plyometrics

- Jumping rope
- Multidirectional step lunges at increasing speeds
- Walking lunges at full depth

Functional Exercises

- Progression from double to single leg Swiss ball curls
- Knee pushups with hip extensions (Figure 24-50)

Milestones for Progression to the Next Phase

- Complete return to all home and work activities
- Successful initiation of jogging and light plyometrics
- Hamstring strength 75% of the contralateral side



FIGURE 24-50. Photograph of knee pushup with hip extension.

Phase VI (weeks 24 to 52)

Clinical Pearl

> Cramping and activity-related discomfort are common as the intensity of the workouts increase.

Goals

- Ability to tolerate exercise with higher impact, resistance, agility, and speed
- Hamstring strength 90% of contralateral side
- Complete return to sport

Management of Pain and Swelling

- Cryotherapy is used posttherapy to mitigate postexercise inflammation and soreness

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- ROM precautions: Within limits of comfort
- PROM: Gentle hip flexion/knee extension stretching may be continued; flexibility should remain limited relative to the contralateral side.

Soft Tissue Techniques

- Desensitization massage to surgical incision and posterior hip PRN

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Continuation of gentle combined hip flexion/knee extension stretches within limits of comfort. The goal is to maintain and not increase ROM.

Other Therapeutic Exercises

- Integrated training activities at this stage should include multijoint movements (i.e., Romanian dead lifts, front squats, power or hang cleans, clean and press, etc.)

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Focus in the late stage of recovery is on establishing preinjury levels of function

Sensorimotor Exercises

- Ball toss exercises while standing
- Medicine balls
- Progression to slosh balls
- Rapid repositioning drills and reaction movement drills

Open and Closed Kinetic Chain Exercises

- Advancing the previous exercises in accordance with sport-specific demands
- Examples of progression may include kettlebell swings

Techniques to Increase Muscle Strength, Power, and Endurance

- Machine hamstring curls with increasing resistance
- Utilizing isolation and combination exercises as appropriate for the athlete's desired sport

Neuromuscular Dynamic Stability Exercises

- Single leg stance and movement on unstable surfaces as necessary to replicate anticipated performance demands

Plyometrics

- Focus on high intensity activities that simulate the athlete's desired sport
- Examples include side to side jumps, box jumps, and agility drills (tires, ropes, etc.)

Functional Exercises

- Progression from double- to single-leg Swiss ball curls
- Knee pushups with hip extensions

Sport-Specific Exercises

- Return to light sport-specific training can begin as early as 24 weeks
- Light jogging can progress to running with slow build-up of speed
- After tolerating full speed running, then explosive activity, speedwork, and agility drills can be added as tolerated

Milestones for Progression to the Next Phase

- Hamstring strength 90% of the contralateral side on isokinetic testing
- Patient has subjective sense of return to baseline

Criteria for Return to Sport

- Hamstring strength 90% of contralateral side on isokinetic testing
- Single leg lop distance 90% of contralateral side
- Ability to complete activities associated with the sport without pain
- For sports requiring rapid deceleration, acceleration, and direction change (football, basketball, track, rugby, soccer, etc.) there should be symmetric lower extremity motion during sprinting and agility drills that persists despite fatigue.

After Return to Sport

Continuing Fitness or Rehabilitation Exercises

- Continued lower body and whole body strengthening exercises

Exercises and Other Techniques for Prevention of Recurrent Injury

- Limitation of bilateral hamstring stretching beyond what is required for the athlete's desired sport
- Ensure appropriate dynamic neuromuscular control (strength, mobility, kinesthetic awareness, and proprioception of the hamstrings, core muscles, and ipsilateral hip and lower extremity musculature).
- Avoidance or limitation of activities (as appropriate) that cause eccentric loading of the hamstring with concomitant hip flexion and knee extension (e.g., water skiing)

Evidence

Cohen S, Bradley J: Acute proximal hamstring rupture. *J Am Acad Orthop Surg* 15:350–355, 2007.

A review article focusing on indications, surgical technique, and treatment outcomes in proximal hamstring injuries with a review of available evidence. (Level V evidence).

Cohen SB, Rangavajjula A, Vyas D, et al: Functional results and outcomes after repair of proximal hamstring avulsions. *Am J Sports Med* 40:2092–2098, 2012.

Fifty two patients undergoing chronic or acute proximal hamstring repairs had successful outcomes as determined by LEFS, Marx, and custom proximal hamstring questionnaires. (Level IV evidence).

Hamersly S, Schrader M: Postoperative rehabilitation of proximal hamstring tears. *Oper Tech Sports Med* 17:219–224, 2009.

Overview of the authors' rehabilitation protocol with comparison to other protocols. (Level V evidence).

Lefevre N, Bohu Y, Naouri JF, et al: Returning to sports after surgical repair of acute proximal hamstring ruptures. *Knee Surg Sports Traumatol Arthrosc* 21:534–539, 2013.

Prospective observational study of thirty four patients that underwent proximal hamstring repair with good results determined by activity level on UCLA and Tegner scores. (Level III evidence).

Pombo M, Bradley JP: Proximal hamstring avulsion injuries: a technique note on surgical repairs. *Sports Health* 1:261–264, 2009.

A technical guide for surgical repair of proximal hamstring injuries. (Level V evidence).

Multiple Choice Questions

QUESTION 1. Which of the statements below is true regarding ROM goals for the repaired hamstring?

A. Preventing postoperative stiffness is a key guiding principle in postoperative rehabilitation of proximal hamstring repairs
B. ROM exercises emphasizing combined hip flexion and knee extension should be started when the patient notes postoperative tightness and cramping.
C. The final goal for ROM is to have functional ROM, but not to match the contralateral side.
D. The final goal for ROM is to have an equal ROM of the operative and contralateral sides.

QUESTION 2. When is it safe to initiate gentle combined hip flexion and knee extension exercises?

A. 0 to 6 weeks
B. 6 to 10 weeks
C. 10 to 14 weeks
D. 14 to 24 weeks

QUESTION 3. When is it safe to begin gentle isotonic AAROM/AROM with avoidance of terminal knee extension?

A. 0 weeks
B. 2 weeks
C. 4 weeks
D. 6 weeks

Answer Key

QUESTION 1. Correct answer: **C** (see Clinical Pearl week 14–24)

QUESTION 2. Correct answer: **D** (see Phase V)

QUESTION 3. Correct answer: **C** (see Phase II)

BEYOND BASIC REHABILITATION: RETURN TO RUGBY AFTER REPAIR OF HAMSTRING AVULSION

James R. Ross, MD, Michael J. Keating, MS, ATC, CSCS, and Bruce S. Miller, MD

Introduction

ASPECTS OF RUGBY THAT REQUIRE SPECIAL ATTENTION IN REHABILITATION

- Improved agility and quickness to allow quick changes in direction, starting and stopping, and sprinting.
- Good joint mobility and muscle flexibility, especially with muscular balance between the quadriceps and hamstrings to be able to better handle explosives, isometric contractions during contact such as tackling, rucking, lineouts and scrimmaging (Figure 24-51).
- Optimal core and back strength to control the body's movements, especially in highly variable conditions such as scrums and lineouts.
- Ability to control the lower extremity during kicking

Literature

- Lefevre et al.[1] demonstrated return to sport at a mean of 5.7 months after surgical repair of proximal hamstring ruptures. Approximately 80% of patients were able to participate at the same level as before the injury. Although the level of activity according the UCLA scale was good (8.7), it was slightly lower than the preoperative score (9.1).
- Cohen and Bradley[2] similarly demonstrated return to sport at a mean of 6.6 months after surgical repair. Besides waterskiing, approximately 94% were able to return to the sport in which they injured their hamstrings.

Phase I: Advanced Strength and Conditioning Programs

A perioperative rehabilitation program is given in Box 24-3. Specific exercises are shown in Figures 24-52 to 24-57).

Periodization

- Linear
- Undulating
- Macrocycles
- Mesocycles
- Microcycles

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- After the initial phases of traditional rehabilitation have been completed and the athlete has restored basic mobility and strength, it is imperative the athlete is integrated back into physical training to bridge the gap from patient to athlete. This will encompass total body training including cardiovascular, strength, power and agility.



FIGURE 24-51. Good joint mobility and muscle flexibility, especially with muscular balance between the quadriceps and hamstrings, is necessary to better handle explosive movements and isometric contractions during contact such as tackling, rucking, lineouts, and scrimmaging.

BOX 24-3 Perioperative Rehabilitation: Preparation for Return to Sport

Preoperative Period

GOALS:

- Decrease pain
- Diminish effusion
- Maintain quad strength
- Patient education

GENERAL OUTLINE:

- Adequate patient education including explaining the surgical procedure, early postoperative care, and the anticipated rehabilitation program
- Crutches for weight-bearing as needed
- Avoidance of any strengthening and stretching exercises of the injured hamstring muscle to minimize muscular and tendinous retraction
- Isometric contractions of the quadriceps and gluteal muscles to minimize muscular atrophy
- Ankle pumps to minimize the risk of deep vein thrombosis

Week 1: "Protection Phase"

- Goal: maintain the hamstring muscle in a shortened and relaxed position, thus avoiding traction on the tendon repair. A brace is typically not needed with acute (< 2 weeks) repairs so long as the leg can be maintained in a neutral position.
- Avoid sitting and direct pressure on the affected ischial tuberosity, except when using an elevated toilet seat
- Toe-touch weight bearing is permitted with crutch-assistance
- Exercises: four times daily with 3 sets of 10 repetitions
  - Isometric quadriceps and gluteal muscle contractions
  - Ankle pumps
  - Supine heel slides up to 30° to 45° of knee flexion

Week 2: Initiation of formal physical therapy (1 to 2 supervised sessions per week)

- Full weight bearing (with crutches) is allowed when patient is able to perform a straight leg raise to 30° of hip flexion
  - Short strides, 10 times daily for 20 minute intervals
- Patient allowed single leg stance to perform minor knee flexion/extension exercises from 0° to 20° of knee flexion.
  - Four times daily, 3 sets of 10 repetitions
- "Safe" isometric hamstring contractions for 6 seconds
  - Supine with 30° of knee flexion
  - Two times daily, 3 sets of 10 repetitions
- Prone, passive knee flexion/extension exercises
  - Three times daily, 3 sets of 10 repetitions

Week 3

- Continue exercises from week 2
- Standing anti-gravity knee flexion curls with ankle in plantar flexion
  - Once daily, 3 sets of 3 repetitions
- Stationary slow walking on a thick pad
  - Twice daily, 3 sets, 30 seconds per set
- Calf strengthening in standing position with straight leg

Week 4

- Continue exercises from week 2 and 3
- If good posture and balance control, discontinue crutch use indoors, continue when outdoors
- Initiate pool therapy if wound is healed
  - Forward/backward and side-to-side walking
  - Two times weekly, 20 minutes per session
- Stationary bicycle with seat in high position when patient is able to perform 70° of hip flexion with the knee flexed 90°

Week 5: Hamstring strengthening initiated

- Discontinue exercises from weeks 1 to 3; continue with week 4 exercises
- Static or isometric leg curls in the seated position on the edge of chair
  - Press the heel of the operative leg against the toe of the non-operated leg (6 second holds)
  - Two times daily, 2 sets of 10 repetitions
- Standing single-leg catches with a cable or a Thera-Band
  - Three times weekly, 3 sets of 10 repetitions on each leg

BOX 24-3 Perioperative Rehabilitation: Preparation for Return to Sport *(Continued)*

- Single leg balance training
  - Start on floor and progress with eyes open and progress to eyes closed
  - Two times daily
- Core stability exercises
  - Supine pelvic thrusts or bridges (Figure 24-57), initially with the majority of body weight on the nonoperative limb. Progressively increase body weight onto the operative leg in a pain-free manner
  - Three times weekly, 3 sets of 10 repetitions

Week 6

- Gait should be normal; discontinue all crutch weight bearing
- Continue exercises from weeks 4 and 5
- Muscle flexibility training: supine, active knee extension exercises with the hip joint held at 90° of flexion with grasped hands under thigh
  - Two times daily, 3 sets of 10 repetitions
- Lunge walking: start with minimal stride length and gradually increase stride
  - Three times weekly, 3 sets of 10 strides
- Step ups on stair or stool
  - Two times daily, 3 sets of 10
- Gluteus medius strengthening—lateral resisted walking with Thera-Band
  - Two times daily, 20 yards, 4 times
- Single leg balance
  - Progress to mini-trampoline and other devices as able
  - Two times daily
- Leg curls in prone position with resistance: 6 seconds for contraction and 6 seconds for relaxation
  - Three times weekly, 3 sets of 10 repetitions

Week 7 and beyond: initiation of eccentric hamstrings training

- Ensure 2 days of rest per week for recovery
- 2 to 4 hamstring exercises at each training session
- Cautious forward and backward jogging with short strides, including acceleration and decelerations
- Stationary jogging with high knee lifts at increasing intensity over time
  - Four times weekly, 3 sets, 20 seconds per set
- Single-leg supine pelvic thrust
  - Progress by moving the heel away from the hip
  - Three times weekly, 3 sets of 8 repetitions
- Combine complex exercises such as lunges, squats, and jumping
- Dynamic leg curls in both the prone and sitting positions
  - Three times weekly, 3 sets of 10 to 15 repetitions

Return to Sport

- Aggressive, sport-specific activities allowing full unrestricted range of motion
- Outdoor training, slope training
- Can return to preinjury level when functional abilities such as jumping, running, and cutting can be performed without pain, stiffness or a feeling of insecurity
- Active hamstring flexibility test without any pain or feeling of insecurity
- 5 consecutive pain-free repetitions of maximal effort in both prone and supine positions
- May take up to 1 year to regain equal strength

Modified from Askling CM, Koulouris G, Saartok T, Werner S, Best TM: Total proximal hamstrings ruptures: clinical and MRI aspects including guidelines for postoperative rehabilitation. Knee Surg Sports Traumatol Arthrosc 21: 515–533, 2013.

- The rugby athlete requires both aerobic and anaerobic conditioning and both should be addressed during this phase—beginning with attaining an aerobic base.
- In regards to strength training, the athlete is now able to begin traditional strength training including all upper body, core and reintroducing lower extremity exercises such as squats and dead lifts. As muscular strength improves and normalizes compared to the uninvolved side, we look to convert this strength to power.

Olympic Lifts Used in the Training Program

- None at this phase, it typically can begin 16 weeks postoperatively

Training Principles Used in the Design of the Program

- Principle of progression
- Principle of overload
- Principle of variation



FIGURE 24-52. Lunge with medicine ball and truck rotation.

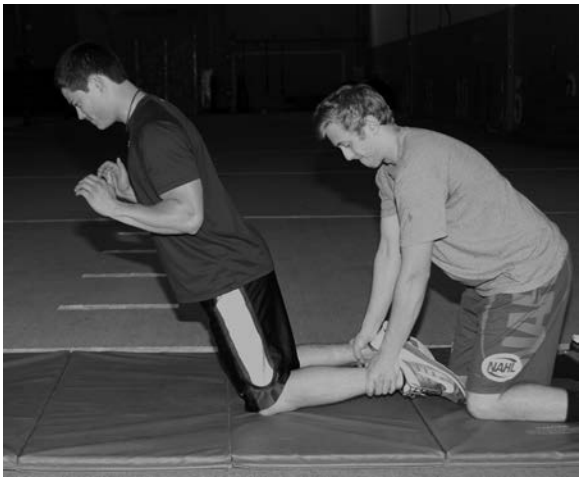


FIGURE 24-54. Russian hamstring curl with partner.



FIGURE 24-53. Single-leg Romanian dead lift on balance disk.



FIGURE 24-55. Single-leg hamstring curl with Swiss ball.

- Principle of individualization
- Principles of specificity—specific adaptation to imposed demands (SAID)

Application of Acute Training Variables

- The basic concept of this phase is to build strength and mass that has likely decreased during the injury and subsequent surgery and recovery.
- Moderate resistance combined with higher reps and sets are preferred. As a strength base is developed, the overload principle should be applied which uses heavier resistance in conjunction with fewer sets and reps. Here are some examples of specific exercises:
  - Back squat
  - Single leg lunge
  - Dead lifts

TIMELINE 24-6: **Beyond Basic Rehabilitation: Return to Rugby after Repair of Hamstring Avulsion**

Weeks 0 to 2	Weeks 3 to 4	Weeks 5
• Crutches with toe touch only • PT modalities • Soft tissue massage (STM) • Gentle PROM of knee/ankle • Isometrics of quads and glutes	• Crutches with progressive weight bearing—discharge at wk 4 indoors, but use outdoors • PT modalities • STM • Gait training • Pool therapy—walking forward, backward and lateral • Begin stationary bike at wk 4 with a high seat	• Crutches only as needed outdoors • PT modalities as needed • Progress hamstring flexibility • Single leg balance • Core strength progression • Hamstring isometrics



FIGURE 24-56. High bench step-up with medicine ball.

- RDL (Romanian dead lift)
- Eccentric hamstring curl
- Step-ups
- Split squats

Phase II: Performance Enhancement Training Techniques

Periodization

- Linear
- Undulating
- Macrocycles
- Mesocycles
- Microcycles

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- During the Return to Sport phase, we begin to transfer the strength that has been established into power and speed.



FIGURE 24-57. Double-leg bridge with Swiss ball.

- This will include review of proper running mechanics (sprint), deceleration and agility with change of direction.
- Addition of a plyometric program is critical during this phase.
- It is important that drills are selected that best represent the demands of the athlete based on the position they play. As an example, a back in rugby will require more agility and a forward will require more explosive power.

Olympic Lifts Used in the Training Program

- Snatch
- Clean and jerk
- Power clean

Training Principles Used in the Design of the Program

- Principle of progression
- Principle of overload
- Principle of variation
- Principle of individualization
- Principles of specificity—specific adaptation to imposed demands (SAID)

Application of Acute Training Variables

- This phase will focus on technique—especially with proper running mechanics. Proper forward lean, knee drive, foot position and arm mechanics are critical to maximize performance and avoid future injury.

TIMELINE 24-6: **Beyond Basic Rehabilitation: Return to Rugby after Repair of Hamstring Avulsion** (Continued)

Weeks 6 to 10	Weeks 11 to 16	Weeks 17+
• Crutches DC • Normal gait • PT modalities as needed • PROM and flexibility progressing • Closed kinetic chain exercises • Step-ups • Lunges • Single-leg balance • Core strengthening • Glut strengthening • Add dynamic warm-up	• ROM and flexibility without limits • STM as needed • Continue strengthening per above • Single-leg hamstring strengthening • Hamstring eccentric strengthening • Begin return to run progression • Double-leg jumping	• Full motion • Begin strength training program with team • Begin agility training with change of direction • Add deceleration drills • Single leg jumping/plyometric drills • Sport-specific training

- Over-striding and heel strike during sprint mechanics are common causes of recurrent hamstring injury.
- Additionally, as most hamstring injuries occur during the eccentric phase, it is important to select training drills that challenge the hamstring eccentrically. This will include change of direction drills and jump and land drills.
- Specific exercises used in the training
  - Running mechanic instruction—plus drills
  - Sprint progression
  - Sprint with deceleration
  - Agility ladder drills
  - Depth drops
  - Single-leg exploding Harvards

Phase III: Sport-Specific Training

Periodization

- Linear
- Undulating
- Macrocycles
- Mesocycles
- Microcycles

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- During this phase it is critical to identify the specific needs of the rugby athlete—specific to their position. For example, a back in rugby will need to have amazing agility and also kicking skills. A forward needs to have explosive and sustained power for scrimmaging and lineouts.
- Analyzing the needs and selecting sport specific exercises is vital for successful return to play.

Olympic Lifts Used in the Training Program

- Snatch
- Clean and jerk
- Power clean

Training Principles Used in the Design of the Program

- Principle of progression
- Principle of overload
- Principle of variation
- Principle of individualization
- Principles of specificity—specific adaptation to imposed demands (SAID)

Application of Acute Training Variables

- During this phase, replication of match play intervals is critical.
- Specific exercises used in the training
  - Kicking drills—conversion/penalty kicks and punting (backs)
  - Lineout and lifting drills (forwards)
  - Scrimmaging drills (forwards)
  - Tackling and rucking drills (all)
  - Passing drills (all)

Sports Performance Testing

General Information

- General history
- Subjective questionnaires
- Medical history
- Sports injury history
- Surgical history
- Chronic conditions/medication

Specific Objective Tests

- Physiological assessments—VO_2 max,
- Body composition tests—Body fat/lean mass assessment, height, weight
- Static/dynamic postural assessments—Functional movement screen, biomechanical movement analysis
- Dynamic muscle performance testing
- Movement performance testing—Functional movement screen
- Sport-specific testing
- Others
  - Yo-Yo Interval Recovery Test (YIRT)
  - Vertical jump
  - Standing broad jump
  - 5–10–5 proagility shuttle
  - 40 m sprint
  - 10 m sprint—with and without ball

Specific Criteria for Progression to the Next Stage to Determine Readiness for Rugby

- Athlete should be demonstrating increases in strength and power and meeting goals of each stage without disability.

Specific Criteria for Release to Unsupervised Complete Participation in Rugby

- Functional testing that demonstrates 90% or better as compared to the uninvolved extremity.
- Functional testing might include: single leg lateral hop in 20 to 30 seconds for max repetitions, single leg triple hop, single leg excursion tests

Recommended Ongoing Exercises

- The athlete should continue to incorporate both hamstring flexibility/mobility exercises along with a regular hamstring eccentric strengthening program.

Evidence

Birmingham P, Muller M, Wickiewicz T, et al: Functional outcome after repair of proximal hamstrings avulsions. *J Bone Joint Surg* 93:1819–1826, 2011.

This retrospective review of 30 patients who were noted to have a complete rupture of the proximal origin of the hamstrings underwent surgical repair and were evaluated. At a mean follow-up of 43.3 months, 91% of patients returned to activity at an average of 95% of their preinjury level. (Level IV evidence).

Chahal J, Bush-Joseph CA, Chow A, et al: Clinical and magnetic resonance imaging outcomes after surgical repair of complete proximal hamstrings ruptures: Does the tendon heal? *Am J Sports Med* 40:2325–2330, 2012.

This retrospective review of 15 consecutive patients that underwent surgical repair of complete proximal hamstrings tears were evaluated with postoperative MRI. The MRI was performed at a mean of 36 months after repair. 100% of the patients had healed the hamstrings repair, with signs of tendinopathy and mild atrophy in 25% of patients. (Level IV evidence).

Cohen SB, Rangavajjula A, Vyas D, et al: Functional results and outcomes after repair of proximal hamstrings avulsions. *Am J Sports Medicine* 40:2092–2098, 2012.

This retrospective review of 52 patients that underwent proximal hamstrings repair with a mean follow-up of 33 months demonstrated improved clinical outcomes (LEFS, Marx, and proximal hamstrings scores). Acute repairs, however, had higher functional and hamstrings scores, as well as estimated hamstring strength. (Level IV evidence).

Lefevre N, Bohu Y, Naouri JF, et al: Returning to sports after surgical repair of acute proximal hamstrings ruptures. *Knee Surg Sports Traumatol Arthrosc* 21:534–539, 2013.

This prospective observational study of 34 patients with a mean follow-up of 27.2 months demonstrated a return to sport at a mean of 5.7 months, with 79.4% of patients reaching the same level of activity. (Level IV evidence).

REFERENCES

1. Lefevre N, Bohu Y, Naouri JF, et al: Returning to sports after surgical repair of acute proximal hamstrings ruptures. *Knee Surg Sports Traumatol Arthrosc* 21:534–539, 2013.
2. Cohen SB, Rangavajjula A, Vyas D, et al: Functional results and outcomes after repair of proximal hamstrings avulsions. *Am J Sports Medicine* 40:2092–2098, 2012.

Multiple Choice Questions

QUESTION 1. The most common lower extremity injury in rugby players is:

A. Anterior cruciate ligament tear
B. Patellar tendon rupture
C. Proximal hamstring rupture
D. Achilles tendon rupture

QUESTION 2. The expected return to play after surgical repair of a proximal hamstrings tear is approximately:

A. 6 weeks
B. 3 months
C. 6 months
D. 9 months

Answer Key

QUESTION 1. Correct answer: **C** (see Introduction)

QUESTION 2. Correct answer: **C** (see Literature)

Chapter 25



Groin Injuries

INTRODUCTION

Bruce Charles Twaddle BHB, MBChB, FRACS, and Kristian Thorborg, PT, MSportsphty, PhD

Introduction

The anatomy of the pubic symphysis region makes it a diagnostic challenge because of the confluence of numerous musculoskeletal attachments, a variety of potential weaknesses in the abdominal wall and its close proximity to both the symphysis pubis and the hip joint.

Groin pain and injury are terms used to describe problems that present with pain in this general region. The complex nature of the anatomy of this region and the close proximity of many anatomical structures that could be the source of pain in this area, make isolating the exact source of pain felt in the lower abdominal or groin region very difficult. The often insidious nature of the onset of pain with a minor initiating injury and the referral or associated pain into the symphysis, the groin or adductor region and towards the hip makes pain and symptoms in this region a diagnostic dilemma. Consequently such terms as abdominal strain, Athletic pubalgia, sportsman's hernia, Gilmore's groin, hockey goalie syndrome, and osteitis pubis can all be attributed to the same or different injuries in this region. As a result "groin pain" has been a curse for athletic trainers, physiotherapists, sports physicians, orthopedic surgeons and musculoskeletal radiologists alike with individual biases and experiences. This has led to varying schools of thought as to the true origin of pain of the same presenting characteristics and inevitably varying beliefs in "successful" treatment. As is often the case where such a diagnostic dilemma and variation in treatment exists, this suggests that either all treatments have some success reflective in part of the self-limiting nature of the condition or none of the treatments are particularly successful. Groin pain in itself can be a very frustrating condition to treat supporting the difficulties with diagnosis and as a consequence the difficulties in tailoring treatment.

Epidemiology

- The incidence of groin injuries appears to be growing in frequency and is now recognized as a significant contributor to time off the field in several professional sports, in particular in various football codes and ice hockey.
- Athletes, particularly those involved in high level competition, can often play through minor symptoms and so the prevalence is likely to be much higher than previous reports of injuries causing time off the field.

Age

- Groin injury occurs more common in athletes who have been competing at an elite level for a number of seasons.
- They were uncommonly seen in rookies in a study of NFL footballers with 95% of players with this injury having played in the NFL for 5 years or longer.
- Average age in the majority studies for patients presenting with this injury is in the late twenties.

Sex

- Groin injury is almost exclusively reportedly as an injury of the male athletic population, most likely because of the sports it has been studied in such as NFL football, soccer, and ice hockey.
- The statistics and reasons for the different incidence between males and females have not been specifically studied.

Sport

- Certain sports, namely ice hockey and soccer, report the highest amount of groin injuries, with an incidence

of 0.8 to 1.3 injuries per 1000 hours of athletic activity, and strains, accounting for up to 43% of all muscle strains in elite Finnish ice hockey players and 10% of all injuries in a study of elite Swedish Ice hockey players.
- The incidence of groin strains in a single National Hockey League (NHL) team was 3.2 strains per 1000 player-game exposures.
- Only limited information exists on acute groin injuries. The only study looking exclusively at acute groin injuries in soccer reports a groin injury incidence of 0.8 injuries per 1000 hours play. In male soccer a prospective study of the elite teams hip/groin injuries accounted for 12% to 16% of all injuries per season. The total injury incidence was 1.1/1000 hours with 3.5/1000 match hours and 0.6/1000 training hours. Adductor-related and iliopsoas-related groin injuries were the most common injuries and 15% of the injuries were re-injuries.
- In the National Football League (NFL) (American football) the most common muscle-tendonous injuries related to the groin were rectus femoris strain and adductor strains.

Position

- The effect of position seems to be far less important than the type of sport. In a review of NFL data, the problem appears to predominantly affect linesmen whereas most playing positions in soccer and ice hockey (the two most common sports for this injury) position has not been highlighted as playing such an important role. Recently, however, it has been shown that hip and groin injuries account for one third of the injuries in goalkeepers in soccer.
- The incidence of hip and groin injuries is higher in goalkeepers than in field players. This highlights that sporting actions such as kicking, stretching out in an abnormal position or rapid change of direction may be of particular importance, and responsible for the development of these injuries.

Pathophysiology

The Pathophysiology of injuries to the groin region is complex and complicated. Anatomically it is a confluence of a number of structures, and a number of structures have been implicated as the "primary" source of groin pain with little supporting robust scientific evidence. The latest example of this is the finding of reduced range of motion and radiological signs of femoro-acetabular-impingement (FAI) in hips of athletes who also get adductor localized groin pain. There have however been no studies that show treating the hip problem makes a difference to the risk or recovery from groin problems in these athletes whereas the response to a well-structured rehabilitation regime has shown significant improvement in well-constructed studies.

Intrinsic Factors

The tendons of the rectus abdominis and the adductor longus effectively form a continuous structure, termed by some authors as the "common adductor-rectus abdominis origin" (Figure 25-1). Biomechanically this acts as a dynamic stabilizer of the pubic symphysis such that any dysfunction of either tendon unit predisposes the other to failure as a result of increased load. Secondary loss or dysfunction of the stabilizers of the symphysis can lead to increased load on this joint as well and as a result symptoms and signs in the region can be distributed over a wide area. Injury to the attachment of the posterior wall of the inguinal canal as part of the anterior rectus sheath

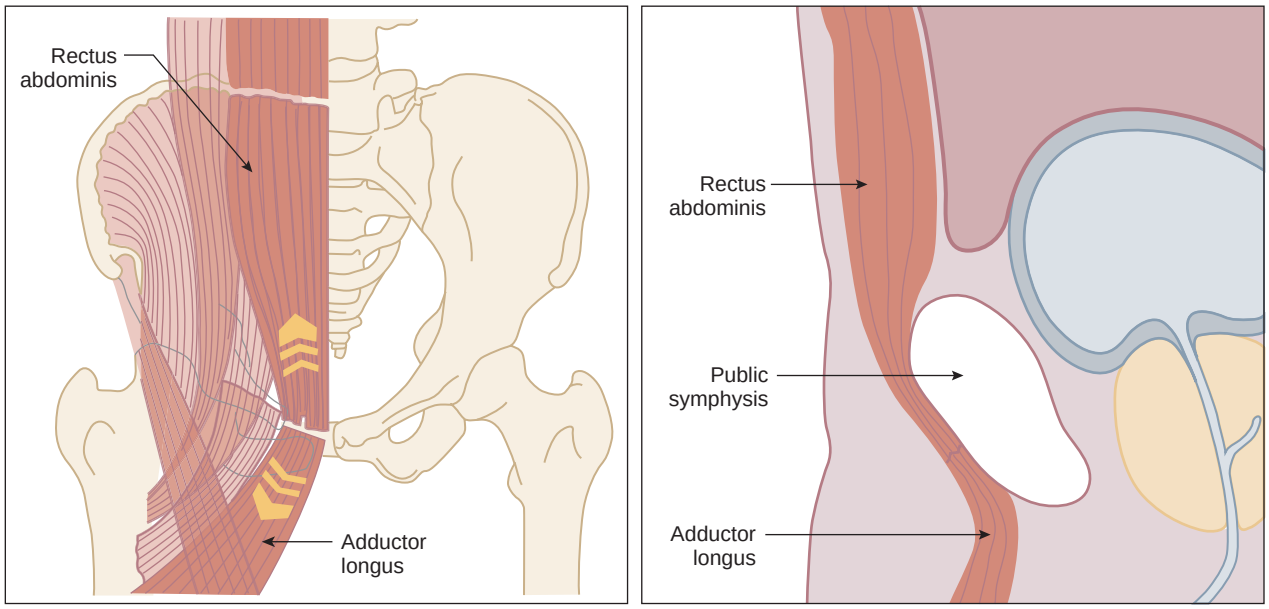


FIGURE 25-1. Schematic representation of the confluent but apposing muculotendinous units of the rectus abdominis and adductor longus muscles. *(Courtesy of Prof. Adam C. Zoga, Department of Radiology, Thomas Jefferson University, Philadelphia, PA.)*

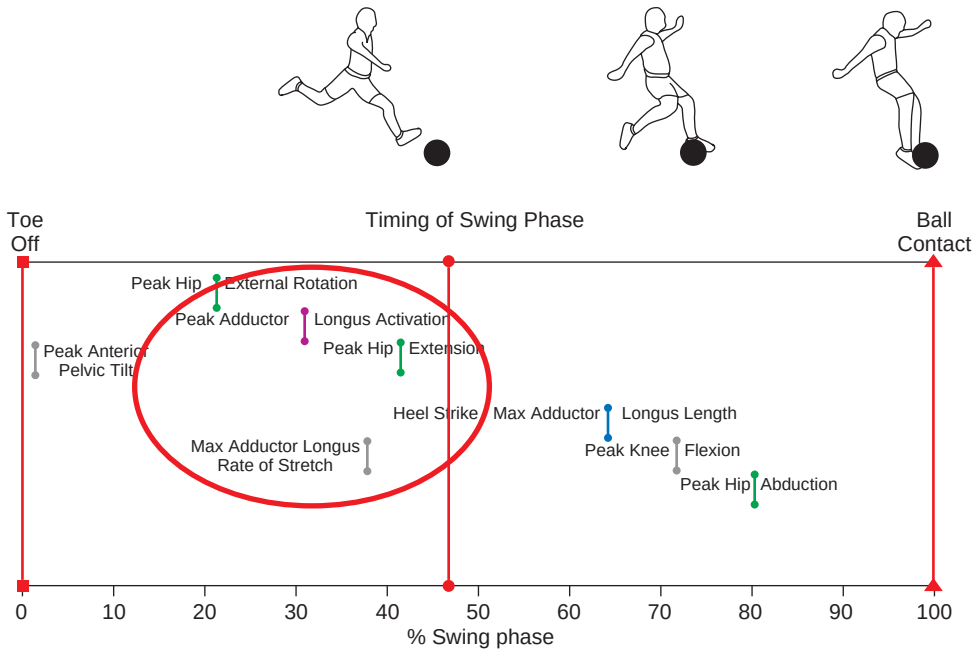


FIGURE 25-2. Timing of the swing phase. *(From Charnock BL, Lewis CL, Garrett WE Jr, Queen RM. Adductor longus mechanics during the maximal effort soccer kick. Sports Biomech 8(3):223-224, 2009.)*

can result in hernia-like formation and symptoms as part of the spectrum of injuries in this region.

Injury to the structures around the groin is intrinsically related to repeated loading of this complex of muscles and the joints they support. It can be seen that specific muscles are activated during the different phases of kicking a football and the maximal activation of the adductors as the leg is reversed from a fully extended position approaching impact with the ball. This places this musculotendinous structure of the adductors at risk of injury. Musculotendinous structures of the adductors are at greatest risk when at their maximal length, which is also the part of the kicking phase (the initial swing phase) where there is peak adductor longus activation, predisposing this region to injury. Also, the specific action of skating on the ice and the necessity for rapid and often unplanned changes of direction, again especially stressing the adductors and the abdominals places repeated maximal loads on the groin region. It is possible that the nature of the walking gait as man has become bipedal also changes the muscle dynamic of the adductor region. Rather than going through phases of rapid stretch and forceful muscle activation, this muscle is seldom stressed in this way in regular walking so activities that require sports-specific movements such as kicking and skating could be seen as atypical for this muscle group (Figure 25-2).

Extrinsic Factors

The unique nature of skating on ice including the rapid acceleration/deceleration and changing direction on skates clearly demonstrates how increasing forces can play a role in this injury. Similarly, injuries to the rectus abdominis insertion have been described in tennis players because of the unique repeated loading of this muscle in this sport. The role of the introduction of artificial turf into the frequency of groin-related injuries has been discussed with American Football injuries, but no good study has been able to correlate an increasing reported incidence of this injury with changes to the playing surface as a significant dependent variable.

Traumatic Factors

Acute muscle tear or strain: Injuries that are the result of a direct blow or rapid stretching/twisting movement can potentially injure a number of structures in the groin region. Characteristically, the patients describe planting and twisting or getting twisted or rapidly bringing the leg from a neutral to an abducted position. Once this region has been injured, it is often the case that repeated minor trauma can continue to aggravate the symptoms and cause ongoing recalcitrant pain, restriction and avoidance of provocative maneuvers whenever possible.

Classic Pathological Findings

Adductor/Abdominal Muscle-Tendinous Injury

Pain arising from adductor tendon damage can be very difficult to localize. The tendon of insertion of the rectus and origin of the adductor have been shown to be very close anatomically and their function is antagonistic in stabilizing the pelvis and the symphysis in a variety of activities. Pain in this region can therefore be classically referred into both areas as well as towards the symphysis and almost impossible to separate out. Such diagnoses

BOX 25-1 Blazina Grading of Tendinopathy

Grade 1	Pain after activity with no functional impairment
Grade 2	Pain at the beginning of activity, disappearing after warm up, reappearing after activity
Grade 3	Pain during and after activity with functional impairment
Grade 4	Complete tendon rupture

fall under the classification of most tendon strains or chronic injuries and can be grouped as the treating physician prefers and finds useful. This can include clinical grading such as that described by Blazina (Box 25-1) in association with the degree of damage defined by imaging studies. Less severe injuries may just have an awareness of pain aggravated by intense loading of the muscles concerned, more symptomatic examples may have pain or discomfort at rest that is initially eased by activity only to return and with increased intensity once the activity has ceased.

Muscular or tendinous injury in this region is far more common in males than females and so making the diagnosis in the female should always make the examiner check for other "pelvic"-related problems as a potential source. Relationship of the pain to the frequency or intensity of activity should allow the examiner to lean towards a tendon or muscle strain or tendinopathy. Aggravation of symptoms by palpation and resisted isometric testing of the affected muscle, either during adductor contraction or abdominal "crunch" type activity, brought on by repeated use or testing can help attribute the symptoms to either one or the other but often testing of both muscles can bring on the symptoms. Use of local anesthetic injection may help localize the pathology but in more severe examples, which have been going on for some time and chronicity, where the pain can be over a wide area and reference zone, makes localizing of the cause of the pain more difficult.

Iliopsoas Muscle-Tendinous Injury

The iliopsoas muscle can also be acutely strained or injured through repetitive overuse. This usually happens as a consequence of specific of repetitive forceful hip flexion during running, skating, jumping, or kicking. It can also be injured during an eccentric contraction, as when the thigh is suddenly forced into extension and the iliopsoas will try to decelerate the movement by an instantaneous eccentric muscle action. The overused iliopsoas tendon will sometimes appear with a spindle shape, near the insertion point on the trochanter minor, which can be visualized by ultrasound examination. Again the use of use of local anesthetic injection may also help localize the pathology from other structures, as iliopsoas symptoms can often coexist with other pathologies, such as adductor related injuries and intraarticular hip problems.

Clinical Presentation

History

These patients will often give a history of one precipitating event or action but may on more detailed questioning admit to having had some aching discomfort in the groin region before this. These minor symptoms are so common in the sports such as soccer and ice hockey that players almost accept it as the "norm." It is only with sudden worsening of intensity to the point where performance begins to be affected do they bring it to the treating clinicians attention. Characteristically these patients have a central aching discomfort in the groin region on one side or the other, aggravated by activity and localizing tenderness to clinical examination made worse by bracing maneuvers or single leg stance loading. The pain will often linger long after exercise has finished and may create sleep disturbance and early morning symptoms. This pain is characteristically brought on by resisted adduction of the leg, typically worsened when performed in an abducted position.

Muscular or tendinous injury in this region is far more common in males than females and so making the diagnosis in the female should always make the examiner check for other "pelvic"-related problems as a potential source. Relationship of the pain to the frequency or intensity of activity should allow the examiner to lean towards a tendon or muscle strain or tendinopathy. Relationship of the pain to bracing or "crunching" activities but not so obvious with resisted adduction should make the clinician consider a hernia or "sports hernia" as part of the differential diagnosis.

A number of risk factors (Table 25-1) have been identified and should be looked for in the history and examination of these patients to alert the examiner to possible cause(s) of the pain. Previous injury, increasing age, weak adductors, and low levels of off-season sports-specific activities have been shown to be significant risk factors for sustaining a groin injury. In Australian Rules Football (AFL) young players reporting a previous hip or groin injury at the draft medical assessment demonstrated a rate of hip/groin injury in the AFL more than six times higher than players without a pre-AFL hip or groin injury history.

Table 25-2 highlights the range of clinical entities that can contribute alone or in combination when taking a history and examining these types of patients.

Physical Examination

Examination of these patients must be comprehensive and cover a large number of potential entities that can contribute to the problem and as can be seen from the previous table, more than one entity can appear to be contributing to the symptoms.

Assessment of gait and leg length is mandatory, as well as signs of bruising for evidence of acute muscle/tendon injury which is usually an obvious sign (see Figure 25-3). In less obvious cases, local tenderness at the origin of the adductor tendons is helpful but localizing tenderness for other of the differential diagnoses is difficult to elicit and the pain can often be in a broad region making localizing

Table 25-1 Multivariate Analysis of Potential Risk Factors for Adductor Injury

Risk Factors	Adjusted OR	95% CI	*p* Value
Player-Dependent Factors			
Age	1.10	0.74–1.63	.65
Counter-movement jump test	1.01	0.89–1.14	.92
Leg-Dependent Factors			
Previous acute groin injury (yes/no)	2.60	1.10–6.11	.03
GrOS total score	1.04	0.78–1.41	.77
Clinical Examination			
External rotation in the hip joint (painful or not)	2.90	0.55–15.2	.21
Functional testing of rectal abdominal muscles (painful or not)	0.89	0.28–2.79	.84
Strength of adductor muscles (weak or not weak)	4.28	1.31–14.0	.02
Strength of iliopsoas muscles (weak or not weak)	2.23	0.39–12.7	.36

From Engebretsen AE, Myklebust G, Holme E, et al: Intrinsic risk factors for groin injuries among male soccer players: A prospective cohort study. Am J Sports Med 38:2051–2057, 2010.

the source difficult. Any swellings or signs of true hernias should be checked for and recurrence of symptoms more proximally in the region, with abdominal "crunching" testing may be more indicative of a "sports hernia" as a potential source of the pain. This, however, is usually a diagnosis of exclusion, often after surgical treatment of other conditions has failed (Figure 25-3).

Hip range of motion is often reduced and has led to the theory, unsupported by scientific evidence so far, that hip impingement may be a contributing factor.

Pain on palpation and aggravation of symptoms by resisted isometric testing of the affected muscle, either during adductor contraction or abdominal "crunch" type activity, brought on by repeated use or resistance testing can help attribute the symptoms to either one or the other but often testing of both the adductors and the abdominal rectus can bring on the symptoms. Use of local anesthetic injection may help localize the pathology but in more severe examples, which have been going on for some time and chronicity, the pain can be over a wide area and reference zone, making localizing of the cause of the pain more difficult.



FIGURE 25-3. Bruising associated with acute adductor longus rupture injury.

Table 25-2 Primary, Secondary, and Tertiary Clinical Entities in Soccer Players with Groin Pain

Clinical Entity	Primary, *n* (%)	Secondary, *n* (%)	Tertiary, *n* (%)
Adductor-related pain	94 (686.)	4 (2.9)	
Iliopsoas-related pain	35 (25.5)	31 (22.6)	6 (4.4)
Sports hernia	2 (1.5)		1 (0.7)
Snapping Iliopsoas	1 (0.7)		
Pelvic floor-related pain	1 (0.7)		
Rectus abdominus-related pain	1 (0.7)	11 (8)	3 (2.2)
Sacrotuberal ligament pain	1 (0.7)	4 (2.9)	1 (0.7)
Sacroiliac joint dysfunction	1 (0.7)		
Hip arthrosis	1 (0.7)	1 (0.7)	
Pain of thorocolumbar origin	1 (0.7)		
Hernia	1 (0.7)		
Piriformis-related pain	1 (0.7)	1 (0.7)	
Stress fracture	1 (0.7)		
Total	137 (100)	52 (38)	11 (8)

From Hölmich P. Long-standing groin pain in sportspeople falls into three primary patterns, a "clinical entity" approach: a prospective study of 207 patients. Br J Sports Med 2007 Apr;41(4):247-52; discussion 252, 2007.

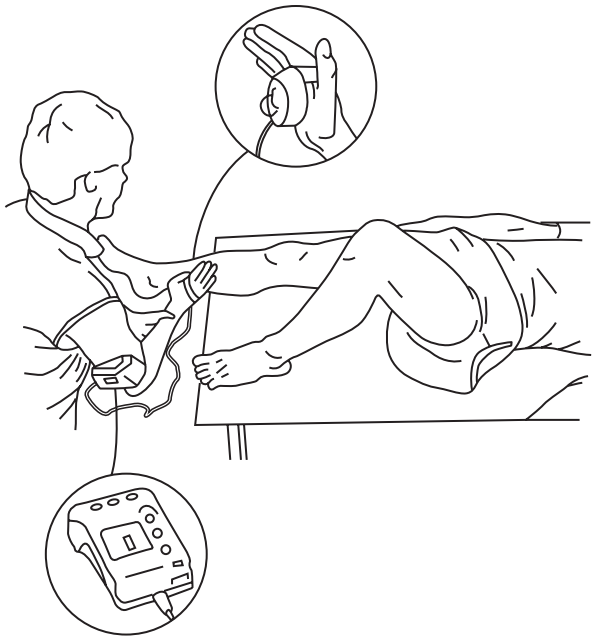


FIGURE 25-4. Use of a hand-held dynamometer to measure adductor strength. *(From Thorborg et al. Clinical assessment of hip muscle strength is reliable. SJMSS 20:493-501, 2010, with permission.)*

Quantifying adductor strength will often make obvious more subtle differences in adductor related problems and highlight the need for a strengthening program as an essential part of overall treatment. Use of a hand-held dynamometer to do this has been shown to be accurate and reproducible and is most sensitive when performed at the ankle with the leg in 0° of hip flexion (Figure 25-4).

One of the challenges with these patients is that the examination findings may be almost entirely normal or very difficult to isolate a single cause for the patient's symptoms. Use of imaging to support the clinical suspicions and exclude such pathologies as stress fractures can be diagnostic. At times "abnormal findings" on imaging will not correlate with your clinical findings and imaging studies should not replace clinical assessment and examination findings.

Imaging

- X-rays of the hip and pelvis are mandatory and a loaded view of the pubic symphysis (the flamingo view) may show evidence of subtle symphyseal instability. Views to look for FAI are considered mandatory for some clinicians and certainly indicated where hip range of motion is markedly reduced.
- CT scanning can further investigate associated hip abnormalities, early osteoarthritis of the hip or changes in the symphysis pubis. Stress fractures of the femoral neck or pubic ramus may also be better seen on CT.
- Ultrasound is useful in acute injuries in particular and if any swellings are visible at examination.
- MRI scanning is usually an inevitable investigation in these patients and many will bring such imaging with them that has been interpreted in a variety of ways by a variety of physicians they have seen previously. Positive findings on MRI scan that correlate with clinical findings are definitely supportive information for the clinician and patient, however, abnormal reported findings that do not have a close clinical correlate should be treated with caution. Features such as edema in the parasymphyseal region of the pubic symphysis may warrant reexamination of the patient, taking these findings into consideration. The diffuse nature of the pain on presentation can make localization of the pathology and diagnosis difficult, so having a structured examination system and correlating findings with MRI changes is likely to produce the highest clinical accuracy.
- A bone scan can be useful in isolating problems to the symphysis or revealing a stress fracture around the groin such as pubic rami or femoral neck. A CT scan to show the detail of the bony injury is then indicated (Table 25-3 and Box 25-2).

Differential Diagnosis

- Hip joint pathology
- Stress fractures (inferior rami and femoral neck)
- Internal or external snapping hip
- Avulsion fractures (sartorius and rectus femoris)
- Bursitis (traumatic or inflammatory)
- Nerve entrapment (obturator, ilioinguinal, and genitofemoral nerve branches)
- Gynecological or urological disorders
- Neoplasms (osteosarcomas, chondrosarcomas, other tumors)

Treatment

Nonoperative Management

Groin injuries can be difficult to treat and are often ignored by athletes and trainers, thus developing into a

Table 25-3 Checklist for MRI Evaluation of Adductor Injury

Muscle and Tendon	Sign/Symptom
Adductor longus	- tendinous (superficial) and muscular (deep) origin on anterior pubic bone (bone without perisoteum) - avulsion usually associated with bone fragment
Adductor brevis	- muscular origin posterior to adductus longus
Adductor tendon injury	- myotendinous injury—proximal (or distal)
Pectineus	- origin lateral public symphysis and superior pubic crest
Obturator externus	- origin postero-lateral pubic systems
Gracilis	- origin anteroinferior pubic symphysis and superior pubic arch
Grading of Injury	
Adductor muscle strain	
Acute	- increased T2 signal
Chronic	- Hypertrophic - Atrophic

BOX 25-2 MRI and Radiology of Groin Injury Associated Pathologies

Rectus Abdominis

- Attachment to superior pubic ramus
- Medial and lateral heads

RECTUS ABDOMINIS/ADDUCTOR APONEUROSIS

- Attachment to antero-inferior pubic bone

RECTUS ABDOMINIS/ADDUCTOR APONEUROSIS INJURY

- Ipsilateral rectus abdominis distal detachment + adductor aponeurosis partial or complete detachment
- Unilateral rectus abdominis atrophy
- Unilateral or bilateral adductor aponeurosis injury

RECTUS ABDOMINIS/ADDUCTOR APONEUROSIS PLATE DISRUPTION

- Secondary Cleft Sign
- Antero-inferior pubic bone curvilinear increased T2 signal

Symphysis Pubis

Bone marrow edema
Location:

- Superior = rectus abdominis
- Antero-inferior = RA/AA
- Lateral = pectineus
- Postero-lateral = obturator externus

Unilateral or bilateral
Degenerative change

- Subchondral cystic change
- Subchondral sclerosis
- Erosions

Acquired Inguinal Wall Deficiency

Frequent coexistent adductor tendon injury
Anterior inguinal ring insufficiency
Tear medial aspect external oblique, resulting in patulous external inguinal ring
Proposed that pain is caused by entrapment of cutaneous branches of the ilioinguinal nerve and genital branch of genitofemoral nerve
Clinical diagnosis
Rare to have findings on MR or US
MR—may see hyperintensity of external inguinal ring

Posterior Inguinal Wall Insufficiency

Conjoint tendon or transversalis fascia attachment tear or weakness
Use of imaging debated for diagnosis
US Posterior inguinal wall bulging—not sensitive or specific sign, as can be present in asymptomatic population
MR dynamic imaging
Asymmetrical focal protrusion of the posterior inguinal wall without a hernia

chronic stage before being recognized as affecting a player's or patient's performance and function. The primary treatment of choice for both acute and longstanding conditions in musculoskeletal groin injuries is an active treatment approach consisting of mobilization and exercise. Treatment is based on a systematic examination and an exact identification of the painful structure(s). This examination is based upon thorough history-taking and identification of the specific injury by palpation and isometric contractions where specific structures are isolated and specific pain responses are elicited. Diagnostic imaging can be relevant to exclude differential diagnoses, and in determining severe structural injury, such as complete and partial ruptures, but it is not advisable to be to obsessed with discrete imaging findings in isolation, as the exact understanding of such findings is not established. Therefore, treatments should primarily be based on clinical findings and their related dysfunctions, instead.

Guidelines for Choosing Among Nonoperative Treatments

The use of adjuvant modalities such as cortisone and more recently platelet enriched plasma injections has little support with scientific study and should be used with caution. Use of cortisone injections carries the same issues as other tendon injuries treated this way. It has a role in allowing short-term improvement but often the symptoms recur unless the "window" of reduced symptoms is used with rigorous rehabilitation to restore strength. An intraarticular anesthetic injection under radiological guidance can be helpful in determining the role any intraarticular hip pathology may be playing in the source of the patient's symptoms. Similarly, injection into the pubic symphysis can provide relief of symptoms where this joint is the main source of pain but repeated injections can lead to significant joint damage and increased symptoms.

The likelihood of a sustained improvement from any passive adjuvant modality is directly related to the regaining of strength and function.

- **Acute muscle-tendinous groin injuries**
  The acute treatment includes the Rest, Ice, Compression and Elevation protocol, then introducing gentle mobilization. Increasing range of motion can be commenced after the acute phase. Progression to isometric and then increasing resistance exercises can follow in a graduated regime. Sports-specific drills can be progressively commenced when isometric and eccentric strength is nearly normalized. Return to sport (competition) can be commenced as recovery improves and normal weekly training loads needs to be tolerated before return to competition is advisable.
- **Longstanding muscle-tendinous groin injury**
  For adductor-related groin pain, controlled static and dynamic exercises with focus on neuromuscular activation of the adductors, followed by increasing load and special emphasis on lengthening contractions, as well as challenging balance and co-ordination exercises has been shown to be very effective. These protocols are outlined in more detail in subsequent chapters
- **Iliopsoas-related groin pain/injury**
  The same principles are applied as with the adductor injuries. Systematic strengthening—including isometric, concentric and eccentric contractions—combined with a series of pelvic stabilization and balance

exercises are included in the treatment of the long-standing iliopsoas related groin pain. Stretching, massage, and trigger point stimulation for symptomatic relief might also be helpful, but is not the primary treatment. These injuries will have a similar favorable response as highlighted in the adductor related rehabilitation guidelines to a period of initial rest in acute injuries and then a structured strengthening program to allow full functional recovery and reduce the risk of re-injury.

- **Rectus abdominis related groin discomfort**
  Injuries that appear to involve the rectus insertion have restoration of strength after control of pain related symptoms as the ideal goal of treatment. Use of specific rectus abdominis strengthening exercises is an integral part of such a program.
- **Sports hernia**
  As the sportsman's hernia is an incipient hernia, rehabilitation should always be initiated first. A training program focusing on strength and coordination of the involved muscles provides an opportunity for the abdominal wall-lesion to heal. Using some of the exercises from the adductor-related program is of relevance as abdominal related injuries are often found in combination with adductor related injuries.
- **Stress fractures**
  A period of rest for 6 weeks and reintroduction of activity over a graduated 6-week period is a standard guideline for most stress fractures in the "adductor region" including compression sided fractures of the femoral neck and fractures of the pubic symphysis. Addressing all the contributing factors in these athletes including the diet, menstrual cycle irregularities and volume of exercise in the female athlete play an important role in this. Investigations of markers of bone metabolism including vitamin D levels are mandatory.

Preventing Groin Injury and Reinjury

Sport-specific prevention strategies to reduce the risk of groin injury in sport should include a specific focus on athletes with previous injury, and early identification of hip strength deficits. Total workload should also be specifically addressed and reduced in periods where athletes show clinical signs of hip and groin pain. In the off-season it is important for athletes to continue sports-specific activities and include strength-training exercises to stimulate muscle-tendinous health and repair.

Because previous groin injury is one of the best established risk factors, athletes displaying this risk-profile may benefit from specific attention by incorporating a specific exercise program focusing on the structures involved in their previous injury, and other related deficits, such as decreased eccentric strength, and possible lack of pelvic stability and coordination. The strength ratio between adductors and abductors seems to be important for injury prevention, as preseason strength training of the adductor muscles in ice hockey players ensuring an adductor/abductor strength ratio of 80% or more could decrease the number of adductor related groin injuries. A randomized treatment study including specific training of the adductor muscles (isometric, concentric, and eccentric), as well as exercises for the muscles related to the pelvis and torso, including 1022 male soccer players found that groin injuries were 31% less in the intervention group, compared with the control group. This difference was, however, not statistically significant, as the statistical power was too low to detect such a difference. As a possible groin injury reduction of 31% in a cohort of soccer players seems to be clinically meaningful, this program may be worthwhile to introduce in soccer teams where groin injuries constitute a significant problem.

Surgical Indications

The surgical management of groin injury depends primarily on accurately identifying the source of the pain. It cannot be emphasized too frequently that detailed clinical examination is the mainstay of making the correct diagnosis and supported by imaging studies. A subgroup of these patients have potentially multiple contributing pathologies and whether taking care of what seems the primary pathology will allow the others to recover or dealing with all apparent recalcitrant causes of pain and restriction is much argued about and seldom agreed on. For those patients with conditions identified that can be helped with nonoperative strategies outlined above, particularly adductor, rectus and psoas related problems, all patients should have undergone a supervised, rigorous, and appropriate rehabilitation schedule, as outlined in detail in following chapters, before surgery should be considered. Similarly the importance of a well-supervised, graduated, detailed progression of strengthening and proprioceptive retraining cannot be under emphasized as the key to a successful outcome. All treatment strategies, be they surgical or nonsurgical have the alleviation of pain to allow the restoration of strength as the primary goal.

Aspects of Clinical Decision Making When Surgery Is Indicated

- **Direct or indirect hernias**
  Thorough clinical examination will usually reveal a true direct or indirect hernia as the main contributing factor in a patient's symptoms. Referral for surgical treatment to an experienced laparoscopic surgeon is indicated and this condition can usually be managed around the competitive requirements of the athlete.
- **Fractures**
  Stress fractures on the tension (superior) side of the femoral neck require surgical management with compression fixation but are rare. Recalcitrant stress fractures of the femoral neck compression side or pubic ramus may require fixation usually with compression and rarely with bone grafting if sclerotic fracture ends are obvious on imaging. Again the key to identifying these diagnoses is an accurate history and physical examination and a screening bone scan if there is high index of suspicion but no obvious fracture on routine radiographs is probably the most sensitive and reliable imaging study.
- **Acute adductor tendon injury**
  As noted previously, repair of adductor tendon injuries are probably not indicated and it is often a difficult

tendon to get a robust repair. Protecting your repair is also difficult as only sustained bed rest is likely to remove tension on the repair while it heals. Unless avulsed with a surgically repairable piece of bone, surgery to repair adductor tears has been associated with significantly longer return to sport and greater risk of complications. There has been no evidence of greater strength loss without repair and as long as the structured program outlined in this section is followed, patients who have had tears treated non-operatively can achieve a similar outcome.

- **Adductor tendinopathy**
  A small subgroup of patients who have had adductor tendon pathology identified as their primary source of groin pain on history, pertinent physical examination findings and supportive imaging studies will continue to have restrictive symptoms despite attempting an appropriate rehabilitation and strengthening program. Surgical intervention in this group of patients provides a frequently rewarding relief of symptoms to allow them to successfully complete a rehabilitation program and regain strength and function. Temporary relief of symptoms with local anesthetic or cortisone, possibly injected under ultrasound control, is a helpful diagnostic adjuvant to support surgical treatment for both the clinician and the patient. It is relatively easily performed under direct vision and having the patient exercise immediately after use of any local and measuring improvement in a documented weakness in adductor strength is very helpful clinical information. Surgical release of the tendinous origin under direct visualization and possibly decompression of the obturator nerve have been associated with significant benefit in patients but long-term follow-up or randomized studies are not available in the literature.

Outcome Evaluation

Reliable, valid, and responsive outcome measures are important in the evaluation of patients with groin injury. The Copenhagen Hip And Groin Outcome Score (HAGOS) is developed specifically for younger patients with hip and groin pain. HAGOS is a patient-reported outcome measure employing five-item Likert scales. HAGOS consists of six subscales: pain, other Symptoms, physical function in daily living (ADL), Function in sport and recreation (Sport/Rec), participation in physical activities (PA), and hip-related quality of life (QOL). HAGOS can be used to assess groups and to monitor individuals, it is patient-administered and the format is user-friendly, and takes about 10 minutes to fill out. HAGOS is self-explanatory and can be administered in the waiting room or used as a mailed survey. HAGOS was found reliable, valid, and responsive in younger patients with hip and groin pain.

Isometric and eccentric strength is also important to evaluate in patients with groin injury. Reliable measures with hand-held dynamometry exist for hip adductors and hip flexors and can be used in the evaluation of when muscle strength is normalized in this region in the clinical setting. Pain during palpation and isometric maximal contraction are also good indicators of improvement in function. Different sports-specific activities, and range of motion measures, are other relevant measures that can be obtained and used for prospective evaluation of the recovery process of these injuries.

Evidence

Emery CA, Meeuwisse WH: Risk factors for groin injuries in hockey. *Med Sci Sports Exerc* 33:1423–1433, 2001.

This was a cohort study aimed at determining the level of off-season sport-specific activity, peak isometric adductor torque, and hip abduction flexibility that are predictive of groin or abdominal strain injury in the National Hockey League (NHL). The subjects were 1292 NHL players assessed during training camp. Estimated relative risks of injury were reported using six different exposures. Players who reported less than 18 sessions sport-specific training in the off-season were at greater than three times the risk of injury than those who did not (relative risk [RR]; 3.38 95% confidence interval [CI], 1.45 to 7.92). Players who reported previous history of this injury were at more than two times the risk of injury than those who did not (RR, 2.88; 95% CI, 1.33 to 6.26). Veterans were at greater than five times the risk of injury than rookies (RR, 5.69; 95% CI, 2.05 to 15.85). Peak isometric adductor torque, total abduction flexibility, and skate blade hollow measurement were not predictive of injury. Low levels of off-season sport-specific training and previous injury were identified as risks for groin injury at an elite level of hockey. (Level III evidence)

Engebretsen AE, Myklebust G, Holme E, et al: Intrinsic risk factors for groin injuries among male soccer players: A prospective cohort study. *Am J Sports Med* 38:2051–2057, 2010.

This was a prospective cohort study conducted to determine if risk factors for groin injuries among male soccer players could be identified. A total of 508 players representing 31 amateur teams were tested during the 2004 preseason for potential risk factors for groin injury through a questionnaire on previous injury and function score and a clinical examination of the groin. The total incidence of groin injuries was 0.6 injuries per 1000 playing hours, 0.3 injuries per 1000 training hours, and 1.8 injuries per 1000 match hours. Previous acute groin and weak adductor muscles as determined clinically were significantly associated with increased risk of groin injuries. A multivariate analysis based only on acute time-loss injuries revealed the 40-m sprint test and functional testing of the rectal abdominal muscles as significant risk factors. (Level III evidence)

Hölmich P, Larsen K, Krogsgaard K, et al: Exercise program for prevention of groin pain in football players: a cluster-randomized trial. *Scand J Med Sci Sports* 20:814–821, 2010.

A cluster-randomized trial including 55 football clubs representing 1211 players was performed. The clubs were randomized to an exercise program aimed at preventing groin injuries (n = 27) or to a control group training as usual (n = 28). The intervention program consisted of six exercises including strengthening (concentric and eccentric), coordination, and core stability exercises for the muscles related to the pelvis. Physiotherapists assigned to each club registered all groin injuries. Twenty-two clubs in each group completed the study, represented by 977 players. There was no significant effect of the intervention (HR = 0.69, 95% CI 0.40 to 1.19). The risk

of a groin injury was reduced by 31%, but this reduction was not significant. (Level I evidence)

Hölmich P, Uhrskou P, Ulnits L, et al: Effectiveness of active physical training as treatment for longstanding adductor-related groin pain in athletes: randomised trial. *Lancet* 353:439–443, 1999.

Sixty-eight athletes with long-standing (median 40 weeks) adductor-related groin pain—after examination according to a standardized protocol—were randomly assigned to active treatment (AT) or passive treatment (PT). The treatment period was 8 to 12 weeks. Four months after the end of treatment a standardized examination was done and 23 patients in the AT group and four in the PT group returned to sports without groin pain (odds ratio, multiple-logistic-regression analysis, 12.7 [95% CI 3.4 to 47.2]). AT with a program aimed at improving strength and coordination of the muscles acting on the pelvis, in particular the adductor muscles, is very effective in the treatment of athletes with long-standing adductor-related groin pain. (Level I evidence)

Thorborg K, Petersen J, Magnusson SP, et al: Clinical assessment of hip strength using a hand-held dynamometer is reliable. *Scand J Med Sci Sports* 20:493–501, 2010.

This was a normal subject based case control study that examined the absolute test-retest measurement variation concerning standardized strength assessments of hip abduction (ABD), adduction (ADD), external rotation (ER), internal rotation (IR), flexion (FLEX), and extension (EXT) using a hand-held dynamometer. Nine subjects (five males, four females), physically active for at least 2.5 hours a week, were included. Twelve standardized isometric strength tests were performed twice with a 1-week interval in between by the same examiner. When the maximum value of four measurements was used, test-retest measurement variation was below 10% in 11 of the 12 individual hip strength tests and below 5% in 5 of the 12 tests. Standardized strength assessment procedures of hip ABD, ER, IR, FLEX, with test-retest measurement variation below 5%, hip ADD below 6% and hip EXT below 8%, make it possible to determine even small changes in hip strength at the individual level using this method. (Level III evidence)

Tyler TF, Nicholas SJ, Campbell RJ, et al: The effectiveness of a preseason exercise program to prevent adductor muscle strains in professional ice hockey players. *Am J Sports Med* 30:680–683, 2002.

This was a prospective risk factor prevention study in 33 of 58 players from the same National Hockey League team who were identified as "at risk" on the basis of preseason hip adductor strength and participated in an intervention program. The program consisted of 6 weeks of exercises aimed at functional strengthening of the adductor muscles. There were 3 adductor strains in the 2 seasons subsequent to the intervention, compared with 11 in the previous 2 seasons (0.71 vs 3.2 per 1000 player-game exposures). A therapeutic intervention of strengthening the adductor muscle group appeared to be an effective method for preventing adductor strains in professional ice hockey players. (Level II evidence)

Zoga AC, Kavanagh EC, Omar IM, et al: Athletic pubalgia and the "sports hernia": MR imaging findings. *Radiology* 247:797–807, 2008.

This study was a retrospective review of MR imaging studies in 141 patients who had been referred because of groin pain were reviewed for findings including hernia, pubic bone marrow edema, secondary cleft sign, and rectus abdominis and adductor tendon injury. MR imaging findings were compared with surgical findings for 102 patients, physical examination findings for all 141 patients, and MR imaging findings in an asymptomatic control group of 25 men of similar age. Compared with surgery, MR imaging had a sensitivity and specificity, respectively, of 68% and 100% for rectus abdominis tendon injury and 86% and 89% for adductor tendon injury. Injury in each of these structures was significantly more common in the patient group than in the control group ($p < .001$). (Level IV evidence)

Multiple-Choice Questions

QUESTION 1. What epidemiological risk factor has not been shown to have an association with increased risk of adductor related groin injury?

A. Sex
B. Type of sport played
C. Playing at an elite level for greater than 12 months
D. Previous adductor injury

QUESTION 2. During which phase of kicking are the musculotendinous structures of the adductors at their greatest risk?

A. Plant
B. Swing
C. Contact
D. Follow through

QUESTION 3. What is the greatest associated risk factor on history and examination for sustaining a future groin injury?

A. Adductor strength
B. Age
C. Iliopsoas strength
D. Previous injury

QUESTION 4. What is the most relevant clinical indication of improvement from a muscle-tendinous groin injury with a structured rehabilitation program?

A. Pain-free single leg hop repetitions
B. Improved tolerance and duration of adductor stretching
C. Pain-free return to running
D. Pain-free maximal contraction and regains of muscle strength

Answer Key

QUESTION 1. Correct answer: **A**. (see Epidemiology)

QUESTION 2. Correct answer: **B** (see Pathophysiology: Intrinsic factors)

QUESTION 3. Correct answer: **A**. (see Clinical Presentation: Table 25-1)

QUESTION 4. Correct answer: **D**. (see Treatment)

NONOPERATIVE REHABILITATION OF LONGSTANDING GROIN INJURY

Kristian Thorborg, PT, MSportsphty, PhD, and Bruce Charles Twaddle, BHB, MBChB, FRACS

- The tendon of the insertion of the abdominals and origin of the adductors often can be involved in overuse and longstanding conditions that include groin pain as the cardinal symptom.
- Characteristically this pain is aggravated by loading of the musculotendinous tissues with some pain or discomfort at rest that may be initially eased by activity only to return and with increased intensity once the activity is increased or after the activity has ceased.
- The iliopsoas muscle can also be injured through repetitive overuse. The overused iliopsoas tendon will sometimes appear with a spindle shape on ultrasound examination, near the insertion point on the lesser trochanter minor.
- One high-quality clinical randomized trial of longstanding adductor-related groin pain has described a specific exercise program found to be highly effective in the treatment of this condition.[1] The exercise program consists of two phases:
  - The first phase is a period of 2 weeks of careful static and dynamic exercises to teach the patient to reactivate the adductor muscles. In most cases the athlete with adductor-related groin pain has difficulties activating these muscles, probably as a result of pain and disuse.
  - In the second phase, the exercises are gradually more demanding; heavier resistance training as well as challenging balance and co-ordination exercises are added.
- Nonoperative treatment of longstanding groin injury consists of active exercises performed at least three times a week for 8 to 12 weeks. This regimen can be done alone or in a group of two to four patients exercising according to the instructions and supervision of a physiotherapist. The duration of each individual training session is about 90 minutes. Patients with longstanding groin injury are told to do the exercises from module I on the days in between the treatment days.
- Patients do not usually receive any other treatment for the groin pain before the final follow-up. No athletic activity is allowed during the treatment period. Patients are allowed to ride a bicycle or swim if it does not cause any pain.
- The adductor exercise program is performed three times a week and the exercises from module I are done on the days in between the treatment days. The total length of the exercise-training period is between 8 and 12 weeks. Sports activities are not allowed in the treatment period. Riding a bicycle is allowed if it does not cause any pain.
- After 6 weeks, running is allowed as long as it does not provoke any groin pain.
- The exercise rehabilitation program is stopped when neither the exercise program nor the jogging causes any pain. The athlete is then allowed to increasingly progress to demanding sports-specific training towards final sports participation.

Exercise Treatment for Athletes With Longstanding Adductor-Related Groin Pain

Phase I: Muscle Activation (weeks 0 to 2)

- Static adduction against soccer ball placed between feet when lying supine; each adduction 30 seconds, 10 repetitions
- Static adduction against soccer ball placed between knees when lying supine (Figure 25-5); each adduction 30 seconds, 10 repetitions
- Abdominal sit-ups both in straightforward direction and in oblique direction; 5 series of 10 repetitions
- Combined abdominal sit-up and hip flexion, starting from supine position and with soccer ball placed between knees (folding knife exercise); 5 series of 10 repetitions
- Balance training on wobble board for 5 minutes
- One-foot exercises on sliding board (Figure 25-6), with parallel feet as well as with 90° angle between feet; five sets of 1-minute continuous work with each leg, and in both positions

Phase II: Muscle Strengthening and coordination (weeks 3+)

Phase II exercises were done twice at each training session.

- Leg abduction and adduction exercises lying on side; 5 series of 10 repetitions of each exercise



FIGURE 25-5. Adduction exercise with a soccer ball between the knees lying supine.



FIGURE 25-6. Adduction exercises on a sliding board.

- Low-back extension exercises prone over end of couch; 5 series of 10 repetitions
- One-leg weight-pulling (can include an elastic band) abduction/adduction standing (Figure 25-7); 5 series of 10 repetitions for each leg
- Abdominal sit-ups (Figure 25-8) both in straightforward direction and in oblique direction; 5 series of 10 repetitions
- One-leg coordination exercise flexing and extending knee and swinging the arms in same rhythm (cross country skiing on one leg); 5 series of 10 repetitions for each leg
- Training in sideward motion on a "Fitter" (rocking base curved on top and bottom; user stands on platform that rolls laterally on tracks on top of rocking base) for 5 minutes
- Balance training on wobble board for 5 minutes

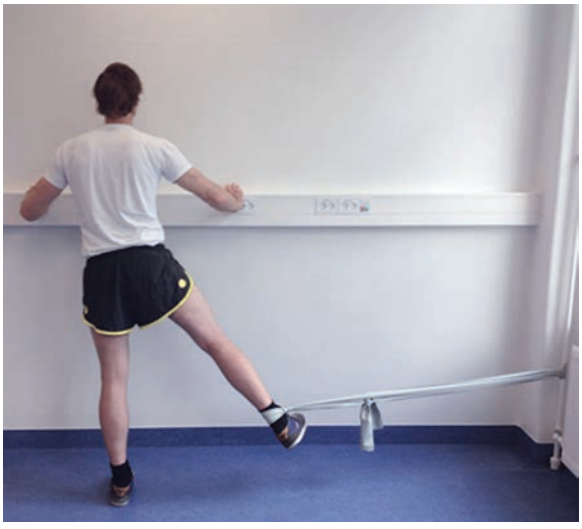


FIGURE 25-7. Elastic band "pulling" exercise to strengthen the adductor muscles.



FIGURE 25-8. Abdominal strengthening exercises using a "Swiss" ball.

- Skating movements on sliding board; five times 1-minute continuous work

Exercise Treatment for Athletes with Longstanding Iliopsoas- and Abdominal-Related Groin Pain

- The authors preferred an initial treatment suggestion for athletes with longstanding iliopsoas- and abdominal-related groin pain following the same principles as with the adductor-related program of systematic strengthening—including both isometric, concentric and eccentric contractions—combined with a series of pelvic stabilization and balance exercises.
- A bias toward specific and injured structures such the iliopsoas and abdominals (rectus abdominis for rectus abdominis tendinopathy or obliques and transversus abdominis for sports hernia) should be included in programs for athletes with these problems.
- Since the sports hernia by nature is an incipient hernia, often involving the abdominal wall (inguinal canal and conjoined tendon injury), rehabilitation should always be tried as a first step. A regular hernia has not yet developed, and a training program including pelvic strengthening and coordination exercises might provide the abdominal wall-lesion a chance to heal. These suggested treatments are, however, not yet supported by scientific evidence.

Supplementary Treatment

- Stretching exercises for the adductor muscle in patients with longstanding adductor-related groin pain is not recommended. The program nonetheless has showed to have the same increase of hip-joint range of motion as a passive treatment protocol that includes stretching.
- Usually, pain is initially a limiting factor to maximum contraction and range of motion activities, but, as the

muscle coordination and strength increased and the groin pain usually decreases and the load and the range of motion is also increased. Tolerance towards an increased range of motion might thereby be achieved.
- Two examples of this type of exercise are performed on the sliding board (see Figure 25-6) and the weight-pulling exercise (see Figure 25-7). Stretching of the adductor muscles in athletes with adductor-related groin pain is not recommended because this may stress the insertions at the pubic bone, which sometimes worsen the injury.
- NSAID and steroid injections for athletes with musculotendinous overuse groin injury are generally not recommended, before or during exercise rehabilitation. In our experience, there is no long-term beneficial effect of these modalities, and if the NSAID or injections affect the pain temporarily, it only makes it more difficult to monitor the training program needed to cure the groin pain. Rarely, NSAID or steroid injections can be used as an adjunctive treatment in patients who have so much pain during training that usual muscle activation and progress with increased symptom relief during the first initial 6 weeks is not possible.

Criteria for Abandoning Nonoperative Treatment and Proceeding to Surgery or more Intense Intervention

- No improvement in musculotendinous symptoms during sporting activity after adhering to a 8 to 12 weeks exercise program, exercising 3 times a week (90 minutes each session)
- Persisting symptoms that indicate subsequent involvement of hip joint, symphysis joint or inguinal canal/conjoined tendon lesion, which do not respond to the exercise program

Specific Criteria for Return to Sports Participation

- No pain on palpation of adductor longus tendon/insertion



FIGURE 25-9. Dynamic core/abdominal and adductor strengthening exercise.

- No pain on adductor longus tendon/insertion on bilateral isometric contraction with straight legs
- No pain during sporting activity

Preventing Reinjury

- To prevent recurrence of previous groin injuries, treatment aiming at healing the structural damage should be combined with the continuance of the exercise program to maintain strength and reduce the risk of recurrence.
- In another randomized controlled trial including 1022 male soccer players, the possible preventive value of such an exercise program has been examined.[2] The exercises consisted of the following:
  - Isometric adduction exercises, squeezing a soccer ball between the feet and between the knees in the supine position
  - Dynamic adductor and abductor strengthening exercises (concentric and eccentric) (Figure 25-9) done with a partner
  - Coordination of the hip joint related muscles and the muscles of the pelvis and torso using a dynamic exercise combining sit-up, hip flexion and adduction
  - Dynamic proprioceptive exercise stimulating both concentric and eccentric strength, and utilizing the principles of pelvic and core coordination and strength

TIMELINE 25-1: **Nonoperative Treatment of Longstanding Adductor-Related Groin Pain**

PHASE I (weeks 1 to 2)	PHASE II (weeks 3 to 5)
• Adductor muscle activation exercises initiated • Abdominal and hip flexor strengthening initiated • Gentle sliding exercises in abduction and adduction on smooth surface • Balance exercises • Passive stretching exercise (psoas) • Walking, aerobic fitness and strength training for upper extremity as tolerated	• Progressive adductor strengthening continued • Progressive core/abdominal strengthening program initiated • Sliding exercises in abduction and adduction on smooth surface • Balance and coordination exercises • Passive stretching exercise (psoas) • Walking, aerobic fitness and strength training for upper extremity as tolerated

  - Stretching exercises for the iliopsoas muscle given the nature of secondary involvement of this muscle in the presence of groin pain
- The trial found groin injuries were 31% less in the intervention group, compared to the control group, but the difference was not statistically significant, as the statistical power was too low to detect such a difference. Despite the inconclusiveness of this study, the 31% reduction in the risk of getting a groin injury would be a considerable advantage, which probably would make it worthwhile for the soccer players to do the program.
- Simple measures of symptoms, pain, and sporting function can help to monitor the athlete after full return to sport. The Copenhagen Hip and Groin Outcome Score (HAGOS) was developed specifically for younger patients with hip and groin pain.[3] This questionnaire refers to the patient's hip and/or groin pain and is therefore also useful in patients with musculoskeletal problems who are treated with exercises or other conservative interventions.
- HAGOS consists of six subscales:
  - Pain
  - Symptoms
  - Physical function in activities of daily living (ADLs)
  - Function in sport and recreation (Sport/Rec)
  - Participation in physical activities (PA)
  - Hip-related quality of life (QOL)
- The past week is taken into consideration when answering the questions. Standardized answer options are given five Likert boxes and each question gets a score from 0 to 4. A normalized score (100 indicating no symptoms and 0 indicating extreme symptoms) is calculated for each subscale. The result can be plotted as an outcome profile. HAGOS is meant to be used over both short and long time intervals. HAGOS can be used to assess groups and to monitor individuals. It is patient-administered and the format is user friendly. It takes about 10 minutes to fill out. HAGOS is self-explanatory and can be administered in the waiting room or used as a mailed survey.
- HAGOS was found to be reliable, valid and responsive in younger patients with hip and groin pain. Median scores close to maximum are present in healthy athletes, and reference values have shown that scores below 75 points seem to indicate problems with the hip and groin in most of the subscales. HAGOS can be used as a monitoring tool for athletes with hip and groin problems to assess the severity and monitor the load of these athletes in relation to their scores as this may be an effective way of reducing the risk of recurrence.

Evidence

Hölmich P, Larsen K, Krogsgaard K, et al: Exercise program for prevention of groin pain in football players: a cluster-randomized trial. *Scand J Med Sci Sports* 20:814–821, 2010.

A cluster-randomized trial including 55 football clubs representing 1211 players was performed. The clubs were randomized to an exercise program aimed at preventing groin injuries (n = 27) or to a control group training as usual (n = 28). The intervention program consisted of six exercises including strengthening (concentric and eccentric), coordination, and core stability exercises for the muscles related to the pelvis. Physiotherapists assigned to each club registered all groin injuries. Twenty-two clubs in each group completed the study, represented by 977 players. There was no significant effect of the intervention (HR = 0.69, 95% CI 0.40 to 1.19). The risk of a groin injury was reduced by 31%, but this reduction was not significant. (Level I evidence)

Hölmich P, Uhrskou P, Ulnits L, et al: Effectiveness of active physical training as treatment for long-standing adductor-related groin pain in athletes: randomised trial. *Lancet* 353:439–443, 1999.

Sixty-eight athletes with long-standing (median 40 weeks) adductor-related groin pain—after examination according to a standardized protocol—were randomly assigned to active treatment (AT) or passive treatment (PT). The treatment period was 8 to 12 weeks. Four months after the end of treatment a standardized examination was done and 23 patients in the AT group and four in the PT group returned to sports without groin pain (odds ratio, multiple-logistic-regression analysis, 12.7 [95% CI 3.4 to 47.2]). AT with a program aimed at improving strength and coordination of the muscles acting on the pelvis, in particular the adductor muscles, is very effective in the treatment of athletes with long-standing adductor-related groin pain. (Level I evidence)

Thorborg K, Hölmich P, Christensen R, et al: The Copenhagen Hip and Groin Outcome Score (HAGOS): development and validation according to the COSMIN checklist. *Br J Sports Med* 45:478–491, 2011.

TIMELINE 25-1: Nonoperative Treatment of Longstanding Adductor-Related Groin Pain (Continued)

PHASE III (weeks 6 to 8)	PHASE IV (weeks 9 to 12)	PHASE V (weeks 13+)
• Progressive adductor strengthening continued • Progressive core/abdominal strengthening program continued • Sliding exercises in abduction and adduction on smooth surface • Running, aerobic fitness and strength training for upper extremity as tolerated • Balance and coordination exercises • Passive stretching exercise (psoas)	• Gradual return to sport if tolerated • Progressive adductor strengthening continued • Progressive core/abdominal strengthening program continued • Sliding exercises in abduction and adduction on smooth surface • Running as tolerated • Aerobic fitness and strength training for upper and lower extremity as tolerated • Balance and coordination exercises • Passive stretching exercise (psoas) • Sport-specific exercises	• Gradual or full return to sport if tolerated • Maintenance of active and passive range of motion • Maintenance of adductor/hip flexor and core/abdominal strength • Maintenance of balance and coordination.

In a prospective study the purpose was to develop and validate a new PRO (HAGOS) in accordance with the COnsensus-based Standards for the selection of health Measurement INstruments (COSMIN) recommendations for use in young to middle-aged, physically active patients with longstanding hip and/or groin pain. Test-retest reliability was substantial, with intraclass correlation coefficients ranging from 0.82 to 0.91 for the six subscales of HAGOS. Construct validity and responsiveness were confirmed. HAGOS has adequate measurement qualities for the assessment of symptoms, activity limitations, participation restrictions and QOL in physically active, young to middle-aged patients with longstanding hip and/or groin pain. (Level II evidence)

REFERENCES

1. Hölmich P, Uhrskou P, Ulnits L, et al: Effectiveness of active physical training as treatment for long-standing adductor-related groin pain in athletes: randomised trial. *Lancet* 353:439–443, 1999.
2. Hölmich P, Larsen K, Krogsgaard K, et al: Exercise program for prevention of groin pain in football players: a cluster-randomized trial. *Scand J Med Sci Sports* 20:814–821, 2010.
3. Thorborg K, Hölmich P, Christensen R, et al: The Copenhagen Hip and Groin Outcome Score (HAGOS): development and validation according to the COSMIN checklist. *Br J Sports Med* 45:478–491, 2011.

Multiple-Choice Questions

QUESTION 1. Exercise treatment of longstanding groin injury usually takes?

A. 2 to 3 weeks
B. 3 to 4 weeks
C. 5 to 8 weeks
D. 8 to 12 weeks

QUESTION 2. What is the duration for a single session for the exercise program for treatment of longstanding groin injury?

A. 30 minutes
B. 60 minutes
C. 90 minutes
D. 120 minutes

QUESTION 3. When is pain-free running allowed in exercise treatment of longstanding groin injury?

A. Immediately
B. 2 weeks
C. 6 weeks
D. 12 weeks

QUESTION 4. What are the criteria for return to full sports participation?

A. No pain during daily activities
B. Normalized muscle strength
C. No pain during sport
D. No pain on palpation of adductor longus tendon/insertion and no pain of adductor longus tendon/insertion on bilateral isometric contraction with straight legs and no pain during sporting movements

QUESTION 5. How can groin symptoms in athletes be measured and monitored?

A. By using the HAGOS
B. By using a visual analog scale
C. By palpation
D. By a squeeze test

Answer Key

QUESTION 1. Correct answer: **D** (see Guiding Principles)

QUESTION 2. Correct answer: **C** (see Guiding Principles)

QUESTION 3. Correct answer: **C** (see Guiding Principles and Phase III)

QUESTION 4. Correct answer: **D** (see Specific Criteria for Return to Sports Participation)

QUESTION 5. Correct answer: **A** (see Preventing Reinjury)

POSTOPERATIVE REHABILITATION AFTER ADDUCTOR RELEASE

Bruce Charles Twaddle, BHB, MBChB, FRACS, and Kristian Thorborg, PT, MSportsPhty, PhD

Indications for Surgical Treatment

- Reliable history and examination findings to support adductor tendonosis as the likely cause of the groin pain (see previous section Clinical Presentation).
- Confirmed supporting changes on an imaging modality (MRI, Ultrasound, SPECT bone scan, and/or favorable response to local anesthetic injection and "stress test")
- Failure of a supervised appropriate rehabilitation program (see previous section Surgical Indications).

Brief Summary of Surgical Treatment

Major Surgical Steps

- Positioning of patient supine in "frog leg" position
- Appropriate draping of the groin area
- Palpation and identification of adductor longus tendon as it originates from the inferior aspect of the pubic ramus
- Transverse groin crease incision
- Split superficial fascia longitudinally in the line of the adductor longus
- Identify the tendon of the adductor longus as it originates from the pubis (Figure 25-10)
- Transversely divide the tendinous part of the adductor longus as close to the origin as possible
- Debride any abnormal tendon or scar tissue
- Careful hemostasis
- Close the superficial fascia
- Close the skin incision
- Infiltrate local anesthetic
- Apply a small padded dressing with a waterproof covering

Factors That May Affect Rehabilitation

Anesthetic

- No specific anesthetic issues are likely to affect rehabilitation apart from those related to any unanticipated complication.

Surgical

- In patients with neuralgic type symptoms affecting the anterior division of the obturator nerve, some authors recommend exposure and neurolysis of this nerve after the adductor longus has been released.
- In patients with multiple suspected pathologies, other surgical procedures may be required. Such procedures as arthroscopic treatment of suspected symptomatic femoro-acetabular impingement (FAI) may be considered, as may surgery for associated Pubic Symphysis pathology. Invariably any other surgical procedure will have a more prolonged period of initial restricted weight bearing and mobilization.

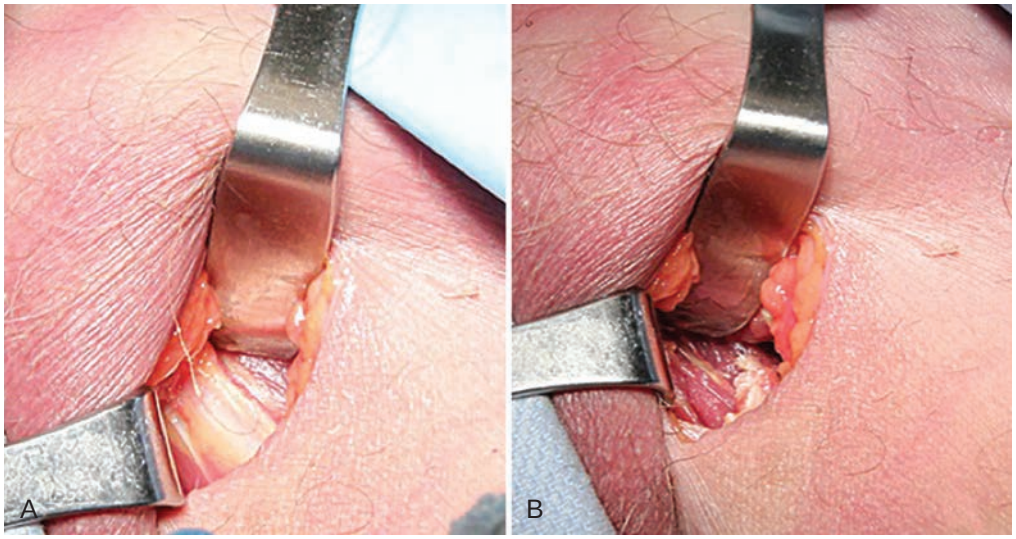


FIGURE 25-10. Surgical exposure and release of the adductor longus tendon. **A,** Transverse groin incision with longitudinal release of the fascia and exposure of the muscle and tendon at its origin off the pelvis. **B,** Release of the tendinous part only leaving the muscle fibers intact.

Other Surgical Techniques and Options

Before Surgery: Overview of Goals, Milestones, and Guidelines[1]

GUIDING PRINCIPLES OF POSTOPERATIVE REHABILITATION

- Initial limited activity and exercise to allow uncomplicated healing of the incision.
- Begin passive range exercises and active range of motion eliminating gravity until mobilizing comfortably off crutches.
- Introduce static adduction muscle activating exercises and controlled motion exercises without full weight bearing on a sliding board, as well as core/abdominal strength and balance/coordination exercises.
- Progress to strengthening exercises including concentric, isometric, and eccentric actions, with more sophisticated movement exercises incorporating eccentric adductor activation, continued core/abdominal and balance/coordination exercises.
- Sport-specific exercises and high-intensity training in specific focused activities

Phase I: Immediate Postoperative Period (days 0 to 14)

Clinical Pearls

Avoid infection: Due to the nature of the region where adductor release surgery is performed, use of removable nylon sutures and careful attention to groin and wound hygiene will prevent an early wound infection slowing beginning more active rehabilitation

Goals

Protection

- The patient can begin weight bearing with crutches as soon as possible and can progress to using one crutch then no crutches as pain allows over the first 10 days.

Management of Pain and Swelling

- Long acting local anesthetic is infiltrated into the surgical site after wound closure and combined use of nonnarcotic oral analgesia and an oral antiinflammatory agent if tolerated is usually all that is required. Avoid use of antiinflammatory medication in the first 2 weeks if possible as these impair healing processes
- Attention to ensuring all bleeding sites are cauterized prior to wound closure is the most important part of controlling swelling.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Passive range of motion exercises for maintaining hip range of motion with cautious introduction of passive assisted abduction are appropriate.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Stretching/flexibility techniques for the musculotendinous unit: Use of the sliding board to allow the patient to begin some active abduction/adduction exercises lying supine to remove the resistance of gravity can be commenced after the first 3 to 4 days using the patient's own comfort as a guide.

Other Therapeutic Exercises

- Core/abdominal exercises with focus on isometric and concentric contractions can begin at the same time as the patient is comfortable enough to begin supine sliding board exercises (4 to 5 days post surgery).
- General body strength and conditioning can continue as pain allows.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Use of the sliding board to allow the patient to begin some active ab/adduction exercises lying supine to

TIMELINE 25-2: **Postoperative Rehabilitation after Open Adductor Longus Release**

PHASE I (weeks 1 to 2)	PHASE II (weeks 3 to 4)
• Crutches • PT modalities • Gentle supine sliding board exercises • Static adduction muscle activating exercises and controlled motion • Core/abdominal activation exercises can begin • TBS/TAS/TLS activities as recommended and tolerated	• Reduce use of crutches • PT Modalities • Continue sliding board exercises • Core/abdominal strengthening program initiated • Graduated resisted adductor strengthening • TB/TAS/TLS activities as recommended and tolerated

[1]*Prehabilitation, if appropriate, is described in the Nonoperative Rehabilitation section of this chapter.*

remove the resistance of gravity can be commenced after the first 3 to 4 days using the patient's own comfort as a guide.

Sensorimotor Exercises

- Commencing heel-to-toe weight bearing pattern with crutches, progressing to one then no crutches should be part of early rehabilitation.
- Balance/coordination exercises with single leg balance can commence on the nonoperative leg.

Open and Closed Kinetic Chain Exercises

- Use of the sliding board with the patient supine as noted above

Milestones for Progression to the Next Phase

- Establish a heel-to-toe walking pattern without crutches.
- Abduct comfortably beyond 20 degrees on the sliding board.

Phase II: Intermediate Postoperative Phase (weeks 3 to 4)

Clinical Pearls

Use of a low resistance sliding board/slippery surface is an ideal tool to allow initial range of motion activities and exercises with the patient lying supine in the early phase of postoperative rehabilitation and recovery. More sophisticated "skating motion" and upright exercises can be introduced utilizing the same apparatus as rehabilitation progresses and becomes more sophisticated. Ideally, the patient will have had a preoperative program that utilized these exercises so that this kind of training has already taken place to ensure these exercises are done correctly

Goals

- Comfortable heel-to-toe walking pattern without crutches
- Introduction of sliding board abduction/adduction exercises lying supine
- Progression to standing abduction/adduction exercises and elastic band type resistance strengthening exercises
- One foot sliding exercises, without weight bearing, on the sliding board as comfort allows

Protection

- Treatment for pain/analgesia: Oral analgesics as tolerated; avoid antiinflammatory medication as it can slow tendon healing in the first 4 weeks.

Management of Pain and Swelling

- Decrease swelling as necessary with ice, rest, analgesia.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Continued increase in passive assisted range of motion exercises of the hip working particularly on range of abduction using pain as a guide

Soft Tissue Techniques

- As required for wound healing and scar formation treatment with massage, taping and application of vitamin E or evening primrose oil-based topical applications

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Use of the sliding board to allow the patient to continue active abduction/adduction exercises lying supine. Progression to standing sliding board exercises can commence.

TIMELINE 25-2: **Postoperative Rehabilitation after Open Adductor Longus Release** (Continued)

PHASE III (weeks 5 to 8)	PHASE IV (weeks 9 to 12)	PHASE V (weeks 13 to 52)
• Running and striding activity begins • PT modalities as needed • Assisted adductor and hip flexor stretching program • Continued resisted adductor strengthening • TBS/TAS/TLS activities as recommended and tolerated • Progressive abdominal/core strengthening exercises • Standing sliding board exercises • Plyometric exercises begin • Introduction of sport-specific training	• Gradual return to full training and sport participation • PT modalities as needed • Progressive strengthening adductor and abductor muscles with elastic band • Active and passive stretching exercises • Continued abdominal/core strengthening • Increased plyometric and change of direction exercise program • Sport-specific training • TBS/TAS/TLS activities as recommended and tolerated • Sport-specific exercises can be tailored to the individuals needs	• Full training and sport participation • PT modalities as needed • Maintenance of abdominal/core strengthening • Maintenance program of strengthening and sliding exercises • TBS/TAS/TLS activities as recommended and tolerated • Sport-specific exercises can be tailored to the individuals needs

Other Therapeutic Exercises

- Reintroduction of other strengthening and sport-specific strengthening as possible, avoiding active resistance or secondary firing of the adductor muscles.
- Unlimited upper body strength work is possible

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Static adduction against soccer ball placed between feet when lying supine; each adduction 30 seconds, ten repetitions
- Static adduction against soccer ball placed between knees when lying supine (see Figure 25-5); each adduction 30 seconds, 10 repetitions
- Abdominal sit-ups both in straightforward direction and in oblique direction; 5 series of 10 repetitions
- Combined abdominal sit-up and hip flexion, starting from supine position and with soccer ball placed between knees (folding knife exercise); 5 series of 10 repetitions
- One-foot exercises on sliding board, with parallel feet as well as with 90° angle between feet (see Figure 25-6); five sets of 1-minute continuous work with each leg, and in both positions.

Sensorimotor Exercises

- Balance training on wobble board for 5 minutes

Open and Closed Kinetic Chain Exercises

- Exercises as noted above

Techniques to Increase Muscle Strength, Power, and Endurance

- One-leg elastic band abduction/adduction standing (see Figure 25-7); for each leg using progressive exercise principles. Progress from 30 to 20 repetitions maximum.
- Neuromuscular dynamic stability exercises

Neuromuscular Dynamic Stability Exercises

- Skating movements on sliding board; five times 1 min continuous work.

Plyometrics

- Introduced in the next phase

Functional Exercises

- Introduced in the next phase

Sport-Specific Exercises

- Introduced in the next phase

Milestones for Progression to the Next Phase

- Pain-free heel-to-toe walking pattern
- Comfortable with supine sliding board exercises in full ROM
- Able to tolerate resisted adductor strengthening exercises from 30 to 20 RM
- Ready for introduction of walking and jogging

Phase III: Late Postoperative Phase (weeks 5 to 8)

Clinical Pearls

Use of an elastic band exercise program helps specifically gain adductor functional strength recovery on both the standing and the moving leg. The muscle activity is less but still substantial on the standing leg, and training can be progressed by increased resistance and by changing from standing to moving leg. Ten repetition maximum with similar resistance as performed on the uninjured leg needs to be performed before progressing into more sport-specific training.

Goals

- Increase strength with resistance using repetition maximum (20 to 10 RM) and dynamometer as a guide
- Introduction of upright sliding dynamic exercise
- Initiating change of direction exercises
- Progression to sport-specific training and exercises

Management of Pain and Swelling

- Oral analgesia as required

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- As felt necessary with passive assisted and active range of motion exercises

Soft Tissue Techniques

- Local deep tissue massage as required

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Introduce adductor stretching as part of the rehab and include general hip stretches, in particular rectus femoris stretches

Other Therapeutic Exercises

- General conditioning in preparation for return to sport with reintroduction of a sport-specific strengthening program for the other muscle groups as per their usual strength training
- Low-back extension exercises prone over end of couch; 5 series of 10 repetitions
- Abdominal sit-ups both in straightforward direction and in oblique direction (see Figure 25-8); 5 series of 10 repetitions

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Muscle activation exercises should be well advanced as discussed in previous sections working towards a reintroduction to sport-specific training

Sensorimotor Exercises

- Advanced sensorimotor retraining can be introduced including single leg landing balance exercises

Open and Closed Kinetic Chain Exercises

- Leg abduction and adduction exercises lying on side; 5 series of 10 repetitions of each exercise
- One-leg weight-pulling abduction/adduction standing; 5 series of 10 repetitions for each leg

Techniques to Increase Muscle Strength, Power, and Endurance

- Progression of strength and power exercises modulated by the individual patients symptoms

Neuromuscular Dynamic Stability Exercises

- One-leg coordination exercise flexing and extending knee and swinging arms in same rhythm (cross-country skiing on one leg); 5 series of 10 repetitions for each leg

Plyometrics

- Introduction of plyometric exercise can begin during this rehabilitation period as long as hand-held dynamometer adduction strength is 80% to 90% of the normal side

Functional Exercises

- Skating movements on sliding board; five times 1-minute continuous work
- Training in sideways motion on a sliding board type area for 5 minutes

Sport-Specific Exercises

- Introduction of sport-specific exercises (see next phase) can begin during this rehabilitation period as long as hand-held dynamometer adduction strength is 80% to 90% of the normal side

Milestones for Progression to the Next Phase

- Hip adduction strengthening with ten repetition maximum and of similar resistance as performed on the uninjured leg needs to be performed before progressing into more sport-specific training.
- Minimal pain with progression of activity with symptoms the following day being the most accurate guide as to how well increases in rehabilitation exercises and duration were tolerated.

Phase IV: Late Oostoperative Phase (weeks 9 to 12)

Clinical Pearls

Use of the hand-held dynamometer as an accurate measure of strength recovery using the nonoperated side as a guide allows progression of more plyometric type activities and return to sport-specific training to be based on clear, accurate milestones. Reduced adductor strength after tenotomy is to be expected but adductor strength recovery should be 80% to 90% of nonoperated side before sport-specific progression.

Goals

- Adduction strength 80% to 90% of the uninjured side (using a hand-held dynamometer if available)
- Full progression to sport-specific training
- Return to play using performance and comfort in training as a guide
- Introduction of maintenance exercises to reduce risk of recurrence

Protection

- Not required

Management of Pain and Swelling

- Oral analgesia as required

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- As necessary using passive assisted and active range of motion exercises

Soft Tissue Techniques

- Local deep tissue massage as required

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Continue active adductor flexibility and include passive hip flexor stretches as return to sport begins

Other Therapeutic Exercises

As noted previously the following exercises are seen as being useful:

- Low-back extension exercises prone over end of couch; 5 series of 10 repetitions.
- Abdominal sit-ups both in straightforward direction and in oblique direction; 5 series of 10 repetitions. Progressed into abdominal sit-ups performed on exercise ball, including eccentric, isometric and concentric contractions of abdominals from near full active lumbar extension over the ball into near full active lumbar flexion.

Sensorimotor Exercises

- Advanced sensorimotor retraining continue including single leg landing balance exercises

Open and Closed Kinetic Chain Exercises

- Both open and closed kinetic chain strengthening are unrestricted

Techniques to Increase Muscle Strength, Power, and Endurance

- One-leg elastic band abduction/adduction standing; 8 to 12 RM
- Progression of strength and power exercises modulated by the individual patients symptoms

Neuromuscular Dynamic Stability Exercises

- One-leg coordination exercise flexing and extending knee and swinging arms in same rhythm (cross-country skiing on one leg); 5 series of 10 repetitions for each leg.

Plyometrics

- Continued plyometric exercise during this rehabilitation period as long as hand held dynamometer adduction strength is 80% to 90% of the normal side

Functional Exercises

- Skating movements on sliding board; five times 1 min continuous work.
- Reintroduction of running, sprinting and kicking training and progression if part of specific sport requirements

Sport-Specific Exercises

- Progression of sport-specific exercises continues during this rehabilitation period as long as hand-held dynamometer adduction strength remains at 80% to 90% of the normal side with minimal pain.
- Reintroduction of running, sprinting, and kicking as part of training progression

Milestones for Progression to the Next Phase

- Hand-held dynamometer adduction strength is still 80% to 90% of the normal side, also in days after plyometric and sport-specific drills
- Minimal pain with progression of activity with symptoms the following day being the most accurate guide as to how well increases in rehabilitation exercises and duration were tolerated

Phase V: Late Postoperative Phase (weeks 13 to 52)

Goals

- Unrestricted activity and training and return to full participation
- Maintenance of a preventative strengthening and stretching program

Protection

- Not required

Management of Pain and Swelling

- Oral analgesia as required

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- As felt necessary with passive assisted and active range of motion exercises

Soft Tissue Techniques

- Local deep tissue massage as required

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Continue active adductor flexibility and include passive hip flexor stretches as return to sport begins

Other Therapeutic Exercises

As noted previously the following exercises are seen as being useful:

- Low-back extension exercises prone over end of couch; 5 series of 10 repetitions.
- Abdominal sit-ups both in straightforward direction and in oblique direction; 5 series of 10 repetitions. Progressed into abdominal sit-ups performed on exercise ball, including eccentric, isometric and concentric contractions of abdominals from near full active lumbar extension over the ball into near full active lumbar flexion.

Sensorimotor Exercises

- Advanced sensorimotor retraining continue including single leg landing balance exercises

Open and Closed Kinetic Chain Exercises

- Both open and closed kinetic chain strengthening are unrestricted

Techniques to Increase Muscle Strength, Power, and Endurance

- One-leg elastic band abduction/adduction standing; 8 to 12 RM
- Progression of strength and power exercises modulated by the individual patients symptoms

Neuromuscular Dynamic Stability Exercises

- One-leg coordination exercise flexing and extending knee and swinging arms in same rhythm (cross-country skiing on one leg); 5 series of 10 repetitions for each leg

Plyometrics

- Continued plyometric exercise during this rehabilitation period as long as hand-held dynamometer adduction strength is 80% to 90% of the normal side

Functional Exercises

- Skating movements on sliding board; five times 1-minute continuous work
- Reintroduction of running, sprinting, and kicking training and progression if part of specific sport requirements

Sport-Specific Exercises

- Progression of sport-specific exercises continues during this rehabilitation period as long as hand-held dynamometer adduction strength remains 80% to 90% of the normal side with minimal pain.
- Reintroduction of running, sprinting, and kicking as part of training progression

Milestones for Progression to Advanced Sport-Specific Training and Conditioning

- Hand-held dynamometer adduction strength is still 80% to 90% of the normal side, also in days after plyometric and sport-specific drills, training and game/competition-related activity.
- Minimal pain with progression of activity with symptoms the following day being the most accurate guide as to how well increases in rehabilitation exercises and duration were tolerated.

Criteria for Return to Sport

General

- Some discomfort at time of returning to sport is acceptable as long as there is no pain and full pain-free training participation is possible the following day
- Monitoring of adductor strength with the hand-held dynamometer ensuring strength is comparable (within 90%) of the nonoperated side
- Symptom-free cutting and change of direction drills as part of practice and participation
- Able to maximally sprint, cut, and kick a ball if required as part of sport-specific training with no discomfort and/or decreased performance in keeping with the athletes preinjury performance

Sport-Specific

- Soccer is covered in other parts of the section.
- Ice hockey and skating sports:
  - Pain-free motion on the sliding board doing upright skating type exercises; graduated reintroduction of ice-based skating; and change of direction exercises including game-related activities, such as passing, shooting, and dribbling with the puck.
- American football, rugby and other lower extremity strength-based sports: graduated reintroduction of running, sprinting, and change of direction exercises including game-related activities, such as passing, kicking.

After Return to Sport

Continuing Fitness or Rehabilitation Exercises

- Continued resistance adductor and core/abdominal strengthening as maintenance work.
- Use of the range of exercise noted in the previous sections that specifically focus on adductor strength and rehabilitation such as the sliding board exercises if there is any recurrence of symptoms

Exercises and Other Techniques for Prevention of Recurrent Injury

- Focused adductor stretching program as part of warmups in practice and training
- Ongoing and focused abdominal/core strengthening
- Weekly sets of adductor and abductor elastic exercise program, plyometric jumping from side to side, and/or upright sliding board "skating"

Evidence

Akermark C, Johansson C: Tenotomy of the adductor longus tendon in the treatment of chronic groin pain in athletes. *Am J Sports Med* 20:640–643, 1992.

This is a cohort study of 18 tenotomies of the adductor longus tendon performed in 16 consecutive male athletes (aged 20 to 42) as treatment for chronic groin pain. The criteria for surgery was a history of longstanding (range, 2.5 to 48 months) and distinct pain at the origin of the adductor longus muscle, refractory to conservative treatment. At follow-up 35 months (range, 4 to 84) after surgery, all patients were improved or free of symptoms. All but 1 of the athletes returned to the same sport within a mean of 6.6 weeks, and 12 of 16 returned to competitive sports within a mean of 14 weeks after surgery. A majority of the patients (10 of 16) returned to full athletic activity, whereas 5 of 16 performed at a reduced level. A decreased muscle strength was observed in this study and did not seem to influence participation in sports. (Level IV evidence)

Davis JA, Stringer MD, Woodley SJ: New insights into the proximal tendons of adductor longus, adductor brevis and gracilis. *Br J Sports Med* 46:871–876, 2012.

In this anatomical dissection study the entheses and proximal musculotendinous junctions (MTJs) of adductor longus (AL), adductor brevis (AB) and gracilis were dissected bilaterally in 10 embalmed cadavers (7 females, mean age at death 79 years [range 57 to 93 years]), focusing on the type of enthesis, and architecture of the proximal tendons and MTJs. Histology was used to determine if the entheses contained fibrocartilage and to semiquantitatively assess the vascularity of each proximal tendon. All entheses were fibrocartilaginous. The proximal tendons of AB and gracilis were fused, forming a common tendinous insertion in all specimens. AL and AB both contained extensive intramuscular tendons of variable length (AL 11.1 ± 1.5 cm; AB 5.4 ± 1.1 cm). The vascularity of AL and AB tendons decreased significantly towards the enthesis ($p < 0.05$), and their entheses were significantly less vascular than that of gracilis ($p < 0.05$). The arrangement and fusion of these muscles, their fibrocartilaginous entheses and differences in vascularity of their proximal tendons, may be important anatomical considerations in the pathogenesis and pattern of adductor-related groin pain. (Level IV evidence)

Mei-Dan O, Lopez V, Carmont MR, et al: Adductor tenotomy as a treatment for groin pain in professional soccer players. *Orthopedics* 36:e1189–e1197, 2013.

This is a retrospective cohort study that reported the outcome of adductor tenotomy and hernioplasty for professional soccer players with groin pain. Between 2000 and 2006, a total of 155 professional and recreational soccer players with

recalcitrant groin pain (with or without lower abdominal pain) and resistance to conservative treatment were treated surgically. Ninety-six patients were treated with adductor tenotomy and 59 patients were treated with combined adductor tenotomy and hernioplasty. No difference in pre- or postoperative parameters was detected between groups, apart from abdominal wall muscle defects revealed during ultrasound for patients in the combined group. The RTP time and subjective and objective outcome measures were compared. Mean RTP was 11 weeks (range, 4 to 36 weeks). Postoperative Tegner score remained 8.2 (same as the preinjury Tegner score). Subjective outcome was rated 4.3 of 5. Surgical intervention allowed RTP at the same level in professional soccer players following failure of nonoperative treatments. The authors' concluded that athletes with adductor syndrome and accompanying sportsman's hernia may benefit from adductor tenotomy alone.(Level XX evidence)

Robertson IJ, Curran C, McCaffrey N, et al: Adductor tenotomy in the management of groin pain in athletes. *Int J Sports Med* 32:45–48, 2011.

This study is a retrospective case series that evaluates the efficacy of adductor longus tenotomy for chronic tendinopathy refractory to conservative management of 109 male athletes all of whom responded to a detailed questionnaire. The criterion for tenotomy was chronic adductor origin pain which prevented training or playing (Level 4), limited training or playing (Level 3), or affected performance (Level 2) and which had failed to respond to conservative management including rest, rehabilitation and/or local steroid injection. Level 1 performance is classified as optimal performance with no pain. Ninety-nine of the 109 patients (91%) reported improvement. Best results were achieved in patients with maximum discomfort preoperatively (Level 4) with 32 of 38 (84%) patients returning to Level 1 performance. (Level IV evidence)

Schilders E, Dimitrakopoulou A, Cooke M, et al: Effectiveness of a selective partial adductor release for chronic adductor-related groin pain in professional athletes. *Am J Sports Med* 41:603–607, 2013.

This is a retrospective cohort study of the use of selective partial adductor longus release as treatment for recalcitrant chronic adductor longus enthesopathy in 43 professional athletes (39 soccer and 4 rugby) with chronic adductor-related groin. All athletes were assessed in a standard way for adductor dysfunction. They received radiographs and a specifically designed magnetic resonance imaging groin study protocol. Pain and functional improvement were assessed with the visual analog scale (VAS) pain score and time to return to sport. The average follow-up time was 40.2 months. Forty-two of 43 athletes returned to their preinjury level of sport after an average of 9.21 weeks. The preoperative VAS score improved significantly (Wilcoxon signed-rank test, $p < .001$) from 5.76 ± 1.08 (range, 3 to 8) to 0.23 ± 0.61 (range, 0 to 3) postoperatively In this study a selective partial adductor longus release provided excellent pain relief for chronic adductor enthesopathy in professional athletes with a high rate of return to the preinjury level of sport. (Level IV evidence)

Multiple-Choice Questions

QUESTION 1. The most important goal of early (two weeks) postoperative care is:

A. Able to be walking without crutches
B. Commencement of strengthening exercises
C. Uncomplicated wound healing
D. To be able to single leg balance on the operated side

QUESTION 2. In the early postoperative period the range of motion exercise likely to be well tolerated by the patient is

A. Able to walk without crutches
B. Use of the low resistance sliding board with the patient lying supine
C. Resisted band strengthening exercises
D. Single leg balance and motion exercise

QUESTION 3. Which of the following exercises is **not** recommended in the first 8 weeks of rehabilitation?

A. Abdominal sit-up combined with hip flexion exercises
B. One foot standing and sliding exercises on the sliding board
C. Sport-specific exercises after appropriate strength testing
D. None of the above

QUESTION 4. In determining return to sport criteria for an athlete:

A. Number of abdominal sit-up type exercises able to be completed is important.
B. Pain the following day after full training should delay return to playing.
C. Return of maximum sprint speed is not an important criteria.
D. Hand-held dynamometer strength has to be 60% of the noninjured side.

Answer Key

QUESTION 1. Correct answer: **C** (see Immediate postoperative period)

QUESTION 2. Correct answer: **B** (see Phase II)

QUESTION 3. Correct answer: **D** (see Phase III)

QUESTION 4. Correct answer: **B** (see Criteria for return to sport)

BEYOND BASIC REHABILITATION: RETURN TO FOOTBALL (SOCCER) AFTER TREATMENT OF ACUTE GROIN INJURY

Kristian Thorborg, PT, MSportsphty, PhD, and Bruce Charles Twaddle, BHB, MBChB, FRACS

Introduction

ASPECTS OF SOCCER THAT REQUIRE SPECIAL ATTENTION IN REHABILITATION

- Soccer is a sport that includes many short passages of high-intensity work.
- The high intensity is caused by repetitive sprints, and repeated sprint ability is especially of high importance in soccer.
- Maximum hip adductor activities, such as sprinting, acceleration, deceleration, including many stops, turns, and changes of direction, should be specifically addressed when returning an athlete for all types of football from a groin injury
- Maximum hip adductor activities, such as kicking, require specific attention for athletes participating in football forms where kicking is performed regularly and when the athletes needs to return to this kind of activity
- The acute groin strain usually involves one or more musculotendinous structures. The lesion can be in the musculotendinous junction itself, but in some cases it is in the tendon itself or the entheses where the tendon inserts into the bone that is the site of the injury.
- These injuries happen during forceful actions such as in kicking, sprinting, sudden change of direction, and other sporting movements where the muscle is being stretched during forceful contraction.
- If the initial injury is not treated appropriately in the first place or if a player is returned to the sport too quickly, these injuries might become longstanding or chronic. If the athlete does not get appropriate treatment and instead continues to participate in soccer, the injury can become very challenging to treat, and the injury pattern will start to resemble overuse-type adductor-related groin pain where more and more soccer-specific activities become problematic, and finally all soccer activities start to cause pain.
- This type of injury can take months to recover from, and what started out as minor acute strain can develop into a longstanding problem, where important and decisive sporting movements in soccer such as maximum kicking, acceleration, deceleration, twisting and turning becomes so problematic and painful that the player's performance is significantly impaired.

Literature

- In soccer about 10% of adductor-related injuries, which is by far the most common groin injury in this sport, last more than 4 weeks. It is not known how many of these injuries become longstanding or chronic. However, it has been reported that if players sustain a re-injury of their groin, the re-injury recovery period is almost twice as long compared with the index injury, emphasizing the importance of proper care initially.[1]
- In athletes with longstanding adductor-related groin pain, the average time before being fully returned to sport was 18.5 weeks, after treatment with an active exercise program.[2] Furthermore, it has been documented in sub-elite soccer that combined adductor and abdominal groin problems add to injury time, by quadrupling injury time compared with other types of groin injuries.[3]
- The groin injuries in soccer are mostly overuse injuries. In the UEFA study 27% were traumatic injuries[1] and the sub-elite study found 39% were traumatic injuries.[3] Very interestingly only in one of five situations, contact with another player was involved in the injury mechanism of the traumatic injuries, implying that the majority (80%) of the traumatic injuries are probably happening as the result of kicking, sprinting, or sudden changes of direction, movements where the groin-related muscles are involved at high speed, often with a forceful eccentric element.[4]
- Complete adductor ruptures are not common, but in the American National Football league (AFL) mean time for return to play in players treated conservatively for an acute adductor longus rupture has been reported to be 6 ± 3 weeks (range, 3 to 12 weeks).[4]
- A recent study of two different adductor ruptures in a soccer player suggests that adductor longus ruptures can have very different recovery times. In this study normal hip adductor strength was obtained after 52 weeks for the first injury, but after 10 weeks for the second injury (Figure 25-11). This highlights the importance of measuring hip adductor strength by using a hand-held dynamometer, as this gives important information on the actual recovery process of the adductors, which cannot be obtained from diagnostic imaging.[5]

The Advanced Rehabilitation Program

- The rehabilitation program after an acute groin injury is divided into four phases by including linear

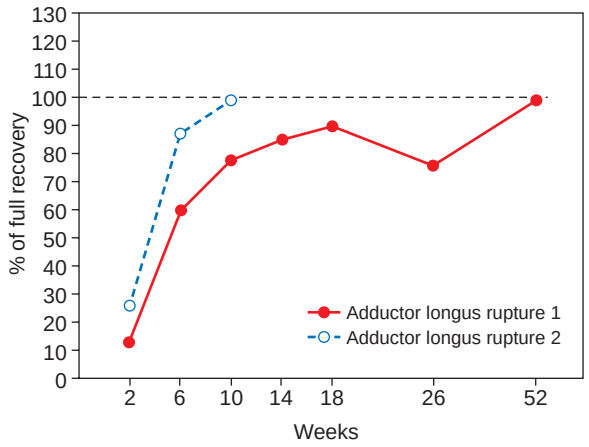


FIGURE 25-11. Variability of strength recovery after adductor groin injury. *(From Thorborg* et al. *Hip adduction strength recovery after adductor longus ruptures.* BMC Research Notes *6:205, 2013.)*

periodization principles within each period, each with a different rehabilitation focus. In general the rehabilitation program works from focus and isolation of the specific tissues involved in the injury towards integration of the specific structures into sports-specific function and return to sport based upon individual and continuous assessment of (1) injury (structural) status, (2) functional status, and (3) performance status, and finally (4) sports participation status, at specific time points during the rehabilitation period.

- In addition supplementary training specific for each phase is important for optimizing recovery and for maintenance of soccer-specific fitness is also included, and can be performed on a daily/weekly basis, depending on the specific intervention.

Phase I: Acute/Subacute Injury Focus (weeks 1 to 2)

- Includes the acute and subacute phase and is characterized by musculotendinous pain and/or inflammation at the musculotendinous junction (MTJ), in the tendon or at the pubic insertion point, usually of the adductor longus and/or the rectus abdominis muscle.
- This phase focuses on the initiation of tissue repair and/or regeneration, but also includes effects of possible disuse, detraining, loss of muscle performance because of potential immobilization as a result of the actual musculotendinous injury.

Goals

- Protection of the adductor and/or abdominal musculotendinous complex
- Control of pain and inflammation
- Normalization of flexibility within restrictions
- Preventing excessive muscular inhibition by isometric contractions (see Figure 25-5) with no or minimal pain provocation

Supplementary Training

- Aerobic fitness maintained on exercise bike. General strength maintained by upper extremity strength training seated rows and chest press exercises, as long as pain is not provoked from adductors and abdominals as a result of maximum co-contractions.
- Isolated quadriceps and calf strengthening and adductor and abductor strengthening of the uninvolved side (sidelying adductions and abductions) for general strength and stimulating cross-over effects to decrease possible inhibition of injured side by central nervous system activation strategies.

Criteria for Progression to the Next Phase

- No or minimal pain with all Phase I exercises
- Clear muscle activation during isometric contractions of adductor and abdominal muscles
- Active hip abduction ROM should be at least 50% of non-injured side

Phase II: Tissue Conditioning Focus (weeks 3 to 4)

- Focuses on tissue repair and/or regeneration. In this phase gradual and progressive loading of adductors and abdominal muscles is commenced while still respecting the structural injury and underlying healing

TIMELINE 25-3: **Return to Football (Soccer) after Treatment of Acute Groin Injury**

PHASE I (weeks 1 to 2)	PHASE II (weeks 3 to 4)
• Protection of injured structures (crutches, compression) • PT modalities for pain relief • Gentle supine active flexibility exercises • Core/adductor/abdominal activation exercises initiated • Walking, aerobic fitness and strength training as tolerated	• PT modalities • Continue gentle supine active flexibility exercises • Progressive core/abdominal strengthening program initiated • Progressive adductor strengthening initiated • Walking, aerobic fitness and strength training as tolerated • Running and sports specific activities as tolerated • Plyometric exercises if tolerated



FIGURE 25-12. Abdominal strengthening as part of Phase II.

processes depending on the location of the injury (MTJ, tendon, aponeurosis or insertion) at this early stage.
- Gentle dynamic muscle exercises are commenced starting with a low load from 30 to 20 repetitions maximum. Strength training machines, sidelying using the weight of the leg and standing exercises with elastic bands can be used for targeting the adductor longus muscle (see Figure 25-7), and at least two different exercise types should be used with 3 × 20 repetitions of each. The musculotendinous conditioning should focus on concentric, isometric and eccentric contractions during these exercises.
- Abdominal crunches in supine (Figure 25-12), frontal rolling exercises with a Swiss ball (see Figure 25-8), or training in a machine should also be performed using the same principles as applied for the adductors. All these exercises should be performed 3 times a week with at least 1 day of rest from these exercise types in between. Pain during exercises must not be neglected, but some discomfort and pulling may be felt during early initiation of these exercises. A general rule of thumb is that pain and discomfort should be less than 3 on a numerical rating scale, during exercise, and that initial pain levels before exercise are reached shortly after exercises are finished. Increasing morning pain and stiffness, compared to the initial state, is also a good indicator of when exercises have been progressed too quickly.

Supplementary Training

- Aerobic fitness maintained on exercise bike, changing functional muscle work demands by alternating between standing and sitting bike drills.
- Finally also anaerobic drills can be incorporated by increasing resistance. Walking and jogging can be commenced when pain-free.
- General strength maintained by upper extremity strength training seated row and chest press, as long as pain is not generated from adductors and abdominals during maximum contractions.
- Isolated quadriceps and calf and gluteus medius strengthening for both sides, and sidelying adductor exercises for the uninvolved side.

Criteria for Progression to the Next Phase

- No or minimal pain with all Phase II exercises, and normal execution (no compensation strategies to avoid loading injured structures) of dynamic exercises of adductor and abdominal muscles.
- Active ROM at least 80% of non-injured side and adductor strength at least 60% of non-injured side, able to do 20 repetitions maximum by using the same resistance based upon 20 repetitions maximum from the uninjured side, and/or able to do 20 sidelying adductor lifts and 20 abdominal crunches lying supine on the floor with proper form, and with no or minimal pain.

Phase III: Sports-Specific Focus (weeks 5 to 8)

- The primary goals during this phase are restoration of musculotendinous endurance and strength, aerobic and anaerobic capacity, and neuromuscular control/balance/coordination.
- Dynamic muscle strengthening exercises in standing using elastic bands as resistance are continued starting with a load of 20 repetitions maximum progressing towards 10 repetitions maximum.
- The same principle is applied for abdominal exercises where a Swiss ball is used (Figure 25-13). The musculotendinous conditioning should focus on slow heavy concentric, isometric and eccentric contractions during these exercises.
- Exercises on a sliding board are commenced by introducing 5 to 10 times 1 minute of skating from side to side. All these exercises should be performed 3 times a

TIMELINE 25-3: **Return to Football (Soccer) after Treatment of Acute Groin Injury** (Continued)

PHASE III (weeks 5 to 8)	PHASE IV (weeks 9 to 12)	PHASE V (weeks 13 to 52)
• PT modalities as needed • Active and passive stretching exercise • Progressive core/abdominal strengthening exercises continued • Progressive adductor strengthening continued • Aerobic fitness and strength training as tolerated • Running and sport-specific activities as tolerated • Plyometric exercises if tolerated	• PT modalities as needed • Active and passive stretching exercise • Progressive core/abdominal strengthening exercises continued • Progressive adductor strengthening continued • Aerobic fitness and strength training as tolerated • Increase sport-specific training as tolerated • Increase plyometric exercises and change of direction if tolerated	• PT modalities as needed • Maintenance of active and passive stretching exercise • Maintenance program of adductor/abdominal/core strengthening • Maintenance program of plyometric and change of direction exercises



FIGURE 25-13. Frontal rolling exercise to improve core strength.

week with at least 1 day of rest from these exercise types in between pain during exercises and must not be neglected, but some discomfort and pulling may be felt during early initiation of these exercises. A general rule of thumb is that pain and discomfort should be less than 3 on a numerical rating scale, during exercise, and that initial pain levels before exercise are reached shortly after exercises are finished. Increasing morning pain and stiffness, compared to the initial state, is also a good indicator of when exercises have been progressed too quickly.

Supplementary Training

- Aerobic fitness maintained/increased by running drills, and anaerobic fitness increased by running drills.
- General strength maintained by strength training of both upper and lower extremity. Strength training including high intensity strength training, and also low to high intensity power exercise progression (Figure 25-14).



FIGURE 25-14. Progression to high-intensity strength training.



FIGURE 25-15. Phase III: Twisting turning exercises on the trampoline.

- Plyometric drills and agility drills using stairs. Repeated sprint ability including maximal and forceful actions such accelerating, decelerating, twisting turning starting in trampoline (Figure 25-15).
- Soccer specific ball drills including juggling, dribbling, progressed into passing and receiving passes, progressed into kicking drills from short to long pass with maximum crosses and shoots on goals (Figure 25-16) as the final and most demanding and stressing exercise for the adductor-abdominal musculotendinous complex. Again, all exercises should be performed with no or minimal pain/discomfort during execution and the morning after.



FIGURE 25-16. Shots on goal: Final level of adductor activation before full return to sport participation.

Criteria for Progression to the Next Phase

- No or minimal pain with all Phase III exercises, and normal execution (no compensation strategies to avoid loading injured structures) of dynamic exercises of adductor and abdominal muscles.
- Active ROM of nearly 100% of the non-injured side and adductor strength of at least 80% of the non-injured side, able to do 3 × 10 repetitions maximum, by using the same resistance based upon 10 repetitions maximum from the uninjured side, or able to do 3 × 10 sidelying adductor lifts with external load of at least 6 kg, and able to do 3 × 10 abdominal crunches lying over Swiss ball with proper form, and with no or minimal pain. Demonstration of initial agility drills with proper form, with no clear and visible compensation strategies during maximal and forceful actions such as accelerating, decelerating, twisting turning and kicking, again with no or minimal pain/discomfort during execution and the morning after.

Phase IV: Return-to-Sport Focus (weeks 9 to 12)

- Characterized by activities that focus on returning the athlete to full sporting function and soccer participation. The primary goals to be addressed during this phase are successful return to previous functional and sporting level, and prevention of reinjury. The primary goals to be addressed during this phase are maintenance of musculotendinous endurance and strength, aerobic and anaerobic capacity, and improving neuromuscular control/balance/coordination.
- Dynamic muscle exercises using the elastic bands are continued with a load of 8 to 10 repetitions maximum, with focus of different and increasing speeds of eccentric contractions.
- Exercises on a sliding board are continued by introducing 10 to 20 times 1 minute of skating from side to side. All these exercises should be performed 2 to 3 times a week with at least 1 day of rest from these exercise types in between.

Supplementary Training

- Anaerobic fitness increased by running drills.
- General strength maintained by strength training of both upper and lower extremity. Strength training including high intensity strength training, and also low to high intensity power exercise progression for abdominals..
- Agility drills and repeated sprint ability including maximal and forceful actions such accelerating, decelerating, twisting turning (Figure 25-17).

Criteria for Return to Play at the Preinjury Competitive Level

- Participation in soccer training with the rest of the team (Figure 25-18), progressing from 45 minutes to 90 minutes of soccer training, and participating in 1 to 3 weeks of full soccer training before full return to sport (match activity) can be commenced, depending on the severity of the initial injury (the more severe the longer participation period before full return).
- Playing 45 minutes or less of second half is recommended to start with until soccer fitness is improved and full game can be performed at preinjury level.
- Again, all training and matches should be performed with no or minimal pain/discomfort during execution and the morning after.



FIGURE 25-17. Phase IV: Forceful change of direction drills.

Sports Performance Testing

General Information

- Medical history
- Sports injury history
- Surgical history
- Chronic conditions/medication



FIGURE 25-18. Full team training participation.

Objective Tests to Determine Readiness For Soccer

Phase I: Structure-specific location of injury
- Palpation
- Ultrasound/MRI

Phase I: Range of motion
- Hip abduction range of motion (supine with goniometer)
- Hip extension range of motion (Thomas test with goniometer)

Phase II: Hip strength
- Isometric hip strength, hip adduction/abduction ratio (HHD)
- Isometric hip strength, hip adduction strength recovery, compared to uninjured side (HHD)
- Eccentric hip adduction strength recovery, compared to asymptomatic side (HHD)

Phases III and IV:
- Self-reported objective measures of pain and function
  - Copenhagen Hip And Groin Outcome score (HAGOS), six subscales
  - Copenhagen groin pain test (groin pain evaluated on a numerical analogue scale 0 to 10, during maximum static hip adduction in the supine position with straight legs)
- Soccer fitness
  - Yo-yo test
  - Repeated sprint ability test

Evidence

Hölmich P, Thorborg K, Dehlendorff C, et al: Incidence and clinical presentation of groin injuries in sub-elite male soccer. *Br J Sports Med* 2013. doi: 10.1136/bjsports-2013-092627. [Epub ahead of print].

Prospective cohort study of 44 soccer clubs at the sub-elite level had recorded baseline characteristics and groin injuries sustained by a cohort of 998 sub-elite male soccer players during a full 10-month season. Adductor-related groin injury was the most common entity found followed by iliopsoas-related and abdominal-related injuries. Age and previous groin injury were significant risk factors for sustaining a groin injury. Having both adductor and abdominal pain also increased the injury time significantly when compared to injuries with no adductor and no abdominal pain (RIT = 4.56, 95% CI 1.91 to 10.91, p = 0.001). (Level II evidence)

Hölmich P, Uhrskou P, Ulnits L, et al: Effectiveness of active physical training as treatment for long-standing adductor-related groin pain in athletes: randomised trial. *Lancet* 353:439–443, 1999.

Sixty-eight athletes with long-standing (median 40 weeks) adductor-related groin pain—after examination according to a standardized protocol—were randomly assigned to active treatment (AT) or passive treatment (PT). The treatment period was 8 to12 weeks. Four months after the end of treatment a standardized examination was done and 23 patients in the AT group and four in the PT group returned to sports without groin pain (odds ratio, multiple-logistic-regression analysis, 12.7 [95% CI 3.4 to 47.2]). AT with a program aimed at improving strength and coordination of the muscles acting on the pelvis, in particular the adductor muscles, is very effective in the treatment of athletes with long-standing adductor-related groin pain. (Level I evidence)

Schlegel TF, Bushnell BD, Godfrey J, et al: Success of nonoperative management of adductor longus tendon ruptures in National Football League athletes. *Am J Sports Med* 37:1394–1399, 2009.

Using the National Football League Injury Surveillance System, adductor tendon ruptures documented by magnetic resonance imaging were identified in 19 National Football League players from 1992 to 2004. Fourteen players were treated nonoperatively, and five players were treated with surgical repair using suture anchors. In both groups, all players eventually returned to play in the National Football League. Mean time for return to play was 6.1 ± 3.1 weeks (range, 3 to 12 weeks) for the nonoperative group and 12.0 ± 2.5 weeks (range, 10 to 16 weeks) for the operative group (p = .001). Nonoperative treatment of proximal adductor tendon rupture results in a faster return to play than does operative treatment in athletes competing in the National Football League. (Level IV evidence)

Thorborg K, Petersen J, Nielsen MB, et al: Clinical recovery of two hip adductor longus ruptures: a case-report of a soccer player. *BMC Res Notes* 6:205, 2013.

A 22-year old male soccer player (white) sustained two subsequent acute adductor longus ruptures, one in each leg. He was evaluated using hip-strength assessments, self-report and ultrasonography until complete muscle-strength recovery of the hip adductors had occurred. The player was able to participate in a full soccer training session without experiencing pain 15 weeks after the first rupture, and 12 weeks after the second rupture. Full hip adductor muscle-strength recovery was obtained 52 weeks after the first rupture and 10 weeks after the second rupture. From this case we can conclude that two apparently similar hip adductor longus ruptures, verified by initial ultrasonography (10 days postinjury), can have very different hip adductor strength recovery times. (Level IV evidence)

Werner J, Hägglund M, Waldén M, et al: UEFA injury study: a prospective study of hip and groin injuries in professional football over seven consecutive seasons. *Br J Sports Med* 43(13): 1036–1040, 2009.

Prospective cohort study of European professional football. During the 2001/2 to 2007/8 seasons, between nine and 17 clubs per season (23 clubs in total) were investigated, accounting for 88 club seasons in total. Time loss injuries and individual exposure during club and national team training sessions and matches were recorded. A total of 628 hip/groin injuries were recorded, accounting for 12% to 16% of all injuries per season. The total injury incidence was 1.1/1000 h (3.5/1000 match hours vs 0.6/1000 training hours, p < 0.001) and was consistent over the seasons studied. (Level II evidence)

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Med 2013. doi: 10.1136/bjsports-2013-092627. [Epub ahead of print].
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5. Thorborg K, Petersen J, Nielsen MB, et al: Clinical recovery of two hip adductor longus ruptures: a case-report of a soccer player. *BMC Res Notes* 6:205, 2013.

Multiple-Choice Questions

QUESTION 1. An acute musculotendinous injury is often caused by?

A. A lengthening contraction
B. A shortening contraction
C. An isometric contraction
D. By being overstretched

QUESTION 2. A reinjury of the groin in soccer players takes how long to recover compared to the initial injury

a. Shorter time than initial injury
b. Same amount of time as initial injury
c. Twice as long as the initial injury
d. Three times as long as initial injury

QUESTION 3. Quantifying hip adductor muscle strength recovery is best performed by?

A. Ultrasound
B. MRI
C. Manual assessment
D. Hand-held dynamometry

QUESTION 4. Phase II of the rehabilitation program for acute adductor injuries should focus on

A. Neuromuscular control
B. Tissue conditioning
C. Muscle power
D. Settling inflammation

QUESTION 5. One of the most stressful sporting movements for the hip adductors is?

A. Running
B. Jumping
C. Kicking
D. Short passing

Answer Key

QUESTION 1. Correct answer: **A** (see Introduction)

QUESTION 2. Correct answer: **C** (see Literature)

QUESTION 3. Correct answer: **D** (see Literature)

QUESTION 4. Correct answer: **B** (see Phase II)

QUESTION 5. Correct answer: **C** (see Introduction)

Chapter 26



Femoroacetabular Impingement and Labral Injuries

INTRODUCTION

John C. Clohisy, MD

Epidemiology

Age

- Average age 35 yrs (range, 16 to 91)

Sex

- 57% male
- 43% female

Sport

- Any sport with repetitive hip flexion, bending and squatting (soccer, hockey, football, baseball, basketball, etc.)
- One recent study indicated:
  - 59% participated in regular sporting activities.
  - 59% classified participation intensity as high.
  - 28% reported intensity as moderate.
  - Average UCLA was 7.1 ± 2.8, consistent with patients participating in activities like fast walking, golfing, and bowling.
  - 29% participated in impact activities like jogging, tennis and ballet on regular basis.

Position

- Athletic activities/positions with repetitive hip flexion are at highest risk.

Pathophysiology

Intrinsic Factors

- Hip pathomorphology—Acetabular overcoverage (Figure 26-1)
- Hip pathomorphology—Femoral head-neck offset deformities (Figure 26-2)
- Soft tissue laxity with excessive hip motion



FIGURE 26-1. Acetabular overcoverage—deep socket, preoperative view.



FIGURE 26-2. Femoral head-neck offset deformity, preoperative frogleg view.

Extrinsic Factors

- Repetitive hip flexion activities including occupational and athletic activities
- Athletics: hockey, soccer, basketball, football, and others that involve repetitive hip flexion activities

Traumatic Factors

- Forced hip flexion can result in acute labrochondral injury
- Forced hip flexion with combined adduction and internal rotation can result in subluxation or hip dislocation.
- Patients with femoroacetabular impingement (FAI) anatomy may be more susceptible to subluxation/dislocation episodes due to levering from anterior impingement.

Classic Pathological Findings

- Structural abnormalities of the acetabulum and proximal femur consistent with femoroacetabular impingement (FAI; see Figure 26-2)
- Acetabular labral abnormalities including detachment, degeneration, and ossification
- Chondral abnormalities specifically of the acetabular rim including delamination, articular cartilage flap formation and full thickness defect (Figure 26-3).
- The most common intraarticular abnormality includes injury to the acetabular labrochondral complex.

Clinical Presentation

History

- Groin pain
- Activity-related symptoms
- Activity limitation owing to hip symptoms
- Locking, catching of the hip
- Groin pain with prolonged sitting or hip flexion activities
- History of recurrent groin pulls, compensatory symptoms (low back pain, SI joint pain, trochanteric bursitis, adductor strain)

Physical Examination

Abnormal Findings

- Limited hip flexion
- Limited internal rotation in flexion
- Positive impingement test (sensitive but not specific for FAI).
- Positive flexion, abduction, external rotation (FABER) test

Pertinent Normal Findings

- Normal external rotation/motion
- Normal gait
- Athletes may have normal muscle strength and function

Imaging

- Plain radiographs including the anteroposterior (AP) pelvis, frog lateral, and 45° Dunn view
- Parameters consistent with acetabular overcoverage
- Femoral head-neck offset abnormalities are present.
- Magnetic resonance imaging (MRI) and magnetic resonance arthrography can demonstrate labrochondral disease, structural anatomy, and secondary articular cartilage changes.
- CT scan with three-dimensional images provides detailed information regarding deformity characteristics.

Differential Diagnosis

- Hip dysplasia
- Secondary hip osteoarthritis
- Lumbar spine dysfunction
- Sacral Iliac joint dysfunction
- Athletic hernia
- Muscle imbalance syndromes
- Stress fractures
- Adductor strain

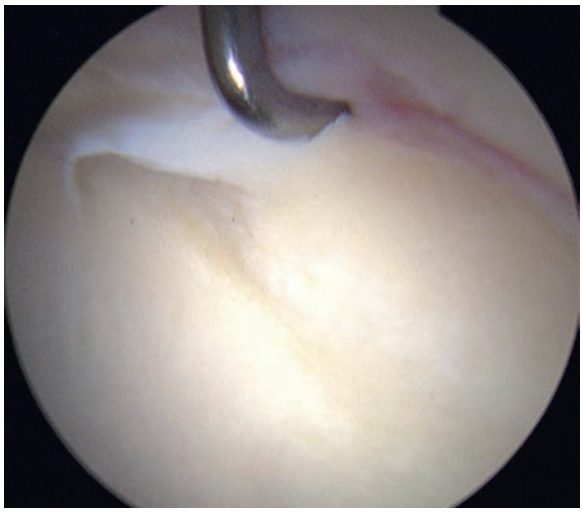

FIGURE 26-3. Chondral abnormality, labral disruption.

- Symphysis pubalgia
- Comprehensive history, physical exam, and imaging evaluation of the patient distinguish the above conditions from a symptomatic femoroacetabular impingement. Compensatory disorders are common and many of the above diagnoses can occur simultaneously with femoroacetabular impingement.

Treatment

Nonoperative Management

- Activity modification and patient education
- Nonsteroidal antiinflammatory medicines
- Physical therapy with muscle strengthening and balancing
- Intraarticular corticosteroid injection

Guidelines for Choosing Among Nonoperative Treatments

- A panel of nonsurgical treatment options to block the pain cycle and optimize function about the hip is preferred.
- Corticosteroid injections are mostly used in patients greater than 40 years of age with early osteoarthritis.

Surgical Indications

- Patients less than 50 years of age
- Symptomatic hip impingement disease
- Failure of nonsurgical treatment methods
- Defined hip impingement deformity
- Imaging studies demonstrate lack of moderate to advanced osteoarthritis of the hip.
- Body mass index (BMI) less than 35
- Positive response to intraarticular injection (with pain relief)

Aspects of History, Demographics, or Exam Findings that Affect Choice of Treatment

- Age
- Physical health
- Deformity characteristics
- Articular cartilage integrity

Aspects of Clinical Decision Making When Surgery Is Indicated

- Open versus closed surgical correction
- Treatment of the acetabular labrum (partial resection or repair)
- Correction of the impingement deformity (acetabuloplasty, femoral plasty or both) (Figures 26-4, 26-5)
- Treatment of acetabular articular cartilage disease including chondromalacia, delamination, articular cartilage flap and full thickness defects.

Evidence

Beaule P: Prevalence of associated deformities and hip pain in patients with cam-type femoracetabular impingement. *J Bone Joint Surg* 91-B:589–594, 2009.



FIGURE 26-4. Deep socket, postoperative view.

One hundred and thirteen patients, 82 male and 31 females aged 55 or less, with symptomatic cam-type impingement of at least one hip were evaluated for this study. Bilateral cam deformity was seen in 77.8% of the population, whereas only 26% had pain in both hips. Hips with alpha angles greater than 60° had an odds ratio 2.59 for being painful. Pincer deformity was seen in 42% of the cases. (Level IV evidence)

Byrd J: Arthroscopic femoroplasty in the management of cam-type femoroacetabular impingement. *Clin Orthop Relat Res* 467:739–746, 2008.

Prospective assessment of 200 patients (207 hips) undergoing arthroscopic treatment for cam-type impingement. Patient cohort consisted of 138 men and 62 women with mean age 33 years. One hundred and sixty-three hips underwent femoroplasty, whereas 44 hips received a concomitant procedure to correct for pincer impingement. The Harris hip score improved an average of 20 points at a minimum of 1 year, whereas 0.5% went on to total hip arthroplasty. (Level IV evidence)

Clohisy JC, Knaus ER, Hunt DM, et al: Clinical presentation of patients with symptomatic anterior hip impingement. *Clin Orthop Relat Res* 2467:638–644, 2009.

This prospective study of 51 patients with a diagnosis of FAI evaluated clinical history, physical exam, previous treatments performed, and patient outcome scores. Patients indicated a



FIGURE 26-5. Head-neck offset postoperative frogleg view.

relatively high level of activity, yet had restrictions of function and overall health. (Level II evidence)

Ellis T: Efficacy of surgery for femoroacetabular impingement. *Am J Sports Med* 38:2337–2345, 2010.

Systematic review of 970 cases included 1 level II, 2 level III, and 20 level IV studies. Patients improved in all studies based on outcome scores. Patients with intraoperative Outerbride classification of III or IV or preoperative radiographic Tonnis grade greater than 1 showed less improvement. Longer follow-up will be needed to determine if onset or progression of osteoarthritis is delayed. (Level III evidence)

Philippon MJ, Briggs KK, Yen Y-M, et al: Outcomes following hip arthroscopy for femoroacetabular impingement with associated chondrolabral dysfunction: minimum two-year follow-up. *J Bone Joint Surg (Br)* 91(1):16–23, 2009.

One hundred and twelve patients underwent arthroscopy for femoroacetabular impingement with a mean age of 40.6 years. Twenty-three patients were treated with osteoplasty for cam impingement only, 3 had acetabular rim trimming for pincer type impingement, and 86 underwent both procedures for mixed type impingement. At a mean follow-up of 2.3 years, the mean modified Harris hip score improved from 58 to 84, and median satisfaction score of 9. Ten patients underwent total hip arthroplasty at mean of 16 months. Predictors of better outcome were preoperative Harris hip score, joint space narrowing, and labral repair versus labral debridement. (Level II evidence)

Siebenrock KA, Ferner F, Noble PC, et al: The cam-type deformity of the proximal femur arises in childhood in response to vigorous sporting activity. *Clin Orthop Relat Res* 469:3229–3240, 2011.

This retrospective review compared 72 hips in 37 male basketball players and 76 asymptomatic hips of 38 nonathletic volunteers. Findings suggest high- intensity sports activities performed in adolescence are likely to increase the risk of cam-type impingements. (Level II evidence)

Multiple-Choice Questions

QUESTION 1. What is the most common pain location of symptomatic hip impingement?

A. Groin
B. Lateral
C. Buttock
D. Thigh

QUESTION 2. What is the most common location of intraarticular damage in patients with femoroacetabular impingement?

A. Acetabular labrum
B. Acetabular labrochondral complex
C. Acetabular articular cartilage
D. Femoral head articular cartilage

QUESTION 3. Nonsurgical management of hip impingement should focus on the following combination of modalities:

A. Hip range of motion and activity modification
B. Hip strengthening and hip range of motion
C. Hip strengthening, muscle balancing, and activity modification
D. Nonsteroidal antiinflammatory medicines, hip strengthening and balancing, and range of motion.

QUESTION 4. What is the most common physical examination finding in patients with symptomatic hip impingement?

A. Reduced hip flexion and external rotation
B. Reduced hip abduction and external rotation
C. Reduced hip flexion and internal rotation
D. Limited extension and external rotation

QUESTION 5. Which of the following disease characteristics is a relative contraindication for hip preservation FAI surgery?

A. Severe deformity
B. History of injury to the joint
C. Symptoms of catching and locking
D. Moderate (50%) joint space narrowing

Answer Key (identify where in text the answer can be found)

QUESTION 1. Correct answer: **A** (see Pathophysiology: Clinical presentation)

QUESTION 2. Correct answer: **B** (see Pathological Findings)

QUESTION 3. Correct answer: **C** (see Nonoperative Management)

QUESTION 4. Correct answer: **C** (see Physical Exam Findings)

QUESTION 5. Correct answer: **D** (see Surgical Indications)

NONOPERATIVE REHABILITATION OF HIP STIFFNESS AND HIP IMPINGEMENT (CAM/PINCER LESIONS)

Erik P. Meira, PT, SCS, CSCS, and Mark B. Wagner, MD

GUIDING PRINCIPLES OF NONOPERATIVE REHABILITATION

- Avoid exacerbating the anterior hip pain associated with femoroacetabular impingement (FAI).
- Range of motion may be limited by bony deformity—DO NOT FORCE MOTION.
- Focus on increasing strength and coordination within pain-free range of motion.
- Specific attention should be made to controlling dynamic knee valgus.
- Activation of hip abductors should be reinforced during each phase of rehab.
- Modify lifestyle to accommodate FAI as able.

Phase I (weeks 0 to 2)

Protection

- Weight bearing as tolerated.
- Limit motion to pain-free range.
- Minimize activation of the iliopsoas.

Management of Pain and Swelling

- Nonsteroidal antiinflammatory drugs (NSAIDs)
- Cryotherapy with compression to the joint

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Long axis traction and gentle lateral glides in supine for pain control

Soft Tissue Techniques

- Gentle massage to anterior hip with the focus on relaxation of regional musculature, specifically pectineus and iliopsoas

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Gentle stretching to the iliopsoas (Figure 26-6) and lumbar extensors

Other Therapeutic Exercises

- Upright exercise bike with elevated seat to minimize hip flexion
- Total leg strength (TLS) may be initiated as tolerated.

Activation of Primary Muscles Involved

- Hip abductors
  - Gluteus medius
  - Gluteus minimus
- Hip external rotators
  - Gluteus maximus
  - Piriformis
  - Gemellus superior
  - Gemellus inferior
  - Obturator internus
  - Obturator externus
  - Quadratus femoris
- Hip extensors
  - Gluteus maximus
- Hip adductors
  - Adductor magnus
  - Adductor longus
  - Adductor brevis
  - Pectineus
  - Gracilis

Sensorimotor Exercises

- Single leg stance as tolerated

Open and Closed Kinetic Chain Exercises

- Clamshells in pain-free range (OKC)
- Bridging (CKC)



FIGURE 26-6. Iliopsoas stretch. Maintain posterior pelvic tilt during the stretch.



FIGURE 26-7. Rhythmic stabilization in side-lying. Be cautious applying resistance to flexion during Phase I.

Techniques to Increase Muscle Strength, Power, and Endurance

- Prone heel squeeze
- Isometric adductor squeeze

Neuromuscular Dynamic Stability Exercises

- Manual resistance hip stability (rhythmic stabilization) in side lying (Figure 26-7)

Milestones for Progression to the Next Phase

- No pain at rest
- Pain free with all rehab activities
- Able to perform one straight leg raise without pain

Phase II (weeks 2 to 4)

Protection

- Limit motion to pain-free range.

Management of Pain and Swelling

- Continue with nonsteroidal antiinflammatory drugs (NSAIDs), and cryotherapy with compression to the joint as needed.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Continue long axis traction and gentle lateral glides in supine for pain control.

Soft Tissue Techniques

- Continue gentle massage to anterior hip with the focus on relaxation of regional musculature as needed.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Progress iliopsoas and low back extensor stretching as tolerated.
- Gentle stretching into combined flexion abduction external rotation as tolerated

Other Therapeutic Exercises

- May progress to elliptical trainer as tolerated.
- Continue to progress TLS.
- May begin core stability training being cautious of excessive load to the iliopsoas.

Activation of Primary Muscles Involved

- Hip abductors
  - Gluteus medius
  - Gluteus minimus
- Hip external rotators
  - Gluteus maximus
  - Piriformis
  - Gemellus superior
  - Gemellus inferior
  - Obturator internus
  - Obturator externus
  - Quadratus femoris
- Hip extensors
  - Gluteus maximus
  - Biceps femoris
  - Semitendinosus
  - Semimembranosus
- Hip adductors
  - Adductor magnus
  - Adductor longus
  - Adductor brevis
  - Pectineus
  - Gracilis

Sensorimotor Exercises

- Single leg stance on uneven surface

Open and Closed Kinetic Chain Exercises

- Clamshells in pain-free range against resistance (OKC)
- Standing hip abduction, adduction, and extension against resistance (OKC)
- Bridging with marching (CKC)
- Double and single leg press in pain-free range (CKC)

Techniques to Increase Muscle Strength, Power, and Endurance

- Begin Romanian Deadlift (RDL) with focus on lumbopelvic coordination.

Neuromuscular Dynamic Stability Exercises

- Single leg lunge on wall with physioball (Figure 26-8) with focus on controlling knee valgus and hip adduction



FIGURE 26-8. Wall lunge with physioball. Avoid knee valgus and Trendelenburg position.

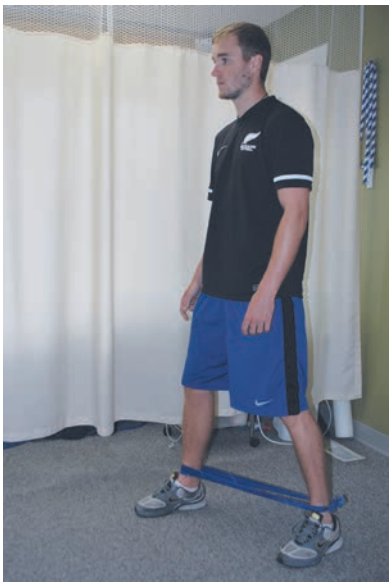

FIGURE 26-9. "Monster walking."

Plyometrics

- Submaximal jumps on shuttle
- Double leg bouncing while maintaining contact on mini-trampoline

Functional Exercises

- Hip band ambulation
  - Forward/backward
  - Side-to-side
  - "Monster walking" (Figure 26-9)

Milestones for Progression to the Next Phase

- No pain with activity of daily living (ADL)
- Pain free with all rehab activities
- Able to hold straight leg raise at 45° hip flexion in supine against minimal manual resistance without pain.
- Able to maintain hip height within 2 cm of uninvolved side during single leg stance phase test.

Phase III (weeks 4 to 8)

Protection

- Continue to limit motion to pain-free range.

Management of Pain and Swelling

- Continue with nonsteroidal antiinflammatory drugs (NSAIDs) and cryotherapy with compression to the joint as needed.

TIMELINE 26-1: **Nonoperative Rehabilitation of Femoroacetabular Impingement**

PHASE I (weeks 0 to 2)	PHASE II (weeks 2 to 4)
• WBAT • PT Modalities • Mobilizations as needed for pain control • Gentle iliopsoas and lumbar extensor stretching • Exercise bike with elevated seat • Total body strengthening/total leg strength (TBS/TLS) activities as recommended & tolerated • Single leg stance as tolerated • OKC Rhythmic stabilization exercises • Prone heel squeezes • Isometric adductor squeeze • Clamshells (OKC) • Bridging (CKC)	• FWB • PT Modalities as needed • ROM-limited to pain-free motion • Mobilizations as needed • Elliptical trainer • TBS/TLS activities as recommended & tolerated • Hip band ambulation • Core stability • Continue OKC/CKC exercises • Standing hip abduction/adduction/extension (OKC) • Bridging with marching (CKC) • Leg press in pain-free range (CKC) • Single leg lunge on wall with physioball (CKC) • Romanian Deadlift (RDL) with focus on lumbopelvic coordination (CKC) • Submaximal jumps on shuttle (Plyo) • Double leg bounces on mini-trampoline (Plyo)

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Long traction with progressive range of motion in all directions as tolerated

Soft Tissue Techniques

- Continue gentle massage to anterior hip with the focus on relaxation of regional musculature as needed.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Progress iliopsoas and low back extensor stretching as tolerated. Continue gentle stretching into combined flexion abduction external rotation as tolerated.

Other Therapeutic Exercises

- Continue elliptical trainer as tolerated.
- Continue to progress TLS.
- Progress core stability training, being cautious as tolerated.

Activation of Primary Muscles Involved

- Hip abductors
  - Gluteus medius
  - Gluteus minimus
- Hip external rotators
  - Gluteus maximus
  - Piriformis
  - Gemellus superior
  - Gemellus inferior
  - Obturator internus
  - Obturator externus
  - Quadratus femoris
- Hip extensors
  - Gluteus maximus
  - Biceps femoris
  - Semitendinosus
  - Semimembranosus
- Hip adductors
  - Adductor magnus
  - Adductor longus
  - Adductor brevis
  - Pectineus
  - Gracilis

Sensorimotor Exercises

- Single leg stance on uneven surface
- Lunges in multiple planes with focus on maintaining proper knee position

Open and Closed Kinetic Chain Exercises

- Continue clamshells in pain-free range against resistance (OKC).
- Continue standing hip abduction, adduction, and extension against resistance (OKC).
- Continue bridging with marching (CKC).
- Side plank (CKC)
- Progress double and single leg press in pain-free range (CKC).

Techniques to Increase Muscle Strength, Power, and Endurance

- Progress Romanian Deadlift (RDL) with focus on lumbopelvic coordination.
- Squatting, first in Smith machine progressing to back squats in pain-free range (CKC)
- Begin deadlifts from floor with focus on proper form (CKC).
- Begin single leg squats in Smith machine with focus on maintaining proper knee position (CKC).

Neuromuscular Dynamic Stability Exercises

- Continue single leg lunge on wall with physioball (Figure 26-8) with focus on controlling knee valgus and hip adduction.

TIMELINE 26-1 **Nonoperative Rehabilitation of Femoroacetabular Impingement** (Continued)

PHASE III (weeks 4 to 8)	PHASE IV (weeks 8+)
• PT Modalities as needed • ROM-limited to pain-free motion • Mobilizations as needed • Elliptical trainer • TBS/TLS activities as recommended & tolerated • Hip band ambulation • Core stability • Side planks • Single leg stance on unstable surface with perturbations • Continue OKC/CKC/Plyo exercises • Lunges in multiple planes with focus on knee control (CKC) • Squats/deadlifts in pain-free range (CKC) • Single leg squats in Smith machine with focus on knee position (CKC) • Resisted sit to stand with kettle bell or dumbbell (CKC) • Double leg jumps on stable surface (Plyo) • Single leg bounces on mini-trampoline (Plyo)	• ROM-limited to pain-free motion • Mobilizations as needed • Progression to running as tolerated • TBS/TLS activities as recommended & tolerated • Hip band ambulation • Core stability • Continue OKC/CKC/Plyo exercises • Power lifts as indicated for specific sports • Double and single leg jumps on stable and unstable surfaces • Sport-specific exercises progressed



FIGURE 26-10. Resisted sit-to-stand with hips abducted and externally rotated (sumo squat) with dumbbell or kettle bell weight.

Plyometrics

- Double leg jumps on stable surface in pain-free range
- Single leg bouncing while maintaining contact on mini-trampoline

Functional Exercises

- Continue hip band ambulation
  - Forward/backward
  - Side-to-side
  - "Monster walking"
- Resisted sit-to-stand with hips abducted and externally rotated (sumo squat) with dumbbell or kettle bell weight (Figure 26-10)

Milestones for Progression to Advanced Sport-Specific Training and Conditioning

- No pain with ADL
- Pain free with all rehab activities
- Able to consistently perform single leg squat into full functional range without pain while controlling dynamic knee valgus without verbal cues
- Able to consistently perform vertical drop jump from 18 inches without pain while controlling dynamic knee valgus without verbal cues

Phase IV (weeks 8+)

Protection

- Continue to limit motion to pain-free range.

Management of Pain and Swelling

- Continue with nonsteroidal antiinflammatory drugs (NSAIDs) and cryotherapy with compression to the joint as needed.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Continue for pain relief if indicated.

Soft Tissue Techniques

- Continue gentle massage to anterior hip with the focus on relaxation of regional musculature as needed.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Progress iliopsoas and low back extensor stretching as tolerated.
- Continue gentle stretching into combined flexion abduction external rotation as tolerated.

Other Therapeutic Exercises

- Progressive running program as tolerated
  - Begin with 10 minute jog, stopping if painful.
  - If pain free during run and over next 24 hours, progress by 5 minutes the next day; if not, stay at 10 minutes.
  - Continue to monitor and progress as above.
- Continue to progress TLS.
- Progress core stability training as tolerated.

Activation of Primary Muscles Involved

- Hip abductors
  - Gluteus medius
  - Gluteus minimus
- Hip external rotators
  - Gluteus maximus
  - Piriformis
  - Gemellus superior
  - Gemellus inferior
  - Obturator internus
  - Obturator externus
  - Quadratus femoris
- Hip extensors
  - Gluteus maximus
  - Biceps femoris
  - Semitendinosus
  - Semimembranosus
- Hip adductors
  - Adductor magnus
  - Adductor longus
  - Adductor brevis
  - Pectineus
  - Gracilis

Sensorimotor Exercises

- Progress single leg stance on uneven surface to incorporate perturbations.
- Lunges in multiple planes with focus on maintaining proper knee position while adding dynamic component such as twisting

Open and Closed Kinetic Chain Exercises

- Continue clamshells in pain-free range against resistance (OKC).
- Continue standing hip abduction, adduction, and extension against resistance (OKC).
- Continue bridging with marching (CKC).
- Continue side plank (CKC).
- Progress double and single leg press in pain-free range (CKC).

Techniques to Increase Muscle Strength, Power, and Endurance

- Progress resistance during RDL with focus on lumbopelvic coordination.
- Free squats in pain-free range with higher intensity (CKC).
- Continue deadlifts from floor with higher intensity and focus on proper form (CKC).
- Progress single leg squats in Smith machine with focus on maintaining proper knee position (CKC).
- Power lifts such as clean, jerk, snatch as indicated for specific sports

Neuromuscular Dynamic Stability Exercises

- Continue single leg lunge on wall with physioball with focus on controlling knee valgus and hip adduction, adding dumbbell resistance as needed.

Plyometrics

- Double and single leg jumps on stable and unstable surfaces in pain-free range

Functional Exercises

- Continue hip band ambulation.
  - Forward/backward
  - Side-to-side
  - "Monster walking"
- Squat to run medicine ball throws (Figure 26-11)

Sport-Specific Exercises

- Begin sport-specific drills as indicated including:
  - Running
  - Cutting
  - Jumping

Milestones for Progression to Advanced Sport-Specific Training and Conditioning

- Has full, functional, and pain-free range of motion as necessary for the athlete's particular sport during training activities
- Lower body strength is within 90% of the involved side during single leg squats in Smith machine.
- Lower body power is within 90% of the uninvolved side.
  - Single hop
  - Triple hop
  - Crossover hop
  - 6-minute timed hop
- Athlete has achieved proper scores in validated functional tests that challenge range of motion, strength, and coordination as appropriate for his or her sport such as the Lower Extremity Functional Test.

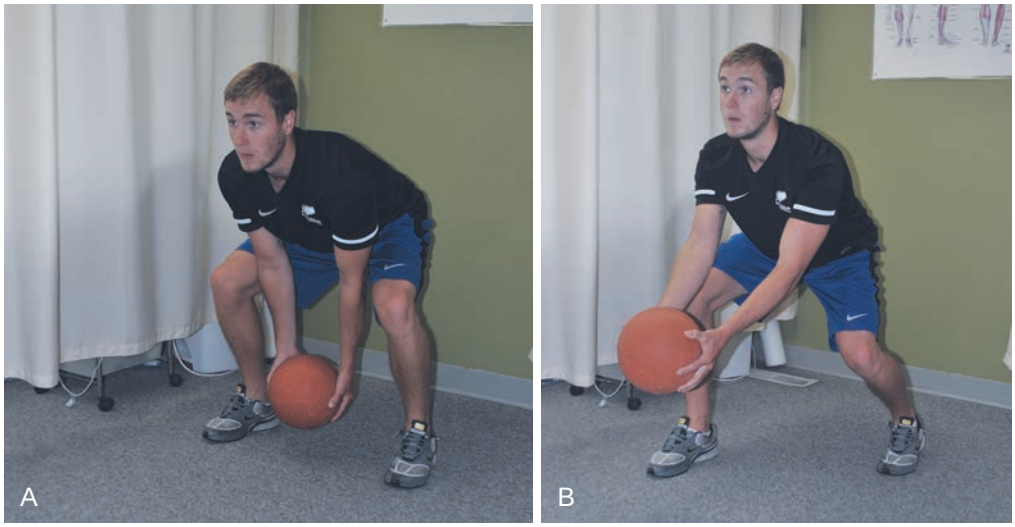

FIGURE 26-11. Squat to run medicine ball throws. Squat (**A**) then throw (**B**) as initiating run.

Criteria for Abandoning Nonoperative Treatment and Proceeding to Surgery or More Intensive Intervention

- Pain-free ROM does not improve to within functional limits of the athlete's particular sport.
- Unable to progress strength or coordination owing to range of motion limitations
- Significant restrictions based on bony morphology observed on radiographs

Tips and Guidelines for Transitioning to Performance Enhancement

- Progress training in a progressive fashion to make sure that the muscles and supporting structures have sufficient time to adapt to the loads unique to the sport.
  - Start with simple controlled sport specific drills in single plane.
  - Progress to more complex multidirectional drills.
  - Advance to more unpredictable activities such as partial and then complete scrimmages.

Performance Enhancement and Beyond Rehabilitation: Training/Trainer and Optimization of Athletic Performance

- Make modifications in training to reduce the amount of internal rotation, adduction, and/or flexion at the hip.
  - Limit squat depth.
  - Convert to sumo squat (see Figure 26-10).
- Focus on controlling dynamic knee valgus during training by avoiding hip adduction and internal rotation during activities.
- If unable to make necessary modifications, the athlete may need surgical intervention to reduce the impingement.

Specific Criteria for Return to Sports Participation: Tests and Measurements

- No pain during gym activities
- No pain during sport-specific drills
- No pain during practice including scrimmages and game simulation for 2 weeks

Evidence

Austin AB, Souza RB, Meyer JL, et al: Identification of abnormal hip motion associated with acetabular labral pathology. *J Orthop Sports Phys Ther* 38:558–565, 2008.

This case study presents a patient with a diagnosis of femoroacetabular impingement who responded well by training to reduce hip adduction and internal rotation. (Level IV evidence)

Bedi A, Dolan M, Hetsroni I, et al: Surgical treatment of femoroacetabular impingement improves hip kinematics: a computer-assisted model. *Am J Sports Med* 39:43S, 2011.

This case series of 10 patients compared preoperative and postoperative hip range of motion using computer-assisted 3-dimensional analysis. Concluded that osteoplasty reliably improves hip kinematics, specifically in internal rotation in a flexed position. (Level IV evidence)

Ekstrom RA, Donatelli RA, Carp KC: Electromyographic analysis of core trunk, hip, and thigh muscles during 9 rehabilitation exercises. *J Orthop Sports Phys Ther* 37:754–762, 2007.

This prospective, single-group, repeated-measures study of 30 subjects compared the EMG activity of core trunk, hip, and thigh muscles during 9 rehabilitation exercises. Concluded that side plank had the highest activity in the gluteus medius. (Level III evidence)

Grindem H, et al: Single-legged hop tests as predictors of self-reported knee function in nonoperatively treated individuals with anterior cruciate ligament injury. *Am J Sports Med* 39:2347–2354, 2012.

This study evaluated the predictive abilities of single leg hop tests for return to sport after ACL injury without reconstruction. It found that they were good predictors, and suggests that they may be useful tests in other nonoperative lower extremity injuries. (Level II evidence, but not in the way we apply it)

Hewett TE, et al: Biomechanical measures of neuromuscular control and valgus loading of the knee predict anterior cruciate ligament injury risk in female athletes: a prospective study. *Am J Sports Med* 33:492–501, 2005.

This study looked for predictors of ACL injury and found that the vertical drop jump demonstrates dynamic knee valgus tendencies during functional activities and is a predictor of ACL injury. This suggests that the same test may predict dynamic knee valgus in other subjects. (Level II evidence, but not in the way we apply it)

Johnston TL, Schenker ML, Briggs KK, et al: Relationship between offset angle alpha and hip chondral injury in femoroacetabular impingement. *Arthroscopy* 24:669–675, 2008.

This study compared surgical findings with preoperative measurements of range of motion and alpha angle in 82 patients. It concluded that increased offset alpha angle was correlated with increased chondral damage, labral injury, and decreased range of motion. (Level II evidence)

Kapron AL, et al: Hip internal rotation is correlated to radiographic findings of cam femoroacetabular impingement in collegiate football players. *Arthroscopy* 28:1661–1670, 2012.

This study compared hip IR range of motion limitations and alpha angle measurements on x-ray. It concluded that there was a strong correlation. (Level IV evidence)

Krause DA, Jacobs RS, Pilger KE, et al: Electromyographic analysis of the gluteus medius in five weight-bearing exercises. *J Strength Cond Res* 23(9):2689–2694, 2009.

This study compared activation of the gluteus medius in 20 healthy subjects during five weight-bearing exercises. It concluded that single leg activity was greater than double leg. Although balance cushion showed increased activity, it was not significantly greater than on solid surfaces. (Level III evidence)

Martin HD, et al: The pattern and technique in the clinical evaluation of the adult hip: the common physical examination tests of hip specialists. *Arthroscopy* 26:161–172, 2010.

The purpose of this study was to systematically evaluate the technique and tests used in the physical examination of the adult hip performed by multiple clinicians who regularly treat patients with hip problems and identify common physical examination patterns. This article describes many intraarticular tests including single leg stance phase and SLR against resistance. (Level IV)

McCurdy K, O'Kelly E, Kutz M, et al: Comparison of lower extremity EMG between the 2-leg squat and modified single-leg squat in female athletes. *J Sport Rehabil* 19:57–70, 2010.

This study compared EMG activity during 2-leg squat and single-leg modified squat in 11 female athletes. It concluded that the modified single-leg squat produced significantly higher EMG in gluteus medius, hamstrings, and quadriceps than 2-leg squat. (Level III evidence)

Rylander JH, Shu B, Andriacchi TP, et al: Preoperative and postoperative sagittal plane hip kinematics in patients with femoroacetabular impingement during level walking. *Am J Sports Med* 39:36S, 2011.

This case series used motion capture to analyze kinematics and kinetics of gait preoperatively and one year after arthroscopic osteoplasty in eleven subjects. This article suggests that patients with FAI present with abnormal gait kinematics and that surgery may be required to restore normal patterns. (Level IV evidence)

Yazbek PM, Ovanessian V, Martin RL, et al: Nonsurgical treatment of acetabular labrum tears: a case series. *J Orthop Sports Phys Ther* 41:346–353, 2011.

This cases series described a treatment program with positive outcomes in four patients with acetabular labral tears. The authors suggest that controlling knee valgus may be the most effective nonsurgical treatment for these patients. (Level IV evidence)

Multiple-Choice Questions

QUESTION 1. Into what direction should range of motion be aggressively pushed?

A. Flexion
B. Adduction
C. Internal Rotation
D. None of the above. May be restricted by bony morphology

QUESTION 2. What muscle activation should be minimized during Phase I?

A. Gluteus medius
B. Quadriceps
C. Iliopsoas
D. Hamstrings

QUESTION 3. What motion should be controlled during return to sport activities?

A. Dynamic knee valgus
B. Hip extension
C. Trunk extension
D. None of the above

QUESTION 4. During which phase can simple plyometrics such as submaximal jumps on a shuttle be initiated?

A. Phase I
B. Phase II
C. Phase III
D. Phase IV

QUESTION 5. Activation of which muscle group should be reinforced during each phase of rehab?

A. Hip flexors
B. Quadriceps
C. Hip abductors
D. Hamstrings

Answer Key

QUESTION 1. Correct answer: **D** (see Guiding Principles of Nonoperative Rehabilitation)

QUESTION 2. Correct answer: **C** (see Phase I)

QUESTION 3. Correct answer: **A** (see Phase IV)

QUESTION 4. Correct answer: **B** (see Phase II)

QUESTION 5. Correct answer: **C** (see Box A)

POSTOPERATIVE REHABILITATION AFTER FEMOROACETABULAR IMPINGEMENT TREATMENT, LABRAL REPAIR, AND LABRAL DEBRIDEMENT

Nancy J. Bloom, PT, DPT, MSOT, John C. Clohisy, MD, and Marcie Harris-Hayes, PT, DPT, MSCI, OCS

Indications for Surgical Treatment

- Nonoperative treatment for at least 3 to 6 months has failed to resolve hip pain. Optimal nonoperative treatment would include corrections for impairments in:
  - Sitting and standing alignment
  - Precision of motion during functional activities, exercise and sport
  - Muscle performance of the proximal hip muscles

  The time frame for nonoperative care may be affected by value of the athletic participation for the individual. For example, a professional athlete may choose surgery earlier than a recreational athlete because return to sport is critical to their life.
- Persistent pain associated with basic functional activities, such as walking or sitting
- There is no pain with basic functional activities, but pain is persistent with athletic activities.
- Physical examination and hip imaging consistent with hip impingement disorder

Brief Summary of Surgical Treatment

Major Surgical Steps

- Hip exposure via arthroscopy or open technique (mini-open or surgical dislocation)
- Correction of acetabular rim disease (rim osteoplasty, labral repair, partial labral resection, articular cartilage procedures)
- Correction of femoral disease/deformity (head-neck osteoplasty, relative neck lengthening, trochanteric osteotomy

Factors That May Affect Rehabilitation

See Table 26-1.

- Less invasive (arthroscopy or limited anterior approaches) or open surgical dislocation
- Open dislocation is performed with a trochanteric osteotomy, which may extend the partial weight-bearing phase (4 weeks).

Table 26-1 Postoperative Precautions for Hip Arthroscopy and Surgical Dislocation

Procedure	Weight Bearing	Movement			
		Hip Flexion	Hip Extension	Hip Rotation	Hip Abduction
Labral resection	50% WB* × 2 weeks then progress to full WB	Active and Passive w/in comfort level but no >90° × 4 weeks	No >0° × 4 weeks	As tolerated	As tolerated
Labral repair	FF × 2 weeks then progress to full WB	Active and Passive w/in comfort level but no >90° × 4 weeks	No >0° × 4 weeks	10° MR and LR × 4 weeks	As tolerated
Osteoplasty chondroplasty osteochondroplasty	50% WB × 2 weeks then progress to full WB	Active and Passive w/in comfort level but no >90° × 4 weeks	No >0° × 4 weeks	As tolerated	As tolerated
Microfracture	FF** × 8 weeks then progress to full WB	Active and Passive w/in comfort level but no >90° × 4 weeks	No >0° × 4 weeks	As tolerated	As tolerated
Surgical dislocation w/trochanteric osteotomy	FF × 4 weeks then progress to full WB	Active and Passive w/in comfort level but no >90° × 4 weeks	No >0° × 4 weeks	As tolerated	4 weeks: No active abduction 8 weeks: add resistance
Arthroscopy + limited open osteochondroplasty	The addition of a limited anterior open procedure to correct CAM impingement does not add any additional precautions. Follow precautions for procedures performed in the scope.				
Combinations	Review procedures and follow most conservative precautions. Exp 1: Labral repair and osteoplasty: TTWB × 2 weeks, no MR or LR or hip flexion >90° Exp 2: Labral repair, osteoplasty, and microfracture: TTWB × 8 weeks, no MR or LR or hip flexion >90°				

*WB, weightbearing;**FF, foot flat.
Capsulorraphy: 6 weeks in brace. No CPM.

- Labral repair (as opposed to partial resection) may extend partial weight-bearing phase (2 weeks).
- Microfracture will increase time of protected weightbearing.

Before Surgery: Overview of Goals, Milestones, and Guidelines[1]

Assuming nonoperative treatment has not satisfactorily resolved the hip symptoms, the patient needs to be readied for surgery. Treatment should include:

- Education regarding positioning, mobility and equipment required postsurgically.
  - Lying down
  - Sitting
  - Crutch training: gait, stairs, sit to and from standing
  - Bed mobility
  - Transfers: car, commode, tub/shower
- Basic strengthening for upper extremities and nonsurgical lower extremity (LE)
- Strengthening for primary hip muscles of the surgical LE without increasing pain
- Encourage cardiovascular fitness to build endurance. Select activities or equipment that minimize forces due to weightbearing and avoid extreme ranges of hip motion. The activity should not increase symptoms.
- Education of potential precautions and postoperative activity level

GUIDING PRINCIPLES OF POSTOPERATIVE REHABILITATION

- Recognize that surgical techniques can be combined; therefore follow the most conservative protocol. For example, labral tear and osteochondroplasty will need to follow labral tear precautions.
- Understand the surgical procedure or combination of procedures and associated precautions (see Table 26-1).
- Understand the specific tissues affected in the surgery (e.g., labrum, acetabulum, femoral head, femoral head-neck junction, cartilage, muscles) and the healing rate of tissues and the moderators affecting healing, such as age, anthropomorphics, and health of patient. Understand the alignment, positions, and movements that may increase stress to the involved structures.
- Most hip pain problems exist several months before surgery, which results in significant tissue adaptations. The longer the duration of symptoms, the more likely it is to find significant impairments in ROM; strength and flexibility and recovery may be slower. Exercise selection should be carefully graded to match the condition of the tissues.
- Avoid pushing end ROM. Normal ROM is highly variable and individual differences need to be respected.
- Emphasis should be placed on precision of movement and proper muscle activation during all therapeutic exercise, functional activities, and sporting skills.
- Understand structural variations and their impact on goals for treatment.
- Musculoskeletal impairments in the nonoperative lower extremity and lumbar spine are common and need to be addressed.

[1]*Prehabilitation, if appropriate, is described in the Nonoperative Rehabilitation section of this chapter.*

Phase I (days 0–2, 4, or weeks 8 postoperatively depending on procedure): Immediate Postoperative Period, Minimal Weightbearing (Foot Flat)

See Table 26-1.

Clinical Pearls

- Movement impairments may be observed during attempted exercise performance. For example, hip medial rotation (MR) may be observed during hip flexion exercises. Observed impairments should be corrected.
- In general, do not push hip ROM too soon or too aggressively.
- Very often a continuous passive movement system is prescribed for passive range of hip flexion and extension. Do not rely on the machine setting alone for ROM. To avoid hip flexion beyond 90°, educate the patient to consider the influence of the trunk/pelvic position on hip flexion when setting up to use the CPM device. When out of the device, precise hip flexion is most easily achieved when combining hip and knee flexion.
- An active straight leg should not be used for hip flexor or quadriceps strengthening or hamstring stretching in this population.
- Pain in the adductor region is often felt during hip abduction exercises. In those cases, cue to activate the gluteus medius and downgrade the movement until it can be performed without a sensation in the adductors.

Goals

- Minimize stress to the affected structures during basic mobility and exercise.
- Decrease pain and inflammation.
- Minimize the effects of immobilization (joint, muscle, and circulation).
- Begin cardiovascular activities within precautions.

Protection

- Instruction in precautions for exercise and daily activities (see Table 26-1)

- Two crutches for ambulation
- Bracing if prescribed by surgeon

Equipment

- Raised toilet seat
- Tub bench and hand held shower
- Long-handled devices: reacher, shoehorn, sponge
- Continuous passive motion (CPM) device
- Assistive device: crutches
- Compressive stocking or mechanical compressive device

Basic Functional Mobility and Positions

- Lying down:
  - Supine (most frequently used): pillow under knees for first few days only. May also place bolsters/towel roll/pillow on the outside of thigh to control lateral rotation (LR).
  - Side lying on uninvolved side (once patient is able to log roll while maintaining precautions, see bed mobility): pillows between knees. Avoid side lying on involved side.
  - Prone (less commonly used for resting position): pillow under hips.
- Sitting: Assess use and type of chair at home. Make recommendations to achieve the following:
  - Hips should be higher than knees (may need wedge or pillow on chair or use of recliner).
  - Weightbearing should be symmetrical
  - Avoid low surfaces.
  - Feet and spine should be supported.
  - Avoid prolonged periods (>20 to 30 minutes) of sitting upright.
  - Do not cross legs.
- Standing with crutches: Allow the foot on the involved side to rest flat on the ground, but avoid putting too much weight through the involved limb. Foot flat is preferred over toe-touch weightbearing to avoid prolonged positioning of hip flexion. Avoid leaning on axillae. Avoid prolonged periods of standing.



FIGURE 26-12 Sit to and from stand. The goal is to avoid hip flexion greater than 90° and place minimal weight on the involved lower extremity. Scoot to edge of chair, place involved lower extremity in front of body with knee straight, and use upper extremities to assist.

- Bed mobility:
  - Rolling: Assume hook lying, place pillow between knees, and log roll toward the nonsurgical side.
  - Supine to sitting: Perform log rolling as above. Once on side, use upper extremities or uninvolved LE to assist in moving the surgical LE to the edge or push up to sitting.
- Sit to and from stand: Scoot forward in the chair. Place involved LE in front of body with knee straight and the opposite foot underneath the seat. Place hands on armrests and use upper extremities to assist standing or sitting. Control the descent when sitting down (Figure 26-12).
- Gait: Use two crutches and minimal weightbearing. Encourage heel to toe pattern to foster normal hip, knee, and ankle motion without placing more than the weight of limb on the foot.
- Stairs: Instruct in a step to cadence, lead with the involved LE when descending stairs, and lead with the uninvolved LE when ascending stairs. The use of two crutches or one crutch and a railing is dependent on the safety and comfort of the patient.

TIMELINE 26-2: **Postoperative Rehabilitation After Femoroacetabular Impingement Treatment, Labral Repair, and Labral Debridement**

PHASE I (weeks 0 to 2, 4, or 8)

- Hip ROM:
  - Flexion/extension: No hip flexion >90°, no hip extension >0°, CPM to 60°
  - MR and LR: 10° for labral repair, otherwise as tolerated
  - Abduction: no active abduction with surgical dislocation for 4 weeks to protect the trochanteric osteotomy site for bony healing
  - Bracing if desired by surgeon
- Function:
  - Gait: Use two crutches and encourage heel-to-toe pattern while maintaining WB precaution
  - Stairs: Step to pattern
  - Adjust positioning for sitting and lying to maintain hip precautions
- Ice, compressive stockings, elevation
- Gentle active range of motion (AROM) for all allowed hip motions: on mat, in pool, upright bike
- Gentle stretching and ROM for other body regions
- Fitness: Upper-body ergometer or cycling with uninvolved LE

PHASE II (weeks 2 to 12)

- Hip ROM: Increase in all directions as tolerated after 4 weeks
- Gait:
  - Progress WB to 50%, then gradually to full WB
  - Reduce use of crutches balanced with increased walking distance
  - Water walking
- Stairs: continue step to pattern
- Ice, compressive stockings, elevation
- Strength:
  - AROM against gravity for all key hip manual muscle (mm) tests; no active straight leg raise (SLR)
  - Increased WB in standing exercises
- Stretching and active exercise for other body regions as tolerated
- Fitness: Upper-body ergometer or cycling on upright bike

- Car transfers: Seat should be moved back and reclined. Back up toward the seat, using car or crutch to assist in sitting down. Lean back into car and use hands or opposite foot to assist moving the LE on the surgical side into the car.

Management of Pain and Swelling

- Ice
- Oral pain medications as prescribed by physician
- Elevation of LE in supine position
- Compressive stocking or mechanical compression devise

Techniques for Progressive Increase in Range of Motion, Muscle Activation, and Other Therapeutic Exercises

Exercises may have multiple purposes such as increasing joint ROM, muscle activation, strengthening, endurance, or flexibility.

Exercises Primarily for the Hip

- Hip flexion: (Precaution: no hip flexion >90°, no active straight leg raises[1])
  Cue to stabilize pelvis by using the lower abdominals[2]
  - Supine or sitting semi reclined: use of CPM to 60°
  - Supine: heel slide
    - Slide foot along surface to the hook-lying position and return. Keep hip in neutral rotation. If painful, a cue to dig the heel in slightly to increase the use of the hamstrings may help. Cue to relax between repetitions.
      - Initially may need to place a pillow under the knees for comfort, but eventually the pillow should be removed to achieve hip extension to 0°.
  - Supine hook-lying: active-assistive hip flexion toward 90°
    - Use towel or upper extremities (UEs) to assist with lifting thigh (Figure 26-13)
    - Progress to active hip flexion without assistance.



FIGURE 26-13 Supine/hook lying: active-assistive hip flexion toward 90°. Use towel to assist with lifting thigh. Gradually progress the exercise by reducing the amount of assistance.

  - Quadruped: partial rocking backward
    - Start with the hips in 60° of flexion. Cue to push with the hands while rocking backward toward 90°. Avoid flexing the lumbar spine as the hip flexes.
  - Standing on uninvolved LE: active hip flexion through partial range motion
- Hip extension: *(Precaution: no hip extension >0°)*[3]
  - Any position: gluteal isometric contractions.
  - Standing on uninvolved LE:
    - Active hip extension (knee extended): lift lower extremity from starting position to 0° (hamstrings)
    - Active hip extension (knee flexed to 90°): lift lower extremity from starting position to 0° (gluteus maximus)
  - Prone with a pillow placed under the hips to avoid increased hip joint force during active hip extension[3] (may need to avoid until after removal of ankle pumps or in general rolling over is safe given rotation precaution). Cue to contract abdominals before performing hip extension.

TIMELINE 26-2 Postoperative Rehabilitation After Femoroacetabular Impingement Treatment, Labral Repair, and Labral Debridement (Continued)

PHASE III (weeks 2 to 16)	PHASE IV (weeks 12 to 24)

• Hip ROM: Increase in all directions as tolerated
• Gait:
  • Increase distance to 10,000 steps/day using optimal gait pattern
  • Include hills and uneven surfaces
• Stairs: step over pattern
• Driving: adjust car seat to avoid excessive hip flexion or MR
• Strength:
  • Add resistance for key hip mm
  • Standing exercises in full WB with double or single limb support
• Stretching and active exercise for other body regions: introduce partial squats and lunges
• Introduce drills for sports readiness: form first, then speed and duration
• Balance and neuromuscular training exercises
• Fitness: Swim, biking, running, use of elliptical
	• Hip ROM, strength, and flexibility: Continue to perform specific exercises targeted at precise joint motion, activation of key hip mm, and stretching one and two joint muscles without substitution or associated faulty motion.
	• Fitness: Increase speed and endurance with swimming, biking, running, or use of the elliptical
	• Advanced exercises and drills: jumping, shuttle runs, cutting
	• Sport-specific exercises and drills: use of equipment, partners, sport cord



FIGURE 26-14 Prone: active hip extension with the knee flexed. **A,** Correct performance because the hip extends toward 0 degrees but not beyond. **B,** Incorrect performance because there is too much hip extension.

  - Active hip extension (knee flexed to 90°): lift lower extremity from starting position to 0° (gluteus maximus). Cue to contract the gluteals and avoid pushing down with the nonmoving LE (Figure 26-14)
  - Active hip extension (knee extended): lift lower extremity from starting position to 0° (hamstrings) (Figure 26-15).
  - Active knee flexion: Although the motion is not hip extension, this exercise is a low level hamstring strengthening and stretch for tensor fascia lata-iliotibial band (TFL-ITB) and rectus femoris. Hip should be in neutral abduction/adduction and rotation. Knee should be fully flexed. If patient has a short TFL-ITB and has trouble keeping the pelvis stable as the knee is flexed, allow the hip to be positioned in slight abduction for this exercise. As flexibility increases, the hip may be positioned in midline.
- Hip abduction/adduction: (Precaution with surgical dislocation: No active abduction × 4 weeks)
- Cue to activate gluteus medius and avoid lateral pelvic tilt as a substitution with the following exercises:

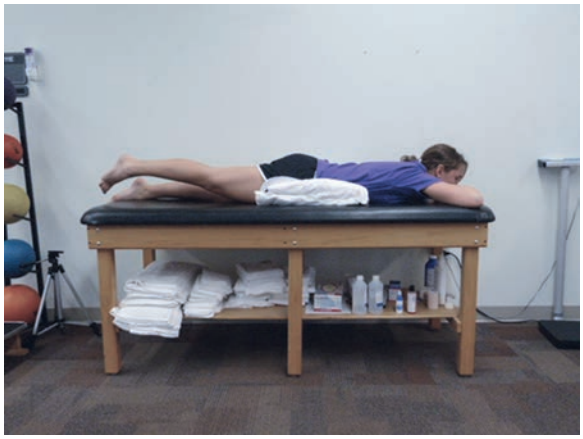

FIGURE 26-15 Prone: Active hip extension with the knee extended. Lift lower extremity from starting position toward 0° hip extension.

  - Standing on uninvolved LE: Abduct hip with slight extension and neutral rotation. Cue to keep pelvis stable and avoid lateral pelvic tilt (Figure 26-16).
  - Supine: Abduct and adduct hip while maintaining neutral rotation.
  - Prone with a pillow placed under the hips: (May need to avoid until after removal of ankle pumps or in general rolling over is safe given rotation precaution.)
  - Active hip abduction and adduction maintaining neutral rotation.
  - Side lying: Keep hips and knees flexed and pillow between the knees. (Precaution: Avoid these exercises which include LR if a labral repair has been performed.)
    - Active abduction and LR (knees separate and feet stay together) (Figure 26-17)
    - Progress to active abduction and LR by lifting the lower extremity off the pillow. *If a labral repair has been performed, cue to abduct the hip in neutral rotation.* Avoid lateral pelvic tilt. Focus on muscle activation of gluteus medius not on performing high numbers of repetitions (Figure 26-18).
- Hip rotation: (Precaution with labral repairs: avoid >10° medial rotation (MR) and LR (LR) × 4 weeks) Perform partial ROM with the following exercises.
  - Supine: Hips and knees extended
    - Roll whole lower extremity in and out. (Cue to move knee and foot together, not just the foot.)
  - Supine hook lying:
    - Allow whole LE to rotate outward and inward (Figure 26-19).
  - Standing on uninvolved LE with involved foot resting on heel, forefoot lifted.
    - Active MR and LR. (Cue to move knee and foot together, not just the foot.) Also avoid lateral pelvic rotation as a substitution (Figure 26-20).
  - Prone with a pillow placed under the hips and knee flexed to 90°.
    - Active MR and LR. (May need to avoid until after removal of ankle pumps or in general rolling over is safe given rotation precaution.)

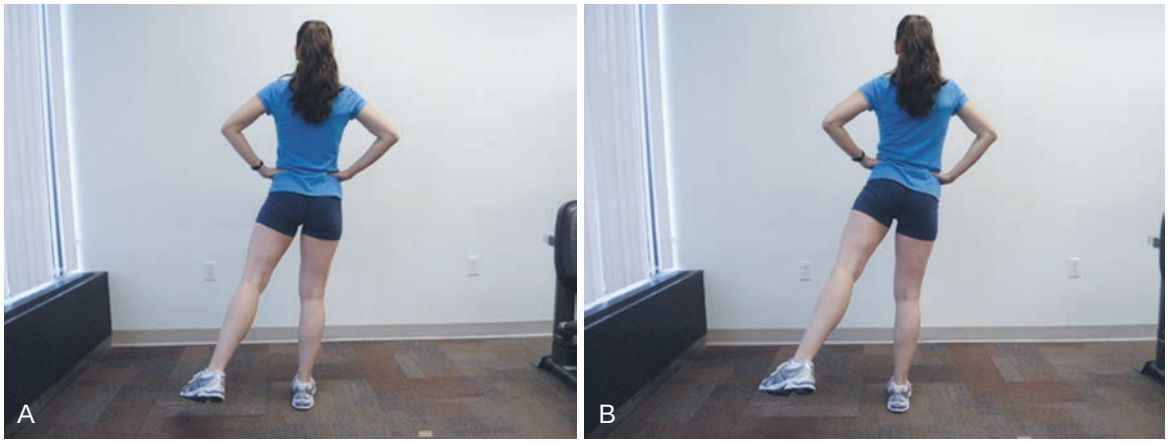

FIGURE 26-16 Standing hip abduction. *A,* Correct: using the posterior gluteus medius, abduct the involved hip in slight extension and neutral rotation. *B,* Incorrect: lateral pelvic tilt as substitution of for hip abduction.

- Other (aquatic and bike)
  - Aquatic exercise: May begin after adequate incision healing and physician permission.
    - Use of flotation device to suspend self while performing
      - Active ROM of the hip within precautions
      - Bicycle motion
    - Use of kick board for flutter kick. (Keep legs below the surface of the water to avoid excessive hip and back extension.)
    - No breast stroke
  - Upright biking:
    - 10 to 20 minutes
    - Adjust height of seat to avoid hip flexion greater than 80°.
    - Low resistance

Exercises for Other Body Regions

- Ankle pumps
  - May be progressed to resistance with elastic band
- Sitting and leaning back on upper extremities: active knee extension with active ankle dorsiflexion (low level quadriceps strength and gentle stretch of hamstrings and gastrocnemius)
- General upper extremity strengthening as allowed while maintaining precautions.

Cardiovascular Fitness

- Upper body ergometer
- Stationary cycling with uninvolved lower extremity only. Uninvolved lower extremity propped so that it is relaxed and not being used to pedal.

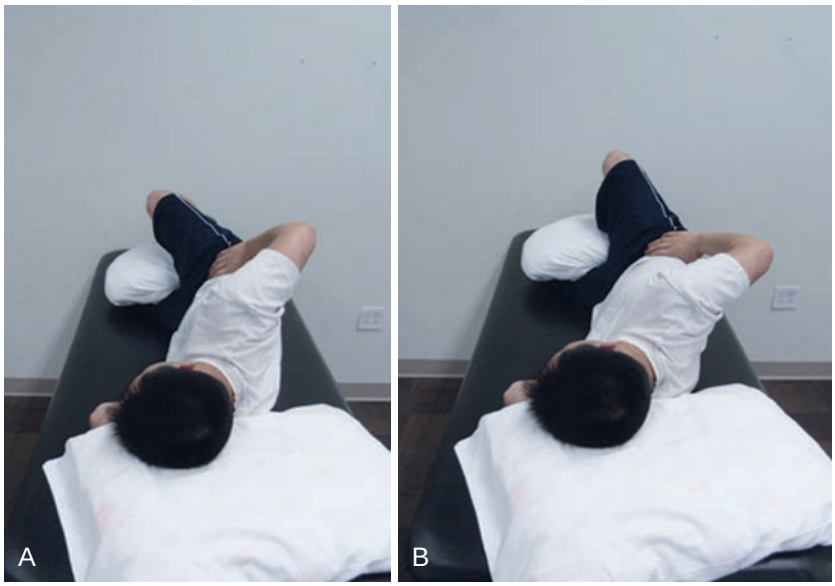

FIGURE 26-17 Side-lying hip abduction (low level). *A,* Correct: active abduction and lateral rotation (knees separate and feet stay together). *B,* Incorrect: pelvic rotation as substitution for hip lateral rotation

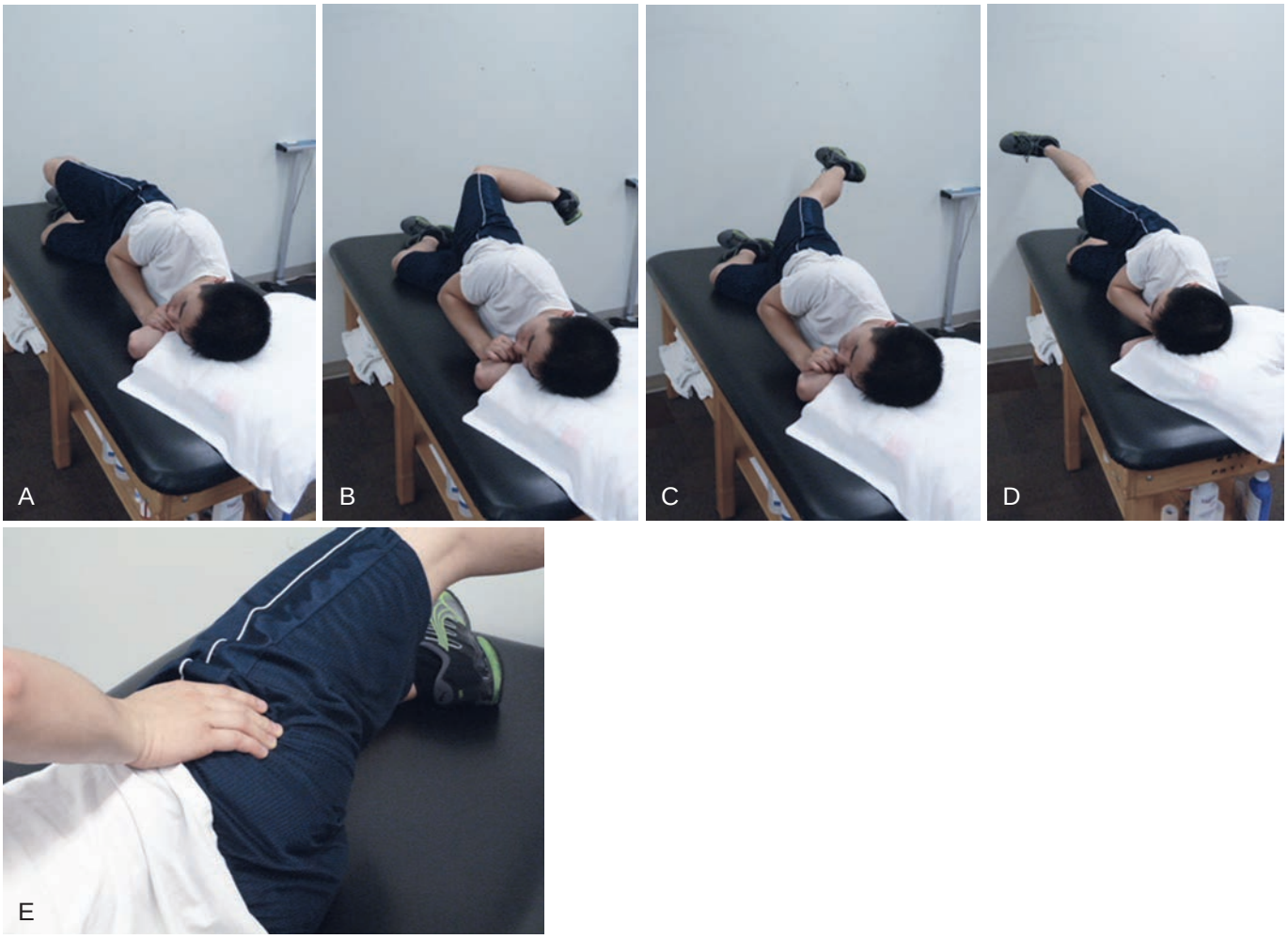

FIGURE 26-18 Side-lying hip abduction (higher level). *A,* Active abduction and lateral rotation. *B,* Abduct and extend hip with knee flexed; maintain neutral to slight lateral rotation. *C,* Extend knee. *D,* Incorrect: abduction in too much flexion. *E,* Placement of hand to monitor muscle contraction.



FIGURE 26-19 Supine hip rotation through partial range of motion. *A,* Medial rotation. *B,* Lateral rotation.

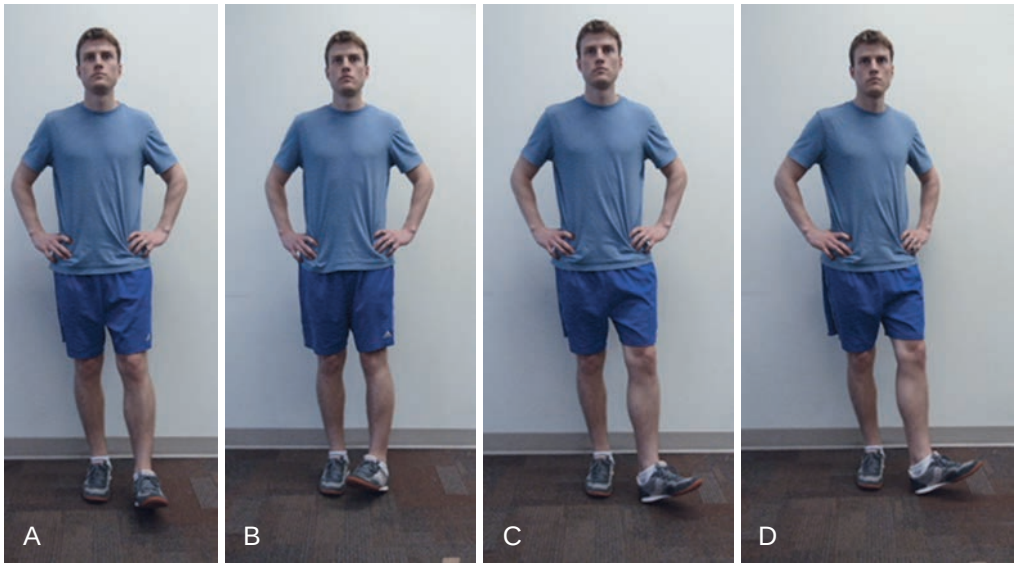

FIGURE 26-20 Standing hip rotation. *A,* Starting position. *B,* Medial rotation. *C,* Lateral rotation. *D,* Incorrect: lateral tibial rotation as substitution for hip lateral rotation (also avoid pelvic rotation).

Milestones for Progression to the Next Phase

- Adequate pain control
- Weight-bearing precautions changed

Phase II (weeks 2 to 12 postoperatively depending on procedure): Partial to Full Weightbearing

See Table 26-1.

Clinical Pearls

- Movement impairments may be observed during performance of daily activities. For example, side bending of the trunk or hip drop may be observed during stance phase of gait. Observed impairments should be corrected.
- Muscle performance during activity is determined by the pattern of movement. Correction of faulty patterns is best achieved by training the correct pattern and not isolated "strengthening" of a muscle.[2] For example, training to perform sit to stand with the knees aligned over the feet is needed in addition to strengthening of the hip abductors and lateral rotators.
- Although cleared for weightbearing, the joint and surrounding soft tissue muscles may not be ready. Avoid gait deviations by using an appropriate assistive device for the proper amount of time, ie transition from walking with two crutches to one crutch part-time to no crutches.
- As hip rotation ROM is increased, consider structural variations in acetabular or femoral versions. For example, if someone has femoral anteversion, the neutral position for hip rotation may appear medially rotated. This patient should be careful with pushing lateral hip rotation and flexion and extension should be performed with the appearance of slight MR. In general males tend to be more retroverted and females more anteverted in the femur.
- People often have problems in both hips so be cautious in using the strength and ROM of the nonsurgical hip as the target for goal achievement.
- Pain and movement impairments in the hip are often combined with problems in the lumbar spine. Therefore, it is important to observe and address the relative flexibility between the hip and the lumbopelvic region. For example, when flexing the involved hip, monitor the lumbar spine to avoid lumbar flexion or rotation.
- Muscle performance of the primary hip muscles is key. Cues to activate the iliopsoas, deep lateral rotators, posterior gluteus medius, and gluteus maximus are important during exercise to promote precise hip motion. Be aware of overuse of the hip adductors during exercise and functional activities.
- People vary in their general joint mobility. The best indication is obtained by assessing the ease of movement during passive motion. Sometimes non-weightbearing strengthening exercises, particularly for the abductors, can be uncomfortable for those with increased joint mobility. In those cases avoid sidelying as a position for strengthening and promote strength through functional activities, such as sit to stand, single leg stance and sidestepping.

Goals

- Within precautions, decrease dependence on assistive device for ambulation and gradually increase distance walked while optimizing gait pattern.
- Progress ROM within patient comfort level, particularly for hip flexion, MR, and LR. Moving precisely through the range frequently is more important than pushing end-range motion.
- Control pain and edema as activity level gradually increases (return to work or school).
- Prepare for return to work/school.
- Progress cardiovascular activities within precautions.

Protection

- Instruction in precautions for exercise and daily activities (see Table 26-1).
- Assistive device for ambulation

Equipment

- Continue use of equipment listed in phase I if appropriate

Basic Functional Mobility and Positions

- Lying down
  - Supine encourage limited use of pillow under knees. May place bolsters/towel roll/pillow on the outside of thigh to control LR.
  - Side lying on uninvolved side: Recommend continued use of pillows between the knees. May begin side lying on involved side. This position may be more tolerable if towel rolls or small pillows are placed above and below the greater trochanter.
  - Prone: May be more tolerable if pillow placed under the hips.
- Sitting: May tolerate increased time in sitting. Assess use and type of chair at home and work/school. Patient may tolerate sitting with hips at 90°. Otherwise, continue to follow recommendations described in Phase I.
- Standing with crutches: Maintain weight-bearing precautions during stance. Avoid excessive hip extension, which may be caused by forward sway of the pelvis or hyperextension of the knee. The hip should be maintained in neutral rotation. Use the distal femur, not the foot, as a guide for the hip rotation position.
- Bed mobility: Encourage continued use of log roll to protect lumbopelvic region. Recommendations from Phase I may continue to be used as needed for patient comfort.
- Sit to and from stand: Maintain weight-bearing precautions during the movement. To avoid too much hip flexion, scoot to the edge of seat maintaining a neutral lumbar spine alignment. Straddle feet so that the foot of involved side is back and the other is forward. During standing and sitting, keep the knees aligned over the second toe and use quadriceps and gluteals to control motion (Figure 26-21).
- Gait:
  - Pre-gait: To determine 50% weightbearing, divide patient's weight in half and use scale to monitor amount. Place the opposite foot on a step of equal height of the scale surface and place foot on involved side on the scale. Transfer weight to scale until the desired amount of weight is achieved. Practice weightshifting to target weight several times.
- Initial gait: Practice gait with 50% weightbearing using two crutches. Monitor symptoms and reduce weightbearing if 50% is too painful. Some soreness is expected; however, pain should not be sharp or persist so that weightbearing is limited for the rest of the day. Encourage heel to toe pattern to foster normal hip, knee, and ankle motion without violating precautions.
- Gait progression: Over the next 4 weeks, gradually increase weightbearing, reduce use of assistive device, and increase distance walked while maintaining optimal gait pattern. For example:
  - 50% WB, two crutches, household distances
  - 100% WB, two crutches, household and community distances
  - 100% WB, one crutches in household, two crutches in community
  - 100% WB, one crutch for all walking,
  - 100% WB, no crutch short distances, one crutch for longer distances
  - 100% WB, no assistive device for limited distances

Avoid prolonged hip extension during the stance phase to reduce stress on the anterior hip joint structures. A helpful cue is to lift the heel sooner after midstance which will allow earlier hip and knee flexion.

May use pedometer to quantify the amount of walking. As patient is progressed monitor symptoms and modify weightbearing, use of assistive device or distance walked accordingly. **Do not progress gait until gait pattern is optimal.** (No trunk sidebending, hip drop, or excessive hip rotation.)



FIGURE 26-21 Sit to stand. To avoid too much hip flexion, scoot to the edge of seat maintaining a neutral lumbar spine alignment. Straddle feet so that the foot of involved side is back and the other is forward. During standing and sitting, keep the knees aligned over the second toe and use quadriceps and gluteals to control motion.



FIGURE 26-22 Posterior glide provided during passive hip flexion. Apply a gentle posterior force over the proximal femur to achieve precise motion in those with limited and painful hip flexion.

  - Water walking may be used during this phase to progress weightbearing. Start by walking with water level chest high. Gradually reduce water level to increase the challenge.
  - Turning: Avoid pivoting on involved side. Pick up foot and turn using a series of small steps.
- Stairs: Continue with step to cadence until 100% weightbearing, and then decrease dependence on AD. Progress to step over step pattern according to patient's ability and symptoms.
- Car transfers: Recommendations from Phase I may continue to be used as needed for patient comfort. Driving is not typically recommended until 100% WB. If driving during this phase, see instructions in the Driving section in Phase III.

Management of Pain and Swelling

- Ice
- Oral pain medications as prescribed by physician or over the counter as needed
- Elevation of lower extremity in supine position
- Use of compressive shorts, such as spandex, may be used to assist with control of swelling

Techniques for Progressive Increase in Range of Motion, Muscle Activation, and Other Therapeutic Exercises

Exercises are described based on the assumption that the precautions for hip MR or LR have been lifted. (Exercises may have multiple purposes such as increasing joint ROM, muscle activation, strengthening, endurance or flexibility.)

Exercises Primarily for the Hip

- Hip Flexion: (No active straight leg raises)
- ROM may increase from Phase I, but should not be forced. For example, 120° may not be an appropriate target for hip flexion ROM after FAI surgery.
- Cue to use lower abdominals to stabilize pelvis[2,4]
  - Supine or hook lying: hip flexion to comfortable range
    - Active hip flexion: If patient reports anterior hip pain as hip flexion approaches 90°, patient can apply a gentle posterior force over the proximal femur to achieve precise motion
    - Passive hip flexion with mobilization: Patient applies a gentle posterior force over the proximal femur while passively flexing the hip with the opposite hand (Figure 26-22)
  - Quadruped:
    - Start with the hips in 70° to 80° of flexion. Push with the hands to rock backward toward 120°. Avoid flexing the lumbar spine as the hip flexes (Figure 26-23).
  - Standing on uninvolved: active hip flexion to 90°
  - Sitting: Use hands to passively flex hip within pain-free range; hold end-range for three to five seconds. May need to allow slight LR as hip is flexed for comfort. Use hands to assist to lower thigh to starting position (Figure 26-24).
    - May progress to active-assistive, then to active hip flexion. If pain or popping is reported when lowering the thigh, cue to "relax the muscles [iliopsoas] and let the thigh drop down"
- Hip extension
  - Prone with a pillow placed under the hips: continue exercises from Phase I.
  - Quadruped: Active hip extension (knee flexed to 90°): lift the involved lower extremity from starting position toward 0°. Do not lift the uninvolved side until the involved weight-bearing status has progressed to 100%. Cue to use lower abdominals to stabilize pelvis while moving the lower extremity. Because many tend to extend the knee during hip extension, cue to keep the knee flexed throughout the movement.
- Hip abduction/adduction: Make sure the patient reports feeling muscle activation in the gluteus medius and not in the lateral hamstrings, groin, or adductors during the following abduction exercises.
  - Standing on uninvolved: Abduct hip with slight extension and neutral rotation with light elastic band for resistance. Keep pelvis stable avoiding lateral pelvic tilt. ***Caution: No resistance until 8 weeks for surgical dislocation.***
  - Stand on involved extremity: Begin with UE support and control hip adduction or pelvic drop and MR. Mirror may be used to provide feedback

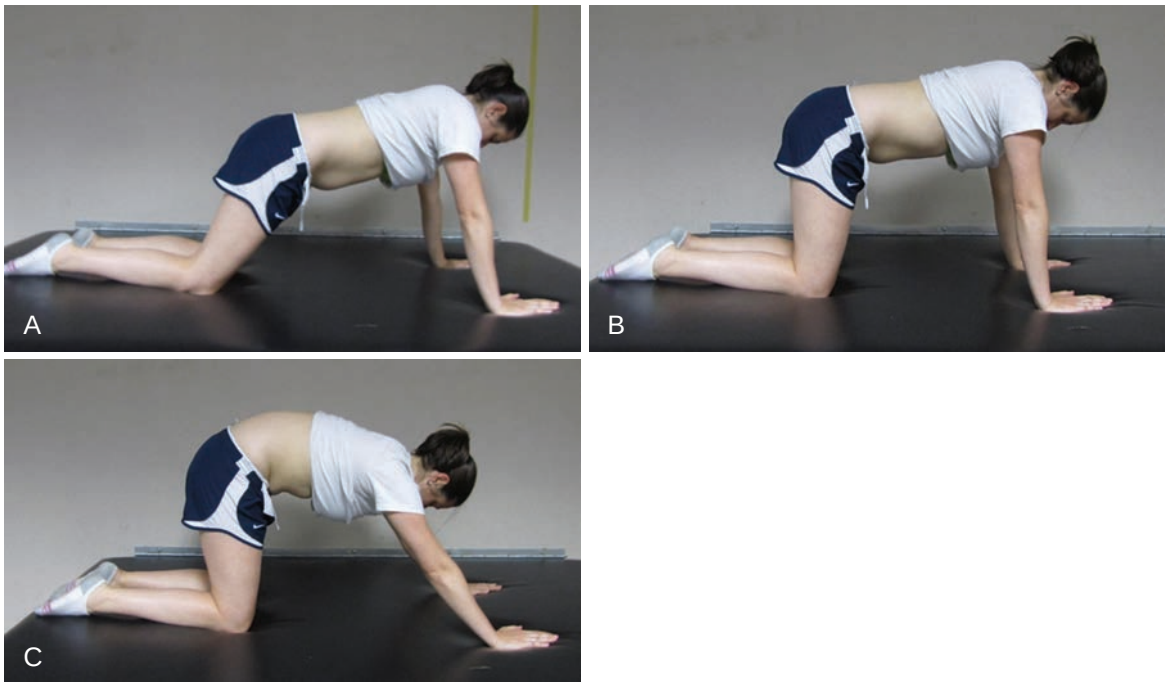

FIGURE 26-23 Hip flexion in quadruped. *A,* Starting position at 70° to 80° of hip flexion. *B,* Push with hands to flex hips from starting position toward 120° keeping the lumbar spine in a neutral position. *C,* Incorrect: lumbar flexion as substitution for hip flexion.

for maintenance of proper alignment during single leg stance. Progress to using no UE support as able.
  - Standing side stepping toward the involved hip
  - Sidelying: Hips and knees slightly flexed and pillow between the knees
    - Active abduction and LR by lifting the lower extremity off the pillow. Do not allow the knee to lock as hip abduction is being performed. Increase repetitions and sets as appropriate.
- Hip rotation:
  ROM may increase from Phase I, but should not be forced.
  - Supine hooklying:
    - Allow whole LE to rotate outward and inward through comfortable ROM. Cue to keep the pelvis stable by contracting the lower abdominals.
      - In patients with overuse and stiffness of the hip adductors, place pillows on the outside of the limb to allow the adductors to relax between repetitions if needed (Figure 26-25).
  - Standing on uninvolved side with involved foot resting on heel, forefoot lifted
    - Resisted MR and LR with light elastic band. (Cue to move knee and foot together, not just the foot) (Figure 26-26).

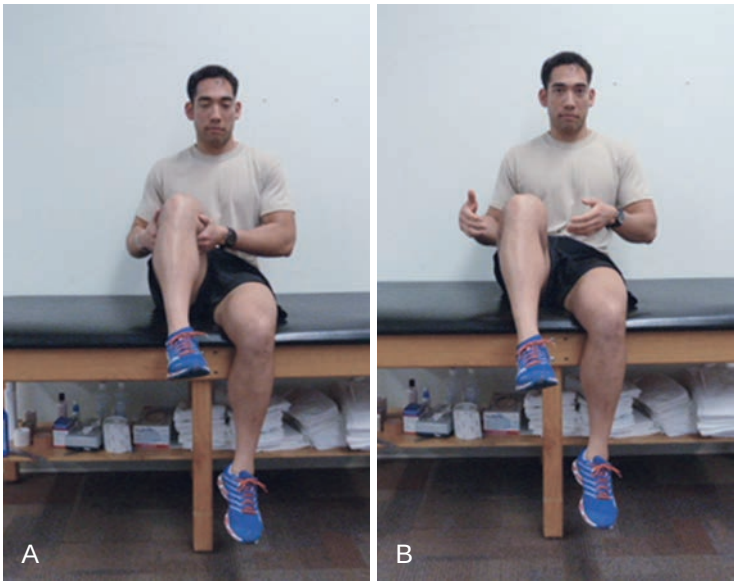

FIGURE 26-24 Hip flexion in sitting. *A,* Use hands to passively flex hip within pain-free range. May need to allow slight lateral rotation as the hip is flexed for comfort. Also use hands to assist to lower thigh to starting position. *B,* Hold end-range for 3 to 5 seconds.



FIGURE 26-25 Supine hip rotation. After performing hip lateral rotation, rest the lower extremity on pillows to allow the adductors to relax between repetitions if needed.

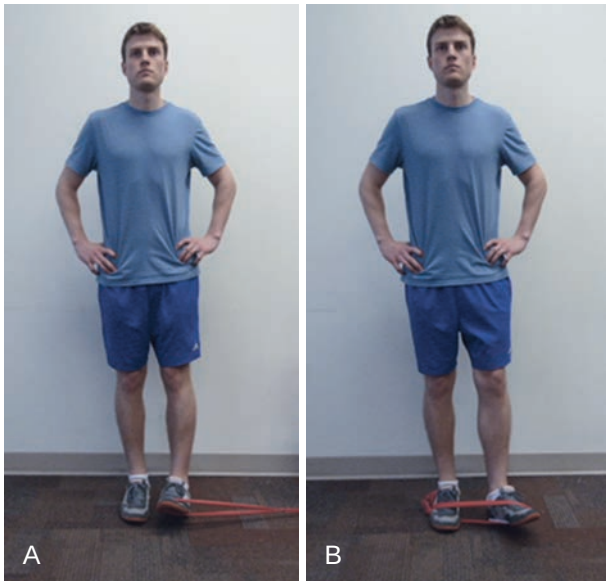

FIGURE 26-26 Standing hip rotation with resistance. *A,* Medial rotation. *B,* Lateral rotation

    - Consider both bony structure and preferred alignment when prescribing rotation exercises. Assess total rotation ROM (MR + LR) and the person's neutral position for rotation when determining the arc of motion to be performed. For example, a person with femoral anteversion may be asked to perform hip LR from a position where the foot is turned to a position that is slightly past midline.
- Prone with a pillow placed under the hips and knee flexed to 90°
  - Active MR and LR: Cue to keep pelvis stable by contracting lower abdominals.
- Sitting leaning back and resting on upper extremities to reduce hip flexion angle:
  - Active ROM for LR. Cue to keep the thigh relaxed on the chair and to activate the buttock muscles (deep lateral rotators) to perform the motion. MR is typically not comfortable or necessary to perform in this position.
  - Rotation control during sit to stand
    - Place a circular elastic band around distal femurs. Perform sit to stand while pushing out against the elastic band. The goal for alignment during performance should be to keep the knee over foot (Figure 26-27).
- Other (aquatic)
  - Continue active ROM and kickboard activities from Phase I.
  - No breast stroke

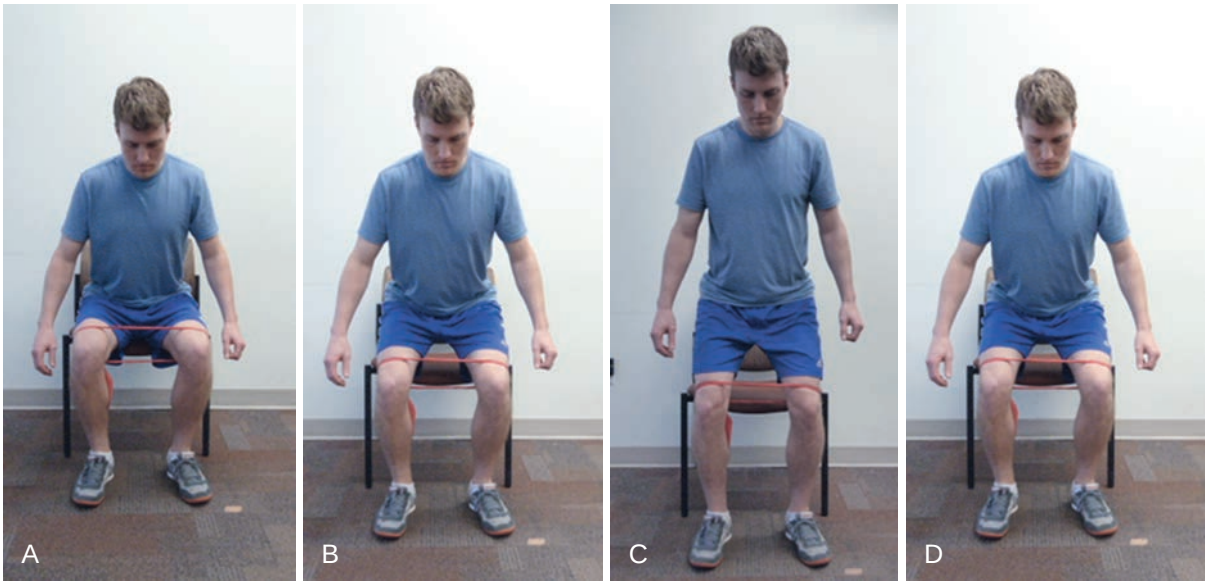

FIGURE 26-27 Sit to stand with resistance to control hip rotation. Perform sit to stand while pushing out against the elastic band. The goal for alignment during performance should be to keep the knee over foot.

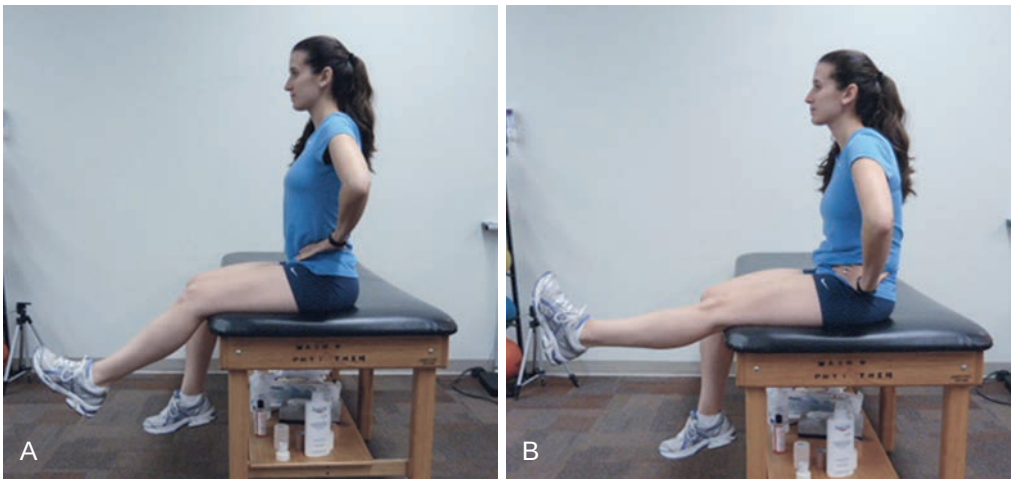

FIGURE 26-28 Sitting hamstring and gastrocnemius stretch. *A,* Correct: active knee extension and ankle dorsiflexion with stabilization of pelvis and lumbar spine. *B,* Incorrect: posterior pelvic tilt and lumbar flexion as substitution during hamstring stretch.

Exercises for Other Body Regions

- Sitting upright: Active knee extension with ankle dorsiflexion for hamstring and gastrocnemius stretching (cue to maintain pelvic and lumbar spine alignment as the knee is extended) (Figure 26-28)
- Standing: Calf stretches
- General upper extremity strengthening as allowed while maintaining precautions
- General trunk strengthening. Focus on activation of the trunk musculature isometrically while maintaining the spine in a neutral position. Avoid single or double straight leg raises as a method for strengthening abdominals.
  - Resisted upper extremity motions
  - Modified planks with base of support at the knees

Cardiovascular Fitness

- Gradually increase duration and intensity. Achieving target heart rate for cardiovascular fitness may not be achieved in early phases. The goal is to increase duration before adding resistance to the activity. May start with 10 minutes and gradually increase to tolerance. Should be able to tolerate multiple episodes at a given dose before increasing duration or intensity. Balance amount of time spent in fitness activities with walking program and work demands.
  - Upper body ergometer
  - Upright biking:
    - Increase duration gradually to 30 minutes within tolerance
    - Adjust height of seat to avoid hip flexion greater than 90°
    - May add moderate resistance

Milestones for Progression to the Next Phase

- No limitations or abnormal movement patterns in basic daily activities except stairs
- ROM necessary for function
- Optimal/normalized gait pattern without assistive device
- Single leg stance with good control of trunk, pelvis, and hip (no sidebending of the trunk, pelvic drop, or hip adduction or MR)

Phase III (weeks 2 to 16 postoperatively depending on procedure): Full Weightbearing Phase

Clinical Pearls

- Although movement impairments have been addressed in Phase I and II, they may reappear as the degree of difficulty increases when performing activities for sports readiness. The critical issue is HOW an activity is performed, not just performing the activity. Proper movement strategy can optimize performance and minimize tissue injury.[2,5]
- Continue to monitor relative flexibility between the hip and lumbopelvic region during exercise and activities.[2,4]
- As sports activities are progressed, consider the hip structure of the individual when setting targets for ROM.
- Goals for fitness and sports vary widely among individuals. Those who achieve their goals after completion of Phase III do not need to be progressed to Phase IV.
- Watch for substitution during stretching exercises. For example, when stretching the hamstrings in sitting, avoid posterior pelvic tilt and lumbar flexion as the knee is extended. Hip MR is another substitution commonly seen with this stretch.

Goals

- Gradually increase ambulation distance to 10,000 steps/day using optimal gait pattern. Include hills and uneven surfaces.

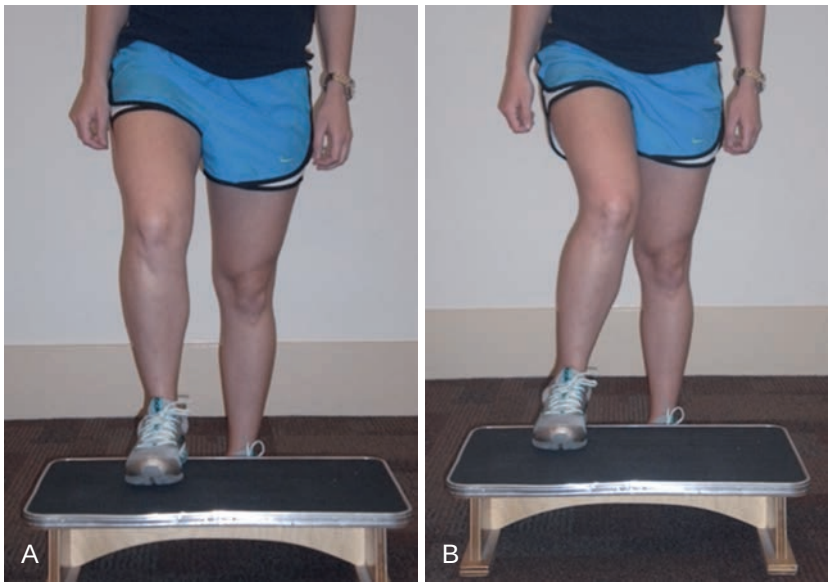

FIGURE 26-29 Ascend stairs. *A,* Correct: knee is aligned over foot. *B,* Incorrect: hip is in adduction and medial rotation resulting in knee being aligned medial to the foot.

- Provide stair training using step-over-step pattern.
- Progress strengthening and endurance of entire lower extremity.
- Progress cardiovascular activities to patient-preferred activities.
- Begin exercises for sport readiness, balance, and neuromuscular training.
- Provide feedback to athlete on performance to help with motivation and reduce fear.

Functional Mobility and Positioning

- Standing: Correct excessive hip extension achieved with forward sway of the pelvis and hyperextension of the knees. The hip should be maintained in neutral rotation. Use the distal femur, not the foot, as a guide for the hip rotation position.
- Gait:
  - Gait progression: Increase distance walked while maintaining optimal gait pattern.
  - May use pedometer to quantify the amount of walking. As patient is progressed monitor symptoms and modify distance walked accordingly if symptoms increase.
  - Initiate walking on uneven surfaces such as hills.
  - Turning: Avoid pivoting on involved side. Pick up foot and turn using a series of small steps.
- Stairs:
  - Use step-over-step method. Initially, may use rail to assist for proper control during stair ambulation. Emphasis on optimal movement pattern.
  - Upright trunk, no trunk sidebending
  - Keep knee over foot, no excessive hip rotation (Figure 26-29).
  - Maintain level pelvis during ascent, no hip drop.
  - During ascent, lean forward and use quads to raise body; avoid snapping knee back to body (Figure 26-30).
  - Control speed during descent.
- Driving: Assess type of seat in car and method of driving.
  - Position seat to avoid excessive or painful hip flexion and allow operation of pedals. Possible adjustments that may be used:
    - Recline backrest.
    - Tilt seat forward.
    - Slide seat backward.
    - Pillow/wedge may be placed on seat.
  - In cars with bucket seats, may need to fill in the bucket with pillow or towels to avoid excessive MR.
  - For those with stiff or short hamstrings, seat may be moved forward to reach the pedals more easily and to avoid excessive posterior pelvic tilt and lumbar flexion.
  - Minimize excessive hip flexion and MR when moving from gas to brake pedals. May suggest sliding foot when possible.
- Shoes
  - Wear supportive, flat shoes.
  - Gradually build tolerance to shoes with elevated heels. Avoid high heels.

Management of Pain and Swelling

- Ice or heat may be used.
- Oral pain medications as prescribed by physician or over the counter as needed.
- Use of compressive shorts, such as spandex, may be used to assist with control of swelling.
- Massage may assist with release of fluids and muscle cramps.

Techniques for Progressive Increase in Range of Motion, Muscle Activation, and Other Therapeutic Exercises

Exercises are described based on the assumption that the precautions for hip MR or LR have been lifted. (Exercises

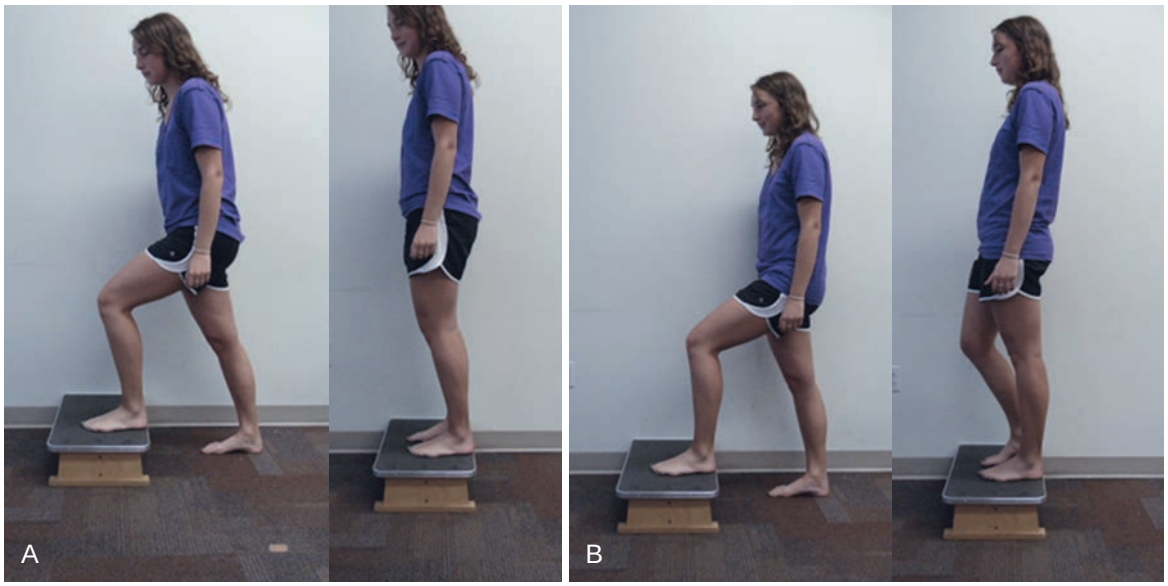

FIGURE 26-30 Ascend stairs. *A,* Correct: lean slightly forward and use quadriceps to lift body up the step. The final knee position should be neutral to slightly flexed. *B,* Incorrect: Trunk is too upright when placing foot on step and during step up. The knee snaps back during step-up and goes into hyperextension in the final position.

may have multiple purposes such as increasing joint ROM, muscle activation, strengthening, endurance or flexibility.)

Exercises Primarily for the Hip

- Hip flexion: *(No active straight leg raises)*
- ROM may increase from Phase II, but should not be forced.
- For example, 120° may not be an appropriate target for hip flexion ROM after FAI surgery.
- Cue to use lower abdominals to stabilize pelvis.
  - Quadruped:
    Exercise to increase hip flexion ROM and flexibility of posterior soft tissues
    - Start with the hips in 90° of flexion. Push with the hands to rock backward toward 120°. Avoid flexing the lumbar spine as the hip flexes.
    - If patient reports anterior hip pain as hip flexion approaches end-range, patient can apply a gentle posterior force over the proximal femur to achieve precise motion (Figure 26-31).
  - Standing on uninvolved: resisted hip flexion to 90° (ankle weights)
  - Sitting: May add resistance at end-range of hip flexion by using the hand. May need to allow slight LR as hip is flexed for comfort. If pain or popping is reported when lowering the thigh, cue to "relax the muscles [iliopsoas] and let the thigh drop down" (Figure 26-32).
- Hip extension
  - Prone with a pillow placed under the hips: Continue exercises from Phase I. May add ankle weights as needed.
  - Quadruped: Active hip extension (knee flexed to 90°): Lift the lower extremity from starting position toward 0°. Cue to use lower abdominals to stabilize pelvis while moving the lower extremity. Because many tend to extend the knee during hip extension,

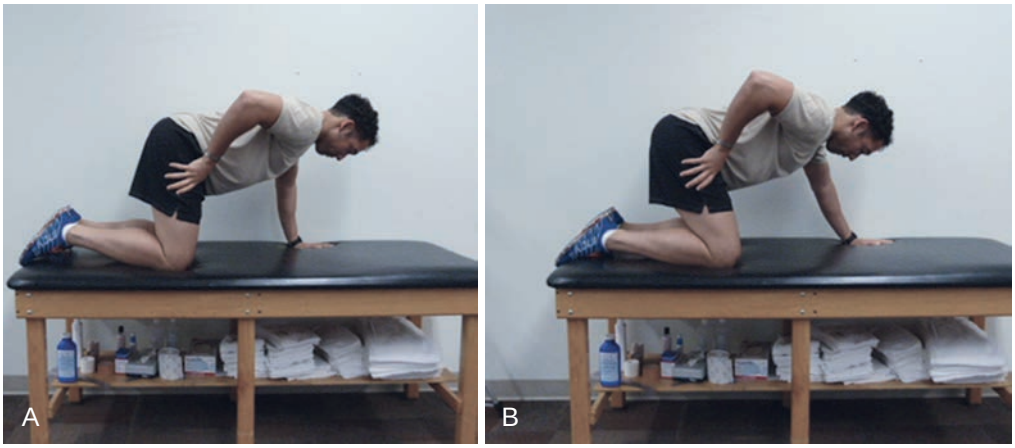

FIGURE 26-31 Posterior glide provided during quadruped rocking. *A,* Place hand over proximal femur in the starting position. *B,* Apply a gentle posterior force while rocking backward to achieve precise hip flexion in those with limited and painful hip flexion.

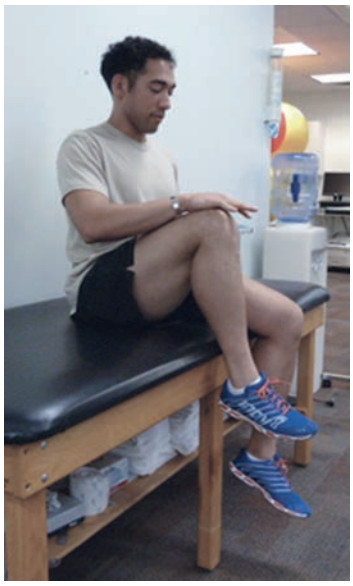

FIGURE 26-32 Hip flexion in sitting (resistance). May add resistance at end-range of hip flexion by using the hand. May need to allow slight LR as hip is flexed for comfort. If pain or popping is reported when lowering the thigh, cue to "relax the muscles [iliopsoas] and let the thigh drop down."

cue to keep the knee flexed throughout the movement. Increase repetitions and sets as appropriate.
  - Supine: Two joint hip flexor stretch. Avoid if athlete has excessive femoral anterior glide[2] during extension. Avoid tibial LR (Figure 26-33).
- Hip abduction/adduction
  Make sure the patient reports feeling muscle activation in the gluteus medius not in the lateral hamstrings, groin, or adductors during the following abduction exercises.
  - Stand on involved extremity: Control hip adduction or pelvic drop and MR. Knee should be slightly flexed to avoid hyperextension or locking the knee. Mirror may be used to provide feedback for maintenance of proper alignment during single leg stance. May be progressed by performing hip abduction against resistance with the uninvolved side.
  - Standing on uninvolved: Abduct hip with slight extension and neutral rotation with elastic band or pulley for resistance. Perform in the opposite direction for hip adduction.
  - Standing side stepping in both directions and progress with elastic band around the ankles or knees. Trunk should remain upright, pelvis level, and knee over foot during side stepping (Figure 26-34).
  - Sidelying: Hips and knees slightly flexed and pillow between the knees.
    - Active abduction, extension and LR by lifting the top lower extremity off the pillow. Slowly lower the lower extremity to neutral abduction/adduction and lift again. Increase repetitions and sets as appropriate. Knee should be relaxed (unlocked).
  - Sidelying: Active adduction of the bottom lower extremity if weak with muscle testing.
- Hip rotation:
  ROM may increase from Phase II, but should not be forced.
  - Supine hooklying:
    - Allow whole LE to rotate outward and inward through comfortable ROM (see Figure 26-19).
      - Place pillows on the outside of the limb to allow the adductors to relax between repetitions if needed (see Figure 26-25).
  - Standing on uninvolved side with involved foot resting on heel, forefoot lifted
    - Progress resisted MR and LR with moderate elastic band. (Cue to move knee and foot together, not just the foot.)
      - Consider both bony structure and preferred alignment when prescribing rotation exercises. Assess total rotation ROM (MR + LR) and the person's neutral position for rotation when determining the arc of motion to be performed.

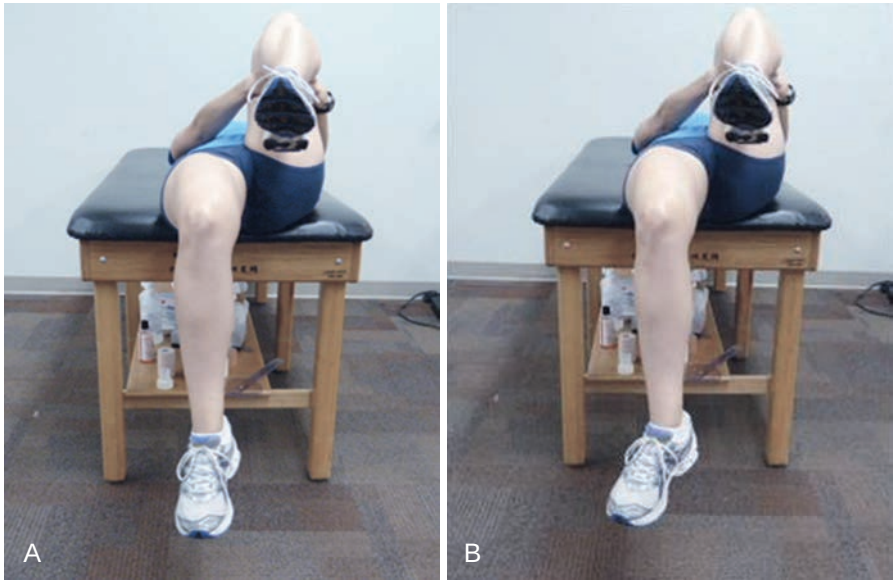

FIGURE 26-33 Two joint hip flexor stretch. *A,* Correct. *B,* Incorrect: Lateral tibial rotation occurs during hip flexor stretch owing to short or stiff tensor fascia lata-iliotibial band. Cue to hold foot in as the hip is extended being careful to avoid hip medial rotation as a substitution for holding the foot in midline.

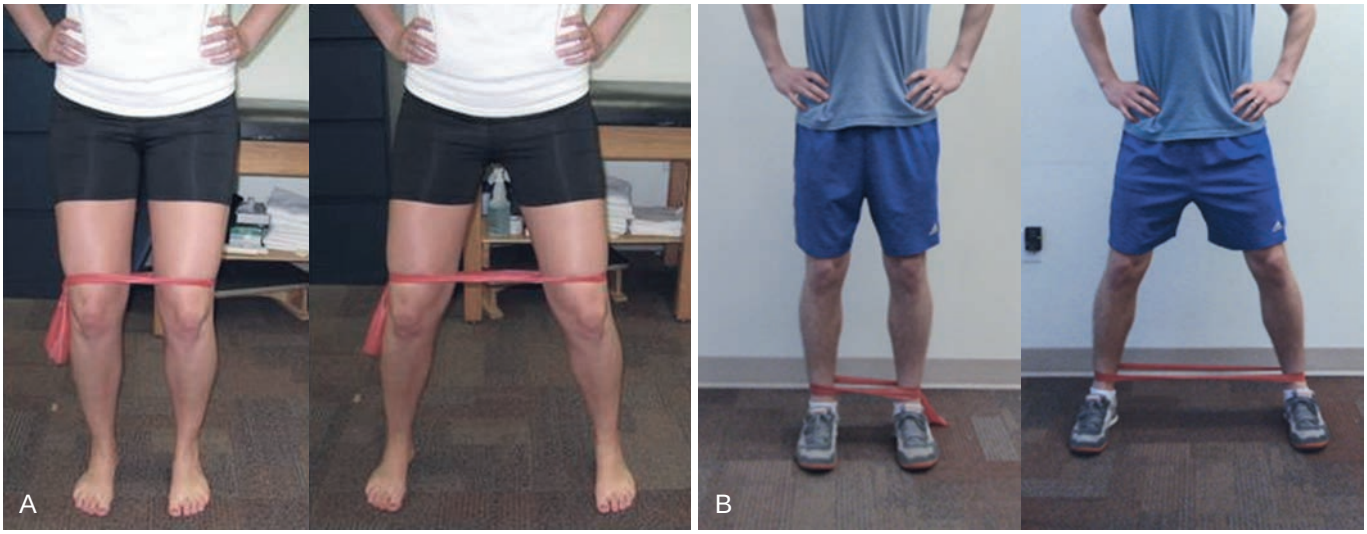

FIGURE 26-34 Standing side stepping with resistance (abduction). *A,* Side step with elastic band placed around distal femur (easier). *B,* Side step with elastic band placed just above the ankles (more difficult). Trunk should remain upright, pelvis level and knee over foot during side stepping.

  - For example, a person with femoral anteversion may be asked to perform hip LR from a position where the foot is turned to a position that is slightly past midline.
  - Clockwise and counterclockwise pelvic rotation against resistance from sport cord or elastic band through partial ROM (Figure 26-35).
- Prone with a pillow placed under the hips and knee flexed to 90°.
  - Active MR and LR
- Sitting upright:
  - Resisted ROM for LR with light to moderate elastic band. Cue to keep the thigh relaxed on the chair and to activate the buttock muscles (deep lateral rotators) to perform the motion. MR is typically not comfortable or necessary to perform in this position.
- Rotation control during sit to stand.
  - Place a circular elastic band around distal femurs. Perform sit to stand while pushing out against the elastic band. The goal for alignment during performance should be to keep the knee over foot (see Figure 26-27).

Exercises for Other Body Regions

- Standing: Hamstring stretch (Figure 26-36).
- Sitting upright: Active knee extension with ankle dorsiflexion for hamstring and gastrocnemius stretching (see Figure 26-28)
- Standing: Calf stretches

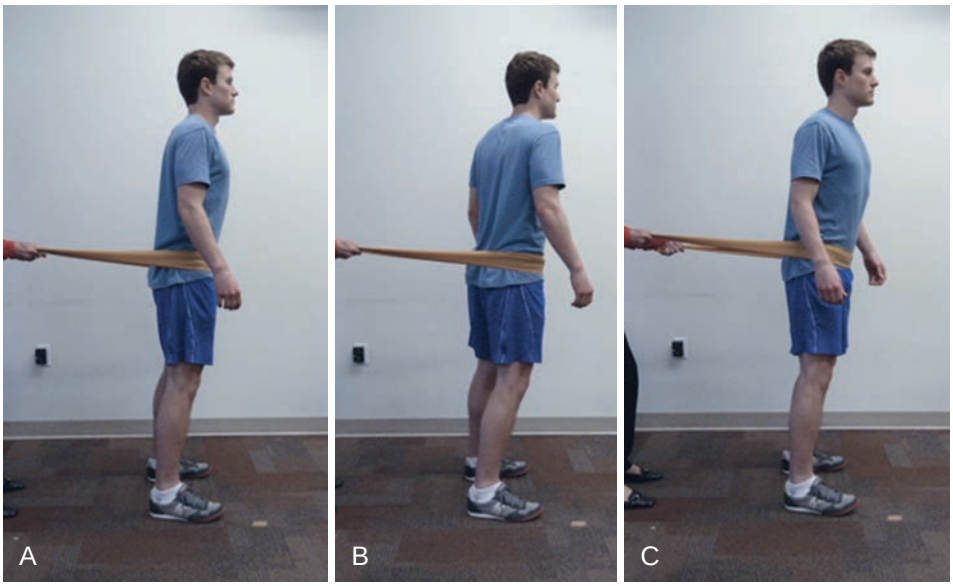

FIGURE 26-35 Pelvic/hip rotation with resistance. *A,* Starting position. *B,* Rotate pelvis counterclockwise (right hip lateral rotation and left hip medial rotation). *C,* Rotate pelvis clockwise (right hip medial rotation and left hip lateral rotation).

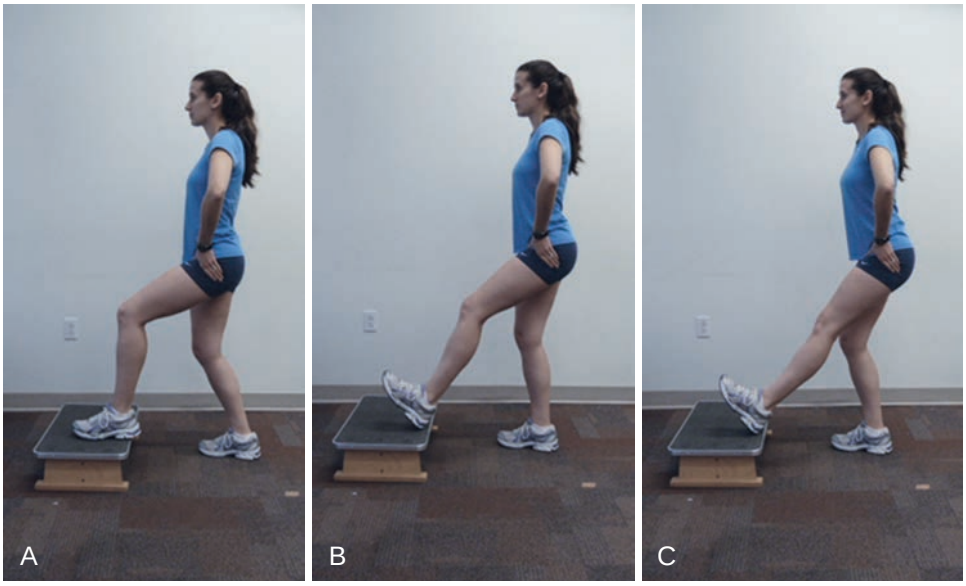

FIGURE 26-36 Standing hamstring stretch. The goal is to maintain an ideal hip joint position while stretching the hamstrings. *A,* Start by placing the foot on a step or short bench so that the hip is flexed. Place hand over proximal thigh. *B,* Apply a gentle posterior force over the proximal femur while extending the knee. *C,* Flexion of the stance knee may be necessary to achieve an appropriate stretch. The trunk may need to shift posteriorly to maintain balance while performing the stretch.

- Standing forward bending with hip flexion only (Figure 26-37)
- General lower extremity strengthening/multipurpose hip and knee
  - Hamstrings and quads (gluts)
    - Partial squat and partial lunge
    - Single leg small knee bend
    - Full lunge
  - Standing: Calf raises
  - General upper extremity strengthening
- General trunk strengthening. Focus on activation of the trunk musculature isometrically while maintaining the spine in a neutral position. Avoid single or double straight leg raises as a method for strengthening abdominals.
  - Resisted upper extremity motions
  - Planks with base of support at the feet.
  - Single leg bridge

Sports Readiness

- Exercises for impact sports, such as soccer, basketball, tennis, running/track, and baseball
- Emphasis is placed on achieving proper form, and then speed or duration may be increased.
  - Hopping: Within each level, begin with short bouts of hopping and longer rests between (15 seconds on: 30 seconds off), then increase on time and decrease off time (30 seconds on: 15 seconds off).
    - Hopping with both lower extremities
      - Emphasis should be placed on landing on both feet evenly and knees aligned over feet (avoid excessive hip adduction).
      - Use support of the upper extremities to decrease the amount of stress through the hip.
      - No upper extremity support
      - Different directions: side-to-side, back and forth, box

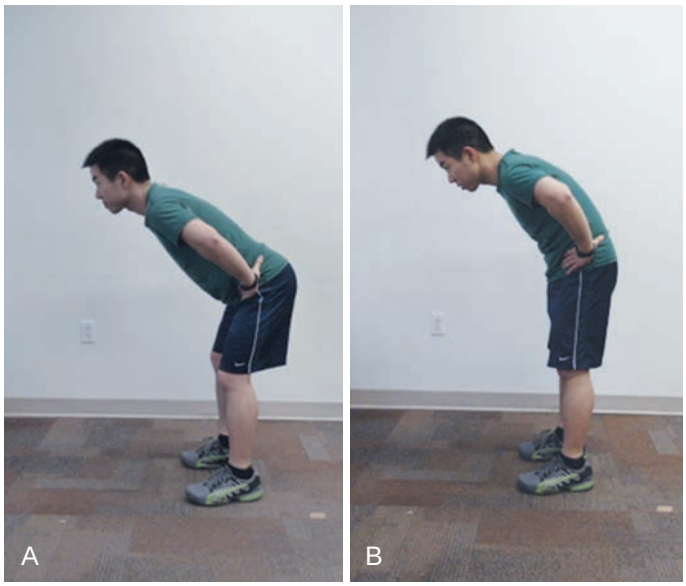

FIGURE 26-37 Standing forward bending and return moving in the hips only. *A,* Correct: Flexion of the trunk over the lower extremities while maintaining a constant position of the spine. Return to standing by contracting the gluteals and extending the hips. *B,* Incorrect: Flexion in the lumbar spine as a substitution for hip flexion.



FIGURE 26-38 Hopping: single lower extremity. *A,* Correct: Note knee is aligned over the foot during landing. *B,* Incorrect: Excessive hip adduction during landing. *C,* Patient attempting to correct alignment after instruction. If patient is unable to correct completely, a lower level activity should be used.

- Progress the same activities using a single lower extremity.
  - During the landing, knee should be aligned over foot (avoid excessive hip adduction) (Figure 26-38).
- Lateral agility (Figure 26-39)
  - Without resistance
  - With sport cord resistance
- Diagonal agility (Figure 26-40)
  - Without resistance
  - With sport cord resistance
- Box lunge (Figure 26-41)
  - Without resistance
  - With sport cord resistance
- Single knee bend
- Jumping down from short surface, 2 inches. Emphasis should be placed on landing on both feet evenly, knees flexed and with knees aligned over toes (avoid hip adduction).The patient should also think about landing softly to help absorb the landing.[6]
  - Jump forward, backward on both feet. Hold the landing with the same guidelines as in the preceding.
  - Jump forward and land on 1 lower extremity with same guidelines as in the preceding.
- Shuffle
  - Sideways in both directions
  - Forward and backward

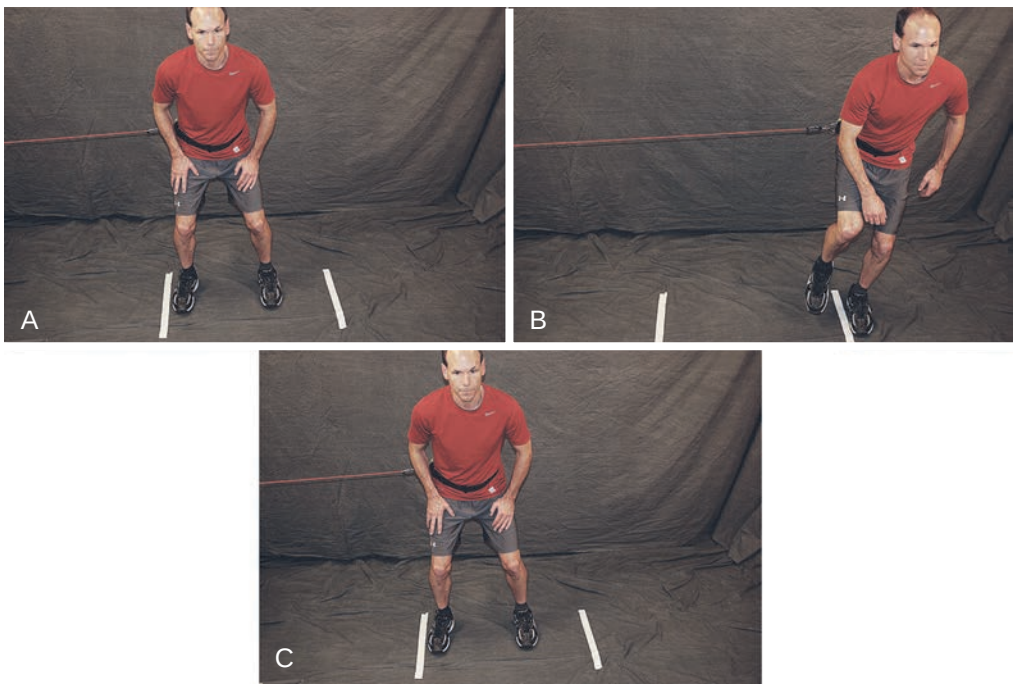

FIGURE 26-39 Lateral agility. *A,* Start position: Sport cord attached from the wall to the waist. First line placed on floor the distance away from wall where the cord remains taut. Second line is placed away from the first line by the distance of the patient's greater trochanter to the floor. *B,* Patient performs a lateral push-off from the leg nearest the wall with enough force to land with the opposite leg past the second line. *C,* The increase in cord tension will result in a force that pulls the patient back. The patient should land in front of the first line and absorb the landing with a controlled squat. *(From Wahoff M, Ryan M: Rehabilitation after hip femoroacetabular impingement arthroscopy.* Clin Sports Med *30(2):463–482, 2011.)*

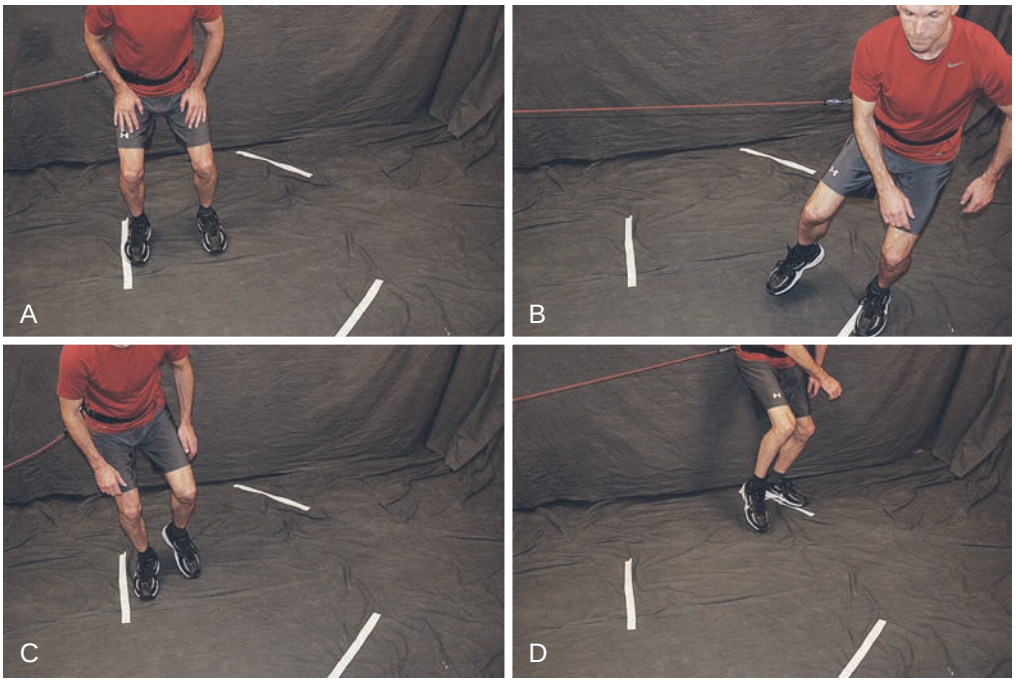

FIGURE 26-40 Diagonal agility. *A,* Start position: Same as lateral agility except two lines are placed at 45° angles forward and backward from the first. *B,* The patient performs the lateral push-off from the leg nearest the wall as before but lands first rep on forward line. *C,* The patient returns to the first line landing in a controlled squat. *D,* The patient performs the next rep landing on the back line and continues alternating forward and backward lines. *(From Wahoff M, Ryan, M: Rehabilitation after hip femoroacetabular impingement arthroscopy. Clin Sports Med 30(2):463–482, 2011.)*

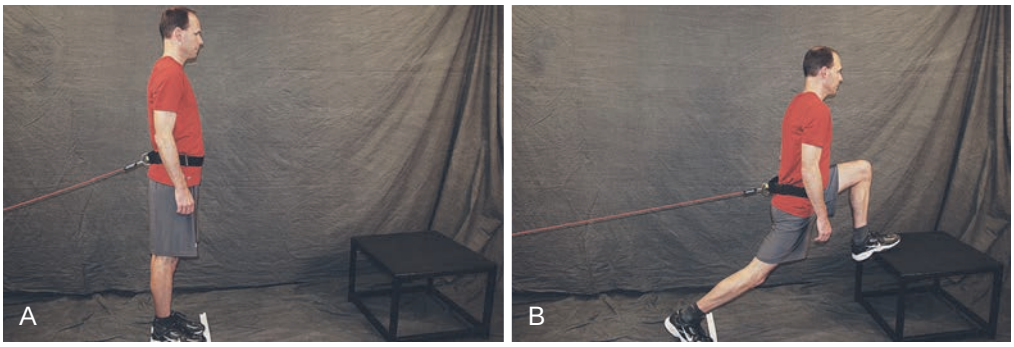

FIGURE 26-41 Forward lunge onto a box. *A,* Start position. Cord attached from wall to back of waist and taut. *B,* Perform a forward lunge onto a box then return and perform with the opposite leg. Height of box will need to be modified according to the patient to avoid excessive hip flexion. *(Modified from Wahoff M, Ryan, M: Rehabilitation after hip femoroacetabular impingement arthroscopy. Clin Sports Med 30(2):463–482, 2011.)*

Exercises for Low Impact Sports (e.g., golf, swimming, and cycling)

- Training activities for individual sports are highly variable. The clinician should consult with coach and athlete to design an appropriate sport-specific program. A few suggestions include:
  - Drills with sport-specific equipment, such as hitting golf balls at the driving range
    - Special considerations for drills require rotation in standing
      - When rotating away from the involved hip, shift weight to the uninvolved limb and be sure the foot of the involved limb pivots around. Do not turn on a fixed foot.
      - When turning toward the involved hip, modify the starting position to allow for optimal hip ROM.
      - For example, the golfer with femoral retroversion in the forward lower extremity should start with the lower extremity turned out slightly to avoid excessive MR during the follow through of the swing.
  - Practice activities specific to the sport at lower levels of intensity and short duration. Progress by gradually increasing either intensity level or duration.

Exercises for Balance and Neuromuscular Training

Activities to improve proprioception of the lower extremity should be incorporated as soon as possible.[4]

- Standing balance activities: The following activities are listed in the order of difficulty.
  - Stance with feet together
  - Tandem stance
  - Stance on unstable surfaces (pillows, foam, trampoline, BOSU ball)
  - Single leg stance
  - Single leg stance on unstable surfaces (pillows, foam, trampoline, BOSU ball)

Each activity can be made more difficult by asking the athlete to maintain balance:

1. For a longer period of time (up to 30 seconds)
2. With eyes closed
3. During perturbations applied by clinician[7]
4. While performing an additional activity, such as playing catch, upper extremity weightlifting, or kicking a ball. Select activity that is meaningful to the athlete's fitness or sport.

- Star balance excursion test[8] can be used as an exercise.

Cardiovascular Fitness

Progress to patient-preferred activities. Increase duration and intensity. Target heart rate is achieved.

- Swimming:
  - Freestyle, backstroke, butterfly
  - No breast stroke
- Upright biking
- Elliptical
- Treadmill
  - Caution to avoid excessive hip extension
- Running
  - When able to walk 30 minutes without increase in symptoms or swelling, may begin running. Alternate walking and running. Gradually increase time running and decrease time walking. For example, walk four minutes, run one minute. Repeat six times = 30 minutes.
  - Once able to run one mile without increasing pain or swelling, may begin other running drills, for example, figure-eight and soft cuts.

Milestones for Progression to the Next Phase

- Many people will achieve their functional and fitness goals after completion of Phase III and may not need to progress to Phase IV.
- If not progressed to Phase IV, the patient should:
  - Be independent in and perform correctly the exercises specific for the hip that are outlined in Phase IV.
  - No limitations or abnormal movement patterns during gait or stairs.
  - No abnormal movement patterns with patient-preferred fitness or sport activity
  - ROM necessary for function and preferred sport
- If progressing to Phase IV, the patient should achieve the milestones noted in the preceding plus:
  - Pass Sport test[9] (Table 26-2)

Table 26-2 Functional Hip Sport Test

Exercise Goal Points
Single knee bends 3 min 1 point earned for each 30 s completed
Lateral agility 100 s 1 point earned for each 20 s completed
Diagonal agility 100 s 1 point earned for each 20 s completed
Forward lunge on box 2 min 1 point earned for each 30 s completed

Passing score: 17 of 20. Emphasis on proper lower extremity alignment during performance of the test.

Modified from Wahoff M, Ryan M: Rehabilitation after hip femoroacetabular impingement arthroscopy. *Clin Sports Med* 30(2):463–482, 2011.

Phase IV (postoperative weeks 12 to 24): Return to Sport

Clinical Pearls

- Work closely with coach to determine appropriate transition back into sport.
- Continue to follow clinical pearls described in Phases II and III, regarding movement impairments, muscle performance, individual variations in bony structure, and joint mobility and relative flexibility.

Goals

- Maximize strength and endurance of lower extremity.
- Maximize agility, speed and power.
- Progress sport-specific activities to include rotational and diagonal movements.
- Promote symmetry with sport-specific drills.
- Education in maintenance program.
- Provide feedback to athlete on performance to help with motivation and reduce fear.

Techniques for Progressive Increase in Range of Motion, Muscle Activation, and Other Therapeutic Exercises

Advanced Exercises and Drills

- Jump-training program[6,10] (Box 26-1)
- Shuttle runs
- Cutting drills with soft cuts, hard cuts, cut and spin
  - Z cuts and W cuts
- Running program to increase speed and endurance

Sport-Specific Exercises and Drills

Training activities for individual sports are highly variable. The clinician should consult with coach and athlete to design an appropriate sport-specific program. A few suggestions include:

- Drills with sport-specific equipment, such as basketball, hockey stick, soccer
- Partner drills
- Sport cord: Sport-specific activities resisted with sport cord

Maintenance Exercises Primarily for the Hip

Recommend continued performance of these exercises a minimum of three per week in addition to the sport-specific workout.

- Strength/muscle activation
  - Iliopsoas:
    - Sitting: Resistance at end-range of hip flexion by using the hand. May need to allow slight LR as hip is flexed for comfort. If pain or popping is reported when lowering the thigh, cue to "relax the muscles [iliopsoas] and let the thigh drop down."
  - Gluteus maximus:
    - Quadruped: Active hip extension (knee flexed to 90°): Lift the lower extremity from starting position toward 0°. Cue to use lower abdominals to

BOX 26-1 Jump-Training Program for Prevention of Anterior Cruciate Ligament Injuries in Female Athletes

Exercise	Duration or Repetitions by Week	
PHASE I: TECHNIQUE	**WEEK 1**	**WEEK 2**
1. Wall jumps	20 seconds	25 seconds
2. Tuck jumps*	20 seconds	25 seconds
3. Broad jump stick (hold) landing	5 repetitions	10 repetitions
4. Squat jumps*	10 seconds	15 seconds
5. Double-legged cone jumps*	30 seconds/30 seconds	30 seconds/30 seconds (side-to-side and back-to-front)
6. 180-degree jumps	20 seconds	25 seconds
7. Bounding in place	20 seconds	25 seconds
PHASE II: FUNDAMENTALS	**WEEK 3**	**WEEK 4**
1. Wall jumps	30 seconds	30 seconds
2. Tuck jumps*	30 seconds	30 seconds
3. Jump, jump, jump, vertical jump	5 repetitions	8 repetitions
4. Squat jumps*	20 seconds	20 seconds
5. Bounding for distance	1 run	2 runs
6. Double-legged cone jumps*	30 seconds/30 seconds	30 seconds/30 seconds (side-to-side and back-to-front)
7. Scissors jump	30 seconds	30 seconds
8. Hop, hop, stick landing*	5 repetitions/leg	5 repetitions/leg
PHASE III: PERFORMANCE	**WEEK 5**	**WEEK 6**
1. Wall jumps	30 seconds	30 seconds
2. Step, jump up, down, vertical	5 repetitions	20 repetitions
3. Mattress jumps	30 seconds/30 seconds	30 seconds/30 seconds (side-to-side and back-to-front)
4. Single-legged jumps, distance*	5 repetitions/leg	5 repetitions/leg
5. Squat jumps*	25 seconds	25 seconds
6. Jump into bounding*	3 runs	4 runs
7. Hop, hop, stick landing	5 repetitions/leg	5 repetitions/leg

GLOSSARY OF JUMP-TRAINING EXERCISES

- 180-degree jump: two-footed jump. Rotate 180 degrees midair, hold landing for 2 seconds, repeat in reverse direction.
- Bounding for distance: start bounding in place, slowly increase distance with each step, keeping knees high.
- Bounding in place: jump from one leg to the other, straight up and down, progressively increasing rhythm and height.
- Broad jump stick (hold) landing: two-footed jump as far as possible, hold landing for 5 seconds.
- Cone jump: double-legged jump with feet together, quickly jump side-to-side over cones, repeat forward and backward.
- Hop, hop, stick landing: single-legged hop, stick second landing for 5 seconds, increase distance of hop as technique improves.
- Jump into bounding: two-footed broad jump, land on single leg, then progress into bounding for distance.
- Jump, jump, jump, vertical jump: three broad jumps with vertical jump immediately after landing the third broad jump.
- Mattress jump: two-footed jump on mattress, trampoline, or other easily compressed device, perform side-to-side and back-to-front.
- Scissors jump: start in stride position with one foot well in front of other.
- Single-legged jump, distance: single-legged hop for distance, hold landing (knees bent) for 5 seconds.
- Squat jump: standing jump raising both arms overhead, land in squatting position, touching both hands to floor.
- Step, jump up, down, vertical: two-footed jump onto 6- to 8-inch step, jump off step with two feet, and then vertical jump.
- Tuck jump: from standing position, jump and bring both knees up to chest as high as possible, repeat quickly
- Wall jump (ankle bounces): with knees slightly bent and arms raised overhead, bounce up and down off toes.

Stretching and Weight-Training Program

STRETCHES†	WEIGHT-TRAINING EXERCISES‡
1. Calf stretch with bent knee	1. Abdominal curl
2. Calf stretch with straight knee	2. Back hyperextension
3. Quadriceps	3. Leg press
4. Hamstring	4. Calf raise
5. Hip flexors	5. Pullover
6. Iliotibial band/lower back	6. Bench press
7. Posterior deltoids	7. Latissimus dorsi pull-down
8. Latissimus dorsi	8. Forearm curl
9. Pectorals/biceps	9. Warm-down short stretch

Note: Before jumping exercises: stretching (15–20 minutes), skipping (2 laps), side shuffle (2 laps).
During training: Each jump exercise is followed by a 30-second rest period.
Post-training: cool-down walk (2 minutes), stretching (5 minutes), weight training (after 15-minutes rest).
*These jumps performed on mats.
†Stretching consists of three sets of 30 seconds each.
‡Weight training consists of one set of each exercise, generally 12 repetitions for upper body exercises and 15 repetitions for the trunk and lower body exercise.
From Hewett TE, Lindenfeld TN, Riccobene JV, Noyes FR: The effect of neuromuscular training on the incidence of knee injury in female athletes. *Am J Sports Med* 27:699–706, 1999.

stabilize pelvis while moving the lower extremity. Because many tend to extend the knee during hip extension, cue to keep the knee flexed throughout the movement. Increase repetitions and sets as appropriate.
  - Posterior gluteus medius:
    - Side lying: Hips and knees slightly flexed
      - Active abduction, extension, and LR by lifting the top lower extremity. Slowly lower the lower extremity to neutral abduction/adduction and lift again. Increase repetitions and sets as appropriate. Knee should be relaxed (unlocked). Cue to keep the pelvis stable and avoid lateral pelvic tilt.
  - Deep hip lateral rotators:
    - Sitting upright resisted ROM for LR with light to moderate elastic band. MR is typically not comfortable or necessary to perform in this position.
  - Medial rotators: (pivoting) something in standing
    - Standing on uninvolved side with involved foot resting on heel, forefoot lifted
      - Resisted MR with elastic band. (Cue to move knee and foot together, not just the foot.)
- ROM/flexibility
  - Hip flexion ROM: Do not force hip flexion ROM. Focus on isolating hip flexion and avoiding lumbar flexion. A safe exercise is rocking backward in quadruped position.
  - Hip extension ROM: Focus on isolating hip extension and avoiding lumbar extension. A safe exercise is prone hip extension with the knee extended. Cues should be given to contract the abdominals to stabilize the pelvis and avoid pelvic anterior tilt or rotation during hip extension.
  - Hip rotation: Focus on isolating hip rotation and avoiding lumbopelvic rotation or tibiofemoral motion.[11] A safe exercise is prone hip rotation with the knee flexed to 90°. Hip should be in neutral abduction/adduction, but if faulty motion cannot be avoided, the hip may be placed in abduction or a pillow placed under the hips.
  - TFL-ITB and rectus femoris: A safe exercise is prone knee flexion with the hip should be in neutral abduction/adduction and rotation. If faulty motion cannot be avoided (anterior pelvic tilt or rotation or lateral tibial rotation), the hip may be placed in abduction or a pillow placed under the hips. To control lateral tibial rotation, may perform bilateral knee flexion with the heels and toes together. A more aggressive stretch can be achieved with the two joint hip flexor stretch (see Figure 26-22). Avoid this stretch if the athlete has excessive femoral anterior glide during extension.
  - Hamstrings: Hamstring stretches should start with the hips flexed and focus on movement of the knee. Avoid lumbar flexion. A safe exercise is sitting knee extension. Another suggestion is the standing hamstring stretch (see Figure 26-36).

Cardiovascular Fitness

Activities to target cardiovascular fitness should be progressed as tolerated.

Criteria for Return to Sport

The following criteria should be met before performing functional testing.
- Pain-free ROM (varies across individuals)
- Pain-free hopping
- Safe and proper performance of hops, broad jumps, lateral step, and direction changes.

Functional Testing

General lower extremity testing to determine if asymmetries exist between the uninvolved and involved extremity. Tests are to be performed on the involved and uninvolved side. The following equations are then used to quantify lower extremity asymmetry.
- Limb symmetry index (LSI)[12]
  - Distance measures = involved side/uninvolved side × 100
  - Timed measures = uninvolved side/involved side × 100

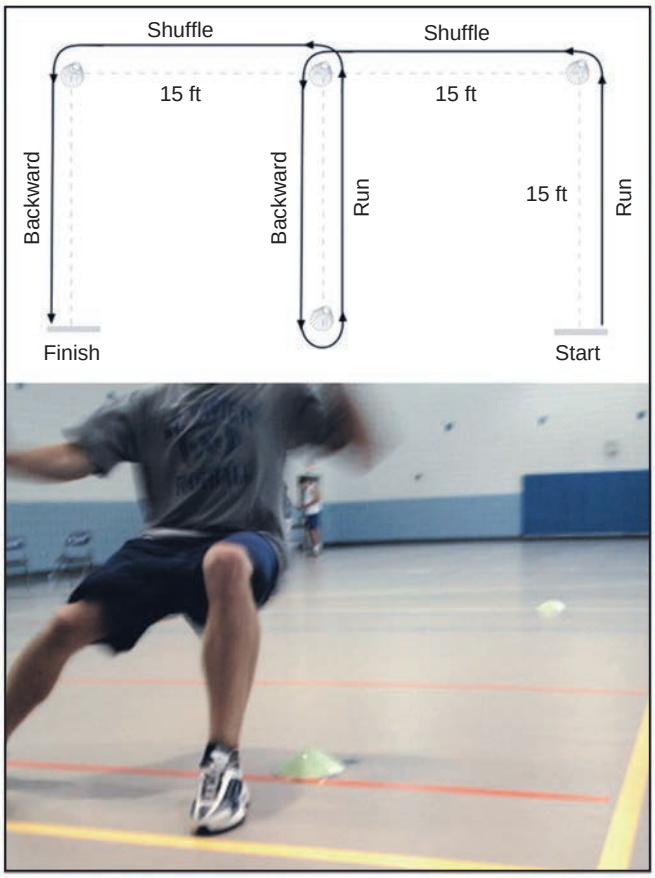

FIGURE 26-42 Modified agility T-test. Test is performed in both directions to assess both lower extremities. The time to complete the test with the involved limb is compared to the time on the uninvolved limb. The limb being tested is the limb pushing off during the shuffle. For example, the direction indicated in the figure would test the right lower extremity. The direction would be reversed to assess the left lower extremity. *(From Myer GD et al: Utilization of modified NFL combine testing to Identify functional deficits in athletes following ACL reconstruction.* J Orthop Sports Phys Ther *41(6);377–388, 2011.)*

Recommend that the athlete participate in one round of testing for practice before scoring.[13]

Performance of Functional Testing

- Double limb performance tests[12]
  Recommend LSI > 85-90%[14]
  - Modified agility T-test (Figure 26-42)
  - Modified ProShuttle (Figure 26-43)
  - Modified long shuttle (Figure 26-44)
- Single limb performance tests

These tests have been shown to be more sensitive to limb asymmetries.[12]

Recommend LSI greater than 85% to 90%[14–17]

- Hop tests[13,18,19] (Figure 26-45)
  - Single hop for distance
  - Crossover hop for distance
  - Triple hop for distance
  - Six-meter timed hop
- Lateral step[20]

The following values are based on a small sample of young, uninjured subjects (14 males and four females); however, the values may be useful to gauge the performance of the athlete.

- Number of repetitions completed in 15 seconds.
  - 0.15 m step = 25.5 ± 3.8 repetitions
  - 0.20 m step = 22.9 ± 3.1 repetitions
- Time needed to complete 50 repetitions
  - 0.15 m step = 29.5 ± 4.6 seconds
  - 0.20 m step = 34.4 ± 6.6 seconds
- Sport/position-specific functional testing
- Sport specific activities may be used to assess the athlete's ability to safely perform activities required in the sport.

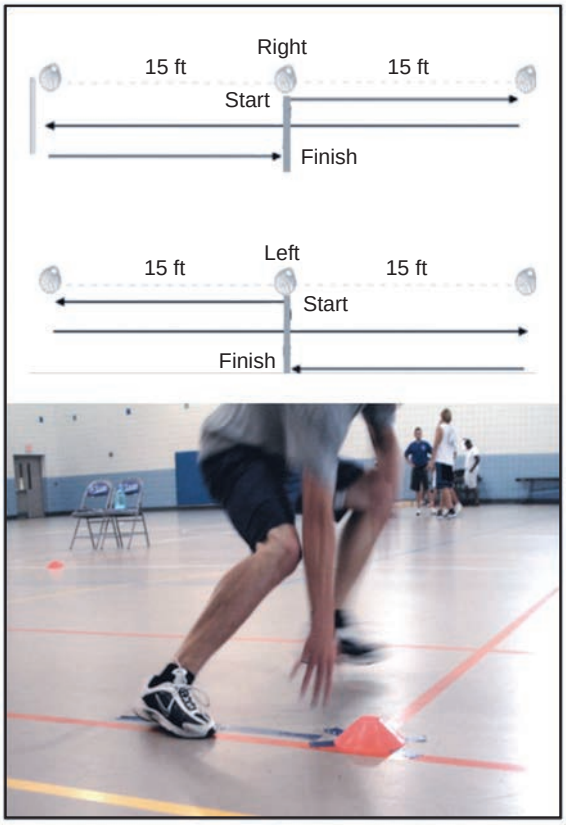

FIGURE 26-43 Modified ProShuttle test. Test is performed in both directions to assess both lower extremities. The time to complete the test with the involved limb is compared with the time on the uninvolved limb. The limb being tested is the limb initiating the first push off. Athlete starts in a three-point stance at the middle cone. The athletes sprints 15 feet, touches the cone with the outside hand, turns, and sprints in the opposite direction (30 feet), touches the cone with the outside hand, turns, and sprints to finish. *(From Myer GD et al: Utilization of modified NFL combine testing to Identify functional deficits in athletes following ACL reconstruction.* J Orthop Sports Phys Ther *41(6);377–388, 2011.)*

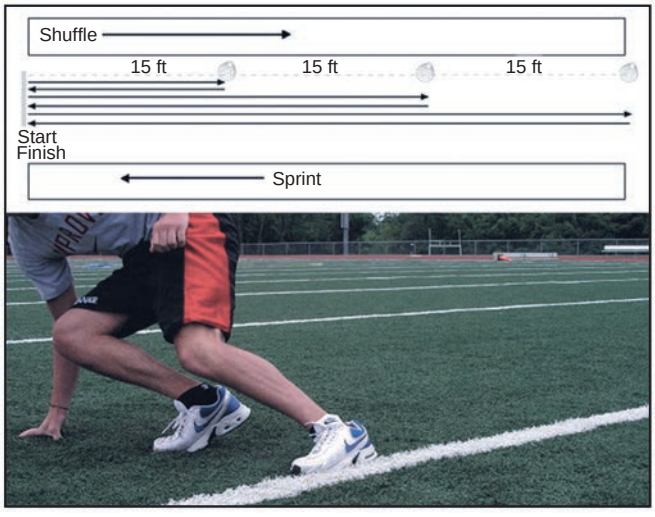

FIGURE 26-44 Modified long shuttle test. Test is performed in both directions to assess both lower extremities. The time to complete the test with the involved limb is compared to the time on the uninvolved limb. The limb being tested is the limb pushing off during the shuffle. The athlete shuffles to the first marker, touching the marker and sprinting to the starting line, turns and shuffles to the second marker and sprints. This is repeated for each of the longer distances. *(From Myer GD et al: Utilization of modified NFL combine testing to Identify functional deficits in athletes following ACL reconstruction.* J Orthop Sports Phys Ther *41(6);377–388, 2011.)*

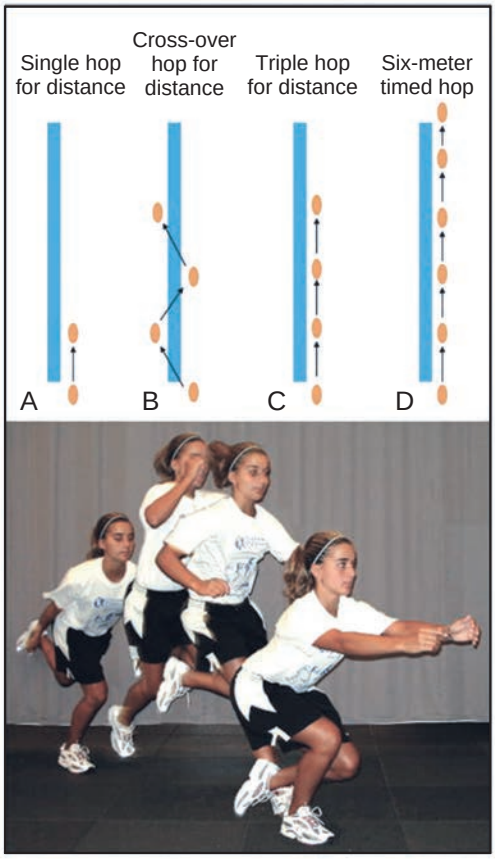

FIGURE 26-45 Hop tests. Tests are performed bilaterally and time or distance compared. *(From Myer GD et al: Utilization of modified NFL combine testing to Identify functional deficits in athletes following ACL reconstruction.* J Orthop Sports Phys Ther *41(6);377–388, 2011.)*

Evidence

Evidence specific to the postoperative rehabilitation after femoroacetabular impingement treatment is limited. Most literature available on rehabilitation is clinical commentary and no treatment trials are available. We have annotated studies that support treatment suggestions provided.

Byrd JW, Jones KS: Arthroscopic management of femoroacetabular impingement in athletes. *Am J Sports Med* 39:7S–13S, 2011.

This is a prospective case series of 200 athletes with femoroacetabular impingement treated with hip arthroscopy. All patients participated in a patient-specific postoperative program that included initial protected gait, ROM, strengthening, then functional return to sporting activities. At 19 months, patients reported a median improvement of 20 points on the modified Harris hip score. Ninety-five percent of the professional athletes and 85% of the collegiate athletes returned to sport. (Level IV evidence)

Clohisy JC, Zebala LP, Nepple JJ, et al: Combined hip arthroscopy and limited open osteochondroplasty for anterior femoroacetabular impingement. *J Bone Joint Surg Am* 92:1697–1706, 2010.

This is a retrospective study of 35 patients with cam femoroacetabular impingement that were treated with hip arthroscopy and limited open osteochondroplasty. At two years, the patients reported reduced symptoms, an improvement in function as demonstrated by a 24-point increase on the Modified Harris Hip score and enhanced activity. (Level IV evidence)

Clohisy JC, St John LC, Schutz AL: Surgical treatment of femoroacetabular impingement. A systematic review. *Clin Orthop Relat Res* 468:555–564, 2010.

The systematic review was performed to determine the level of evidence available related to surgical management of femoroacetabular impingement. Eleven studies that reported a minimum of 2-year follow-up were included in review. The studies reported reduced symptoms and improved hip-specific function in 68% to 96% of patients over a mean of 3.2 years. (Level IV evidence)

Hewett TE, Lindenfeld TN, Riccobene JV, et al: The effect of neuromuscular training on the incidence of knee injury in female athletes, a prospective study. *Amer J Sport Med* 27:699–706, 1999.

This prospective cohort study of 1263 athletes compared the ACL injury rate between 2 groups, 1 group completing a training program before sports participation, and the other group not trained. The training program included jump training emphasis the pattern and technique of the movements. Female athletes who participated in the training program demonstrated a decreased incidence of knee injury. (Level I evidence)

Lewis CL, Sahrmann SA, Moran DW: Effect of position and alteration in synergist muscle force contribution on hip forces when performing hip strengthening exercises. *Clin Biomech* 24:35–42, 2009.

The authors use a musculoskeletal model to estimate the hip joint forces during common lower extremity strengthening exercises. The authors concluded that hip joint forces are increased when the hip moves into extension while performing prone hip extension. Forces are increased further if the gluteus maximus is not performing optimally. (Measurement study)

Klingenstein GG, Martin R, Kivlan B, et al: Hip injuries in the overhead athlete. *Clin Orthop Relat Res* 470(6):1579–1585, 2012.

This retrospective study assessed the outcomes of 34 high-level baseball and lacrosse players after arthroscopic treatment of FAI. Surgical procedures varied according to patient pathology to include acetabuloplasty, femoroplasty, and labral repair or debridement. All patients participated in a standard postoperative rehabilitation program that included initial protected weightbearing, ROM, and isometrics that was then progressed to active and resistive activities. Modified Harris Hip score improved from 70 to 92. At 12 months, 33 of 34 returned to their previous level of sport. (Level IV evidence)

Myer GD, Schmitt LC, Brent JL, et al: Utilization of modified NFL combine testing of identify functional deficits in athletes following ACL reconstruction. *J Orthop Sport Phys Ther* 41:377–387, 2011.

This case control study used a modified NFL Combine testing technique to assess performance in athletes following ACL reconstruction. The testing included double- and single-limb activities. The authors found that unilateral tests, such as single leg hopping, are needed to identify unilateral deficits. (Level III evidence)

Nepple JJ, Zebala LP, Clohisy JC: Labral disease associated with femoroacetabular impingement. Do we need to correct the structural deformity? *J Arthroplasty* 24(6 Suppl):114–119, 2009.

This prospective cohort study compared the outcomes of 23 patients with labral disease and FAI undergoing arthroscopic labral resection to 25 patients undergoing arthroscopic labral resection with a limited open osteochondroplasty. The Modified Harris hip score tended to be higher and fewer subjects required subsequent surgery among patients undergoing the combined arthroscopy and osteochondroplasty, compared to those undergoing arthroscopy alone. (Level III evidence)

Philippon MJ, Weiss DR, Kuppersmith DA, et al: Arthroscopic labral repair and treatment of femoroacetabular impingement in professional hockey players. *Am J Sports Med* 38(1):99–104, 2010.

Twenty-eight professional hockey players unable to participate in their sport because of painful FAI underwent arthroscopic acetabular rim trimming, femoral neck osteoplasty, and labral tear. Postoperative physical therapy started with restoring passive hip ROM, followed by active ROM and strengthening. Average time to return to hockey drills was 3.8 months. Modified Harris Hip score improved from 70 to 95 at two years. Two players required additional surgery. (Level IV evidence)

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Multiple-Choice Questions

QUESTION 1. A variety of surgical procedures may be performed when correcting FAI. Across all procedures, which ROM precaution is key and for what time frame?

A. Minimal medial and lateral rotation for 2 weeks
B. Hip abduction to 20° for 2 weeks
C. Hip flexion no greater than 90° for 4 weeks
D. Hip extension to 10° for 4 weeks

QUESTION 2. Why are active and resistive abduction exercises delayed with patients treated by surgical dislocation?

A. Acetabular labral repair protection
B. Need for joint healing from the dislocation
C. To prevent femoral head osteonecrosis
D. Protect the trochanteric osteotomy site for bony healing

QUESTION 3. As weightbearing is increased in Phase II, which of the following gait deviations is the most common and should be corrected before removal of an assistive device?

A. Hip adduction or pelvic drop during stance
B. Prolonged hip extension during midstance to push off
C. Excessive hip medial rotation
D. Sidebending of the trunk during stance
E. All of the above

QUESTION 4. When should sports readiness drills and neuromuscular retraining be introduced in the rehabilitative process?

A. Weeks 4 to 8
B. Weeks 8 to 16
C. Weeks 12 to 24
D. Weeks 24 to 30

QUESTION 5. Proper muscle activation and performance of the primary hip muscles is a focus of rehabilitation throughout all phases. In addition, exercises to maintain optimal performance of these muscles is important. Identify these primary hip muscles.

A. Iliopsoas, gluteus maximus, gluteus medius, deep LRs, MRs
B. Rectus femoris, hamstrings, posterior gluteus medius, gluteus maximus
C. Tensor fascia lata-iliotibial band, hamstrings, adductors, rectus femoris
D. Iliopsoas, adductors, hamstrings, tensor fascia lata-iliotibial band

Answer Key

QUESTION 1. Correct answer: **C** (see Table 26-1).

QUESTION 2. Correct answer: **D** (see Timeline 26-2).

QUESTION 3. Correct answer: **E** (see Gait section, Phase II).

QUESTION 4. Correct answer: **B** (see Phase III).

QUESTION 5. Correct answer: **A** (see Clinical Pearl box, Phase II, and Exercises for Primary Hip Muscles in all phases, especially Phase IV).

BEYOND BASIC REHABILITATION: RETURN TO BASEBALL AFTER OPERATIVE TREATMENT OF FEMOROACETABULAR IMPINGEMENT

Trevor Ryan Gaskill, MD, Mark Andrew Ryan, MS, ATC, CSCS, and Marc J. Philippon, MD

ASPECTS OF BASEBALL THAT REQUIRE SPECIAL ATTENTION IN REHABILITATION

- Sport-specific activities of baseball players require a unique coordination between the upper and lower extremity.
- These are unique to the player's position (pitcher vs. position player) and rehabilitation must be individualized based on these specific requirements.
- It is critical to "train" the athlete throughout all rehabilitation phases.
- It is our experience that this approach improves athlete motivation and ensures physical conditioning of the unoperated extremities for safe return to sport.
- Maintenance of upper and nonoperative lower extremity strength as well as cardiovascular conditioning are emphasized.
- Although training is incorporated into all rehabilitation phases, it should be progressively emphasized in successive phases when more advanced activities can be safely tolerated.
- The return to sport timeline should be individualized based on the specific needs of the athlete.
- Return to sport, however, should not exceed the body's physiological ability to heal the surgical repair.
- Therefore return to sport should occur no faster than indicated in protocol timelines; however, additional rehabilitation time may optimize the ability to return to sport in some circumstances.
- All athletes should successfully complete a "sports test" prior to returning to sport.
- This test is designed to help ensure adequate physiological hip conditioning prior to returning to high demand activities.

Introduction

- Femoroacetabular impingement (FAI) is increasingly being identified as an etiology of hip pain in young, athletic populations.
- The movements used to play baseball require cooperation between the upper and lower extremities that functionally places the "at-risk hip" in a position of abnormal bony conflict.
- For this reason, symptomatic femoroacetabular impingement is not uncommon in this population.
- The functional demands placed on the hip, however, are varied and position specific.
- For example, pitchers experience deep hip flexion of the leading leg and extension and external rotation of the push-off leg during the pitching motion.
- Position players by contrast experience explosive axial rotation of the hips during hitting and fielding activities.
- This variability makes the treatment and rehabilitation of these athletes more complex.
- It requires surgical intervention and postoperative rehabilitation to be individualized to the activities that result in hip impingement.
- For this reason, no one rehabilitation protocol can be ubiquitously applied. Therefore position specific rehabilitation protocols will be discussed.

Literature

- It is established that femoroacetabular impingement is a common cause of hip dysfunction in athletes and is responsible for mechanical damage to labral and cartilaginous tissue.
- Though hip impingement is no longer a novel concept, our understanding of, ability to treat, and rehabilitation experience has grown exponentially over the past few years.

- To date, very little published literature is available to guide rehabilitation of athletes undergoing decompression of abnormal bony conflict within the hip.
- To our knowledge no published scientific literature describes rehabilitation specific to baseball players.
- Under these circumstances both an understanding of the stresses experienced by the hip when competing in baseball and experience treating these particular athletes become critical to optimizing return to sport for these athletes.

Phase III: Sport-Specific Training

Periodization

- The return to sporting activity after hip arthroscopy for femoroacetabular impingement and labral repair has several important physiological considerations.
  - Healing of a surgical repair occurs over a relatively defined and predictable timeframe. Introduction of certain activities prior to sufficient healing may jeopardize surgical outcomes. This fact alone makes linear periodization a primary consideration in the design of postsurgical rehabilitation protocols.
  - After sufficient healing of the surgical repair, more advanced strength and endurance activities are introduced. Because training for these modalities has been limited in the acute postsurgical period, a gradual progression into these activities is also necessary, as discussed in previous chapters.
  - Once a foundation of conditioning is established and healing has occurred, functional sport-specific activities are introduced. Because many of these activities have not been performed vigorously for months, a linear progression is also necessary.
- It is our goal to incorporate as many sport-specific activities as is safe beginning in the immediate postoperative period and progress these activities as healing allows. The postoperative program therefore consists of multiple microcycles and mesocycles within a linear progression, within physiological healing parameters. Athletes are progressed through basic to complex skill sets while increasing performance speed and duration.

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- Most return to sport programs begin approximately 2 weeks after normal gait has been established. This typically occurs around 6 to 8 weeks postsurgically. Prior to this time frame, flexibility and joint mobility are emphasized to minimize the risk of postsurgical adhesions within the hip. Core strengthening, gait, and balance training are also part of the early training process prior to introduction of conditioning exercises. When appropriate, upper extremity and nonoperative cardiovascular conditioning are incorporated into the program.
- Subsequent to this initial healing phase, it is safe to incorporate training to optimize balance, strength, endurance, and power. For example, a squat type progression might include basic double leg body weight squats, progress to body weight squats on uneven surfaces such as a BOSU, weight-resisted squats, single leg squats, and finally squat jumps. Additional progressions for core, hamstrings, deep hip rotators, and lateral hip stabilizers (gluteus medius) would also be concurrently completed.
- Concurrently, sport-specific progressions are initiated, including a throwing, running, fielding, and hitting progression. These progressions are included at the end of the chapter. Once these progressions are successfully completed, the athlete may return to their preinjury training regimen.

Olympic Lifts Used in the Training Program

- No Olympic lifts are routinely used in our return to baseball progression after arthroscopic treatment of femoroacetabular impingement. Alternatively, it is our preference to incorporate functional, sport-specific activities throughout the rehabilitation period to introduce these complex motor activities at a gradual pace; for example, exercises such as multiplanar lunges and resisted cable chops. Prior to actual hitting, athletes will swing a lighter weight fungo bat or broomstick for dry swinging and a slower speed, progressing to higher speeds, and finally a game bat. They will then progress to hitting in the cage.
- Additionally, it is our experience that athletes experience greater satisfaction and motivation as these activities are progressively instituted into the rehabilitation/training progression. Olympic lifts may be added back into the athlete's strength and conditioning program upon full return to game activity if the athlete has had previous experience performing the lifts.

Training Principles Used in the Design of the Program

- Progression and specific adaptation to imposed demand are used in the design of the return to sport program. As the athlete is able to perform the prescribed sport specific activities with the appropriate technique and without undue fatigue or pain, the prescribed activities can be advanced. Progression occurs through activity complexity, speed, intensity, and duration. Moreover, the frequency the athlete participates in the prescribed activity may also be increased.

Application of Acute Training Variables

- During each aspect of the return to baseball progression, several acute training variables are applied. Initial movements are performed in a controlled environment with planned movement patterns such as dry swinging in the clinic with a lighter weight bat at slow speeds, throwing short distances (30 ft), and fielding hand-fed ground balls to a known location to the athlete. These movements are progressed from basic to complex while speed and duration of activities are also increased gradually.
- To this end, sets and repetitions are gradually increased. In later phases, the frequency of training within each week also increases. As throwing distances increase for

pitchers and activities become more unpredictable for position players, intensity similarly increases. Tempo of the activities is also gradually increased over the training to simulate game conditions prior to return to unrestricted sporting activity.

Application of Chronic Training Variables

- The goal of return to sport training is to safely return an athlete to sport-specific activities while minimizing the risk of recurrent injury while the body is deconditioned. Therefore after successfully returning the athlete safely to sport, the athlete's typical training program can be restarted. It is important for the athlete, however, to continue a hip-specific strengthening program to maintain strength, endurance, and stability of the hip musculature This may include double and single leg squats, glute bridging, single leg RDLs, multidirectional core movements such as resisted wood chops or med ball throws, and core stabilization exercises such as planks and side planks

Sports Performance Testing

General Information

- A general history is obtained that includes the athlete's activity level, playing position, injury mechanism, inciting activities, and surgical procedure performed.
- Any other medical history, chronic injuries, or medications that may affect rehabilitation are also elicited.
- Subjective patient outcome questionnaires are also routinely obtained prior to surgery and intermittently throughout the rehabilitation process.

TIMELINE 26-3: **Beyond Basic Rehabilitation: Return to Baseball after Surgical Treatment of Femoroacetabular Impingement**

Weeks 1 to 6	Weeks 7 to 16
	All positions—running progression (3×/week)

• Follow general FAI rehabilitation protocol.
• Athlete may include cardiovascular activities beginning at 2 weeks postop.
  • General recommendations include: swimming with pull buoy, one-leg rowing, UBE and upper body exercise
• Athlete may include light upper body conditioning at 2 weeks postop.
  • General recommendations include: TRX suspension trainer
• Athlete may initiate rotator cuff maintenance program at 2 weeks.
All athletes should prepare to pass sport test between weeks 10 and 12 postoperatively.
	Weeks 1–6: Continue general FAI rehabilitation protocol in entirety.
	Begin Week 8 after 2 weeks of waist-deep water running if normalized gait, good abductor control, and the ability to perform 1 minute of single leg squats is present.
	Week 8: Walk 4 min, jog 1 min × 4 = 20 min
	Week 9: Walk 3 min, jog 2 min × 4 = 20 min
	Week 10: Walk 2 min, jog 3 min × 4 = 20 min
	Week 11: Run 8 × 180 yds (Poles) w/180-yd walking recovery
	Week 12: Run 10 × 180 yds (Poles) w/180-yd walking recovery (faster pace)
	Week 13: Run 10 × 180 yds (Poles) w/180-yd walking recovery (faster pace)
	Week 14: Base running (home to first × 4, first to third × 2, second to home × 2)
	Week 15: Base running (see above) Game Speed
	Week 16: Base running (see above) Game Speed + sliding

Specific Tests

- The Hip Sports Test is performed approximately 10 to 16 weeks postoperatively. It is intended to ensure adequate hip musculature conditioning necessary to protect the hip during sporting activities. No formal research has been completed to validate its effectiveness in predicting reinjury or readiness for return to sport. The authors have found it to be an effective clinical tool to test muscular endurance and stability of the hip musculature and also demonstrate what movement patterns may be painful to the athlete. We have found clinically that athletes who go through the process of training for the sport test have high compliance with the overall rehabilitation process and have proved to have high levels of endurance and stability. How this relates specifically to their ability to play baseball has yet to be determined.
- If the athlete is not able to pass the testing, it also serves as a guide to the type of rehabilitation necessary to optimize the athlete's recovery.

Objective Tests

- Single leg squat (3-minute max): 6 pts
  - **Description:** The athlete will perform single knee bends with cord resistance to 60° at a cadence of 1 second up and 1 second down for a goal of 3 minutes. The movement is between 30° to 60° of flexion with the knee never fully straightening past 30° throughout the 3 minutes. To cue the athlete to the depth of 60°, the buttocks can lightly touch the seat of a chair

TIMELINE 26-3 Beyond Basic Rehabilitation: Return to Baseball after Surgical Treatment of Femoroacetabular Impingement (Continued)

Weeks 7 to 16

Pitchers—throwing program	Position players—fielding progression
Weeks 1–6: Continue general FAI rehabilitation protocol in entirety. Week 7: • Monday: 10 @ 30', 20 @ 45' • Wednesday: 10 @ 30', 20 @ 45' • Friday: 20 @ 30', 20 @ 45' Week 8: • Monday: 20 @ 30', 20 @ 45' • Wednesday: 20 @ 30', 20 @ 45', 10 @ 60' • Friday: 20 @ 30', 20 @ 45', 10 @ 60' Week 9: • Monday: 10 @ 30', 20 @ 45', 20 @ 60' • Wednesday: 10 @ 30', 20 @ 45', 20 @ 60' • Friday: 10 @ 30', 10 @ 45', 20 @ 60', 10 @ 75' *Beginning week 10 add light toss on Tuesday, Thursday, and Saturday* Week 10: • Monday: 10 @ 30', 10 @ 45', 20 @ 60', 10 @ 75' • Wednesday: 10 @ 30', 10 @ 45', 20 @ 60', 20 @ 75' • Friday: 10 @ 30', 10 @ 45', 20 @ 60', 20 @ 75' Week 11: • Monday: 10 @ 45', 10 @ 60', 20 @ 75', 10 @ 90', 10 @ 60' • Wednesday: 10 @ 45', 10 @ 60', 20 @ 75', 10 @ 90', 10 @ 60' • Friday: 10 @ 45', 10 @ 60', 10 @ 75', 20 @ 90', 10 @ 60' Week 12: • Monday: 10 @ 45', 10 @ 60', 10 @ 75', 10 @ 90', 10 @ 105', 10 @ 60' • Wednesday: 10 @ 45', 10 @ 60', 10 @ 75', 10 @ 90', 10 @ 105', 10 @ 60' • Friday: 10 @ 45', 10 @ 60', 10 @ 75', 10 @ 90', 20 @ 105', 10 @ 60' Week 13: • Monday: 10 @ 45', 10 @ 60', 10 @ 75', 10 @ 90', 20 @ 105', 10 @ 60' • Wednesday: 10 @ 45', 10 @ 60', 10 @ 75', 10 @ 90', 10 @ 105', 10 @ 120', 10 @ 60' • Friday: 10 @ 45', 10 @ 60', 10 @ 75', 10 @ 90', 10 @ 120', 10 @ 60' Week 14: • Monday: 10 @ 45', 10 @ 60', 10 @ 75', 10 @ 90', 10 @ 105', 20 @ 120' • Wednesday: Side mound 55', 20-25 pitches • Friday: Side mound 60', 30-35 pitches, Week 15: • Monday: Side mound, 35-40 pitches, • Wednesday: Side mound 40-45 pitches • Friday: Side mound 45-50 pitches Week 16: • Monday: Sim game 40-45 pitches (2-3 innings) • Wednesday: Long toss • Friday: Sim game 50 pitches (3-4 innings) Week 17: Game activity	Weeks 1–7: Continue general FAI rehabilitation protocol in entirety. *Position dependent. Athletes should be progressed from basic sport-specific movement patterns to predictable reactive movements, to faster predictable movements, and finally unpredictable game simulation movements over a 6-week period.* Week 8: • Infielder: Lateral shuffles, crossovers (backhand) • Outfielder: Lateral shuffles, drop-step, backward jogging Week 9: • Infielder: Hand thrown grounders (easy reach and direction known by athlete) • Outfielder: Hand-thrown pop-ups & grounders Week 10: Infielder & Outfielder: Predictable fungo at position (add range) Week 11: • Infielder & Outfielder: Predictable fungo at position (add range) • Catcher: Bullpens Week 12: • Infielder & Outfielder: Reactive fungo at position • Catcher: Bullpens, blocking Week 13: • Infielder & Outfielder: Reactive fungo at position (add range) • Catcher: Bullpens, blocking, foul balls • Pitcher: Predictable fungo at position Week 14: • Infielder & Outfielder: Field bullpen • Catcher: Bullpens, blocking, foul balls • Pitcher: Predictable fungo at position, situational fielding Week 15: All: Simulated game Week 16: All: Simulated game activities (add range) Week 17: All: Game activity

or object. Two fingers are allowed for balance on a chair back.
  - **Setup:**
    - With a goniometer, measure a 60° knee bend and place a chair in a position to allow the athlete's buttocks to lightly touch at that depth.
    - The athlete places the heel of the foot on the cord at a position so the D-ring of the handle is aligned with the knee joint line to remove slack from the cord.
    - Tension is set by pulling the cord handle to the waist line and holding. Having the athlete hook her or his thumb around the pant line is helpful in maintaining tension on the cord.
    - Two fingers of the opposite hand are allowed to lightly touch another chair back for balance.
  - **Technique:** The athlete must perform each repetition of a single knee bend *without* the following:
    - Trendelenburg sign (pelvis must remain level)
    - The knee locking in full extension
    - The knee "collapsing" into medial rotation/adduction
    - The patella extending past the toe

    Cuing should be provided when one of the following compensations are noted. **If unable to correct, STOP THE TEST.**
  - **Scoring:** One point is earned for each 30-second increment completed with proper form for a total of 6 possible points.
  - **Testing is stopped if and when:**
    Form: once the subject is unable to complete single knee bends without compensation even with cuing
    - Pain: the patient has pain greater than 3/10 OR reproduces his/her pain
    - Endurance: the athlete fatigues
- Lateral agility test (100 seconds max): 5 pts
  - **Purpose:** To test the ability of the leg to accept load (absorb) and push off in a lateral direction
  - **Supplies:** Sport cord (Topper Sports Medicine, black cord), stopwatch, and tape
  - **Description:** The athlete will hop laterally with cord resistance from the surgical leg, land momentarily on the nonsurgical leg, only to return onto the surgical leg with the cord pulling the athlete back to the starting position for a total test time of 100 seconds. Each repetition of 1 second includes exploding laterally off the surgical side, landing momentarily on the opposite leg, and then returning to the starting position with emphasis on absorbing by bending at the hip and knee with 30° of knee excursion. Excursion is defined as the amount of absorption from knee flexion at landing to max knee flexion.
  - Setup:
    - Place the belt through the sport cord handles and then attach around the waist.
    - Attach the other end of the sport cord to the door jam or secure post.
    - Stand sideways with the involved leg toward the cord attachment.
    - Step away laterally until tension is reached where the athlete slightly compensates with leaning and place a line with tape on the lateral aspect of the involved foot.
    - Measure the distance from the greater trochanter to the floor.
    - Use this measured distance to place a second tape line parallel to the first.
  - **Technique:** The athlete must perform each lateral hop by landing on or inside the first tape line with the *involved* foot and on or outside the second tape line with the *uninvolved* foot. Only one foot should be on the ground at the same time and the athlete must absorb onto the involved leg without the following:
    - Trendelenburg sign (pelvis must remain level)
    - The knee "collapsing" into medial rotation/adduction
    - The patella extending past the toe
    - Losing control or stability

    Cuing should be provided when one of the following compensations are noted. **If unable to correct, STOP THE TEST.**
  - Scoring: One point is earned for each 20 second increment completed with proper form for a total of 5 possible points.
  - Testing is stopped if and when:
    - Form: once the subject is unable to complete single knee bends without compensation even with cuing
    - Pain: the patient has pain greater than 3/10 OR reproduces her/his pain
    - Endurance: the athlete fatigues
- Diagonal agility test (100 seconds max): 5 pts
  - **Purpose:** To test the ability of the leg to accept load (absorb) and push off in a diagonal direction.
  - **Supplies:** Sport cord (Topper Sports Medicine, black cord), stopwatch, and tape
  - **Description:** The athlete will hop diagonally forward at a 45° angle with cord resistance from the surgical leg, land momentarily on the nonsurgical leg, only to return onto the surgical leg with the cord pulling the athlete back to the starting position. The following repetition the athlete will hop diagonally backward at a 45° angle. The goal is 100 seconds total. Each repetition of 1 second includes exploding diagonally forward or backward at 45° angles off the surgical side, landing momentarily on the opposite leg, and then returning to the starting position with emphasis on absorbing by bending at the hip and knee with 30° of knee excursion. Excursion is defined as the amount of absorption from knee flexion at landing to max knee flexion.
  - Setup:
    - Place the belt through the sport cord handles and then attach around the waist.
    - Attach the other end of the sport cord to the door jam or secure post.
    - Stand sideways with the involved leg toward the cord attachment.
    - Step away laterally until tension is reached where the athlete slightly compensates with leaning and place a line with tape on the lateral aspect of the involved foot.
    - Measure the distance from the greater trochanter to the floor.
    - Use this measured distance to place a second tape line at a 45° angle forward and a third tape line at a 45° backward to form a V if connecting the lines.

- **Technique:** The athlete must perform each diagonal lateral hop by landing on or inside the first tape line with the *involved* foot and on or outside the second or third tape line with the *uninvolved* foot. (Each foot should land parallel with each tape line). Only one foot should be on the ground at the same time and the athlete must absorb onto the involved leg *without* the following:
  - Trendelenburg sign (pelvis must remain level)
  - The knee "collapsing" into medial rotation/adduction
  - The patella extending past the toe
  - Losing control or stability

    Cuing should be provided when one of the following compensations are noted. **If unable to correct, STOP THE TEST.**
- Scoring: One point is earned for each 20-second increment completed with proper form for a total of 5 possible points.
- Testing is stopped if and when:
  - Form: once the subject is unable to complete single knee bends without compensation even with cuing
  - Pain: the patient has pain greater than 3/10 OR reproduces his/her pain
  - Endurance: the athlete fatigues

- Forward single leg lunges (2-minute max): 4 pts
  - **Purpose:** To test the lower extremity strength and endurance into extension.
  - **Supplies:** Sport cord (Topper Sports Medicine, black cord), stopwatch, and tape
  - **Description:** The athlete will perform alternating forward lunges onto a box with cord resistance at a cadence of 2 seconds per lunge for a goal of 2 minutes. The movement is a forward lunge with maximum hip extension without compensation at the pelvis or spine throughout the 2 minutes.
  - **Setup:**
    - Place the belt through the sport cord handles and then attach around the waist.
    - Attach the other end of the sport cord to the door jam or secure post.
    - Stand facing away from the cord attachment.
    - Step forward until tension is reached where the athlete slightly compensates by leaning and tape a line in front of the feet.
    - Measure the distance from the greater trochanter to the floor.
    - Place a stable box or chair the height of the athlete's knees in front of them at a distance equal to the measure of the greater trochanter to the floor.
  - **Technique:** The athlete must perform *alternating* forward lunges onto the box keeping their planted leg behind the line and extending the hip *without* the following:
    - Trendelenburg sign (pelvis must remain level)
    - Excessive lumbar hyperextension
    - Pelvic rotation

      Correct performance of this activity is through proper extension of the hip.
  - **Scoring:** One point is earned for each 30-second increment completed with proper form for a total of 4 possible points.
  - **Testing is stopped if and when:**
    - Form: once the subject is unable to complete single knee bends without compensation even with cuing
    - Pain: the patient has pain greater than 3/10 OR reproduces her/his pain
    - Endurance: the athlete fatigues
- A score of greater than 16 is required prior to return to advanced sporting activities. Points are deducted based on inadequate form (i.e., Trendelenburg, collapse of the leg into internal rotation of adduction, or the use of a chair for support rather than balance) or the lack of endurance (i.e., failure to maintain rhythm or trembling).[1]

Specific Criteria for Progression to the Next Stage to Determine Readiness for Baseball

- Progression to any subsequent phase of rehabilitation should not occur until the goals of the previous phase can be completed appropriately and without undue discomfort. These goals include pain-free completion of each step of the throwing, hitting, running, and fielding progressions listed at the end of the chapter.
- Sport specific rehabilitation (apart from general rehabilitation after arthroscopic hip surgery) should not be started until the surgeon and therapist are satisfied sufficient biological healing has occurred and that the hip musculature has been conditioned to a point the functional sporting activity is not likely to be detrimental to the overall recovery process. This typically occurs 6 to 8 weeks postsurgically at the postop followup with the surgeon, though some basic components can be incorporated earlier if cleared verbally by the surgeon.
- Each phase of the sports specific training should be able to be completed without discomfort. If discomfort occurs, the athlete should return to the prior satisfactorily completed phase.

Specific Criteria for Release to Unsupervised Complete Participation in Baseball

- Prior to returning to complete participation without further supervision, several criteria must be present.
  - First, each phase of the general femoroacetabular impingement rehabilitation protocol must be completed to ensure appropriate conditioning of the hip musculature. As part of this non–sport-specific rehabilitation program, the athlete should be required to pass the hip sports test.
  - Second, the athlete should be progressed through a sport-specific training program as detailed later. This progression ensures gradual return to functional sport specific activities to minimize injury risk.
  - Ultimately, as part of a return to sport program, the athlete should be able to perform in simulated game situations without limitation prior to full return to sport, including baseball practice, simulation games, and gradual return to play such as playing three innings, then six innings, and finally nine-inning games.

Recommended Ongoing Exercises

- Analogous to the shoulder's rotator cuff, it is important for all athletes to engage in a general hip conditioning program. This is even more important in the postsurgical patient.
- Exercises including single leg squats, stool rotations, and standing hip abduction exercises are frequently recommended as maintenance exercises in postsurgical patients. They also serve as a good basic hip program for all athletes. Additionally, glute bridges (one and two legged), step-ups, and lateral band walks can be used.

Evidence

Enseki KR, Martin RL, Draovitch P, et al: The hip joint: arthroscopic procedures and postoperative rehabilitation. *J Orthop Sports Phys Ther* 36:516–525, 2006.

This report emphasizes the need for rehabilitation protocols to be individualized based on the principals of soft tissue healing and patient characteristics. These concepts remain critical in the postoperative rehabilitation of femoroacetabular impingement. (Level V evidence)

Philippon M, Schenker M, Briggs K, et al: Femoroacetabular impingement in 45 professional athletes: associated pathologies and return to sport following arthroscopic decompression. *Knee Surg Sports Traumatol Arthrosc* 15:908–914, 2007.

This retrospective review of professional athletes treated arthroscopically for femoroacetabular impingement indicates 93% of athletes were able to return to sport and 78% remained active in professional sport an average of 1.6 years later. Athletes unable to return to professional sport all demonstrated diffuse osteoarthritis at the time of arthroscopy. This suggests that arthroscopic treatment of hip impingement, coupled with rehabilitation and return to sport training, allow athletes to return to a high level of functioning when osteoarthritis is not present. (Level IV evidence)

Stalzer S, Wahoff M, Scanlan M: Rehabilitation following hip arthroscopy. *Clin Sports Med* 25:337–357, 2006.

This report describes an early rehabilitation protocol that stresses several important theoretic considerations. These principles include consideration of soft tissue healing constraints, edema control, early passive motion, early neuromuscular control, strengthening and proprioception, and sport-specific rehabilitation. While rehabilitation after hip arthroscopy continues to evolve, these considerations remain important. (Level V evidence)

Wahoff M, Ryan M: Rehabilitation after hip femoroacetabular impingement arthroscopy. *Clin Sports Med* 30:463–482, 2011.

The phases of a current rehabilitation protocol and their rationale are discussed. Because few evidence-based rehabilitation studies have been reported, current protocols are frequently based on expert opinion. To this end, it is thought that the introduction of early passive circumduction and functional sport progressions will better enable patients to effectively return to sport. (Level V evidence)

REFERENCE

1. Garrison JC, Shanley E, Thigpen C, et al: The reliability of the Vail Sport Test™ as a measure of physical performance following anterior cruciate ligament reconstruction. *Int J Sports Phys Ther* 7(1):20–30, 2012.

Multiple-Choice Questions

QUESTION 1. Maintenance of cardiovascular conditioning should be incorporated into the rehabilitation protocol:

A. As soon as feasible.
B. Six-weeks postoperatively.
C. Three months postoperatively.
D. Not until sport-specific training is completed.

QUESTION 2. Return to baseball after arthroscopic treatment of femoroacetabular impingement is different from other sports because:

A. There is no difference
B. Athletes do not suffer from FAI.
C. Position played affects rehabilitation timing and drills.
D. Impingement is typically in the upper extremity.

QUESTION 3. Sport-specific training should begin:

A. In the immediate postoperative period where appropriate.
B. Six weeks postoperatively.
C. 12 weeks postoperatively.
D. After basic hip rehabilitation is completed.

QUESTION 4. A hip sport test should be completed 10 to 12 weeks postoperatively and is intended to:

A. Judge hip range of motion.
B. Evaluate for residual impingement.
C. Slow return to sport.
D. Ensure adequate hip musculature conditioning to protect the hip during sport activity.

QUESTION 5. Return to sport principals include which of the following?

A. Soft tissue healing rate
B. Individual athlete goals
C. Gradual return to sport-specific activities/situations
D. All of the above

Answer Key

QUESTION 1. Correct answer: **A** (see Introduction)

QUESTION 2. Correct answer: **C** (see Introduction)

QUESTION 3. Correct answer: **A** (see Introduction)

QUESTION 4. Correct answer: **D** (see Objective Tests)

QUESTION 5. Correct answer: **D** (see Evidence)

BEYOND BASIC REHABILITATION: RETURN TO GOLF AFTER OPERATIVE TREATMENT OF FEMOROACETABULAR IMPINGEMENT

Trevor Ryan Gaskill, MD, Mark Andrew Ryan, MS, ATC, CSCS, and Marc J. Philippon, MD

ASPECTS OF GOLF THAT REQUIRE SPECIAL ATTENTION IN REHABILITATION

- Competitive golfers place considerable torsional loads on the hip joint. These activities are unique to golfers and therefore require an individualized approach to rehabilitation after hip arthroscopy.
- It is critical to "train" the athlete throughout all rehabilitation phases. It is our experience this approach improves athlete motivation and ensures physical conditioning of the unoperated extremities for safe return to sport.
- Maintenance of upper and nonoperative lower extremity strength as well as cardiovascular conditioning is emphasized.
- Although training is incorporated into all rehabilitation phases, it is progressively emphasized in successive phases when more advanced activities can be safely tolerated.
- The return to sport timeline should be individualized based on the specific needs of the athlete. Return to sport, however, should not exceed the body's physiological ability to heal the surgical repair.
- Therefore return to sport should occur no faster than indicated in protocol timelines; however, additional rehabilitation time may optimize the ability to return to sport in some circumstances.
- All athletes should successfully complete a "sports test" before returning to sport. This test is designed to help ensure adequate physiologic hip conditioning prior to returning to high-demand activities. Femoroacetabular impingement is a common cause of hip pain in young active athletes.
- Although symptoms may be produced by any activity sufficient to result in bony conflict, the torsional load that occurs repetitively to a golfer's hip places the "at-risk hip" in a position capable of impingement and is unique to these athletes.
- To this end, an individualized return to golf program is imperative to the successful return to sport after arthroscopic management of femoroacetabular impingement.

Introduction

Literature

- It is established that femoroacetabular impingement is a common cause of hip dysfunction in athletes and is responsible for mechanical damage to labral and cartilaginous tissue.
- Although hip impingement is no longer a novel concept, our understanding of, ability to treat, and rehabilitation experience continues to evolve.
- To date, little literature is available to guide rehabilitation of athletes undergoing decompression of abnormal bony conflict within the hip. To our knowledge, no published scientific literature describes rehabilitation specific to golfers.
- Under these circumstances, both an understanding of the stresses experienced by the hip when competing in this sport and experience treating these particular athletes become critical to optimizing return to sport for these athletes.

Advanced Strength and Conditioning Programs

Periodization

- The return to sporting activity after hip arthroscopy for femoroacetabular impingement and labral repair has several important physiological considerations.
- First, healing of a surgical repair occurs over a relatively defined and predictable time frame.
- Introduction of certain activities before sufficient healing may jeopardize surgical outcomes. This fact alone makes linear periodization a primary consideration in the design of postsurgical rehabilitation protocols.
- After sufficient healing of the surgical repair, more advanced strength and endurance activities are introduced. Because training for these modalities has been limited in the acute postsurgical period, a gradual progression into these activities is also necessary, as discussed in previous chapters.
- Once a foundation of conditioning is established and healing has occurred, functional sport-specific activities are introduced.
- Because many of these activities have not been performed vigorously for months, a linear progression is also necessary.
- It is the authors' goal to incorporate as many sport-specific activities as is safe beginning in the immediate postoperative period and progress these activities as healing allows.
- The postoperative program therefore consists of multiple microcycles and mesocycles within a linear progression within physiological healing parameters.
- Athletes are progressed through basic to complex skill sets while increasing performance speed and duration.

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- Most return to sport programs begin approximately 2 weeks after normal gait has been established. This typically occurs around 6 to 8 weeks postsurgically.
- Before this time frame flexibility and joint mobility are emphasized to minimize the risk of postsurgical adhesions within the hip.
- Core strengthening, gait, and balance training are also part of the early training process before introduction of conditioning exercises.
- When appropriate, upper extremity and nonoperative cardiovascular conditioning are incorporated into the program.
- Subsequent to this initial healing phase, it is safe to incorporate training to optimize balance, strength, endurance, and power. For example, a squat type progression might include basic double leg body weight squats, progress to body weight squats on uneven surfaces such as a BOSU, weight-resisted squats, single leg squats, and finally squat jumps. Additional progressions for core, hamstrings, deep hip rotators, and lateral hip stabilizers (gluteus medius) would also be concurrently completed.
- Sport-specific activities are incorporated gradually beginning with putting, chipping, and pitching. The athlete can begin incorporating a progression of full swinging with irons at approximately 50% intensity with increased intensity of 10% to 20% a week until full power swinging is achieved provided there is no increase in hip pain. Drivers can then be added to the practice program in Week 5. (The full progression is described in the chart at the end of the chapter.)
- Olympic lifts used in the training program
  - Olympic lifts are not routinely used in our return to sport progression for golfers after arthroscopic treatment of femoroacetabular impingement.
  - Alternatively, it is our preference to incorporate functional, sport-specific activities throughout the rehabilitation period to introduce these complex motor activities at a gradual pace. For golfers, these include performing simulated golf swings in the pool, slow-speed simulated golf swings with resistant

TIMELINE 26-4: **Beyond Basic Rehabilitation: Return to Golf after Surgical Treatment of Femoroacetabular Impingement**

Weeks 0 to 2	Weeks 4 to 12	
	All golfers swing progression (3×/week)	**Concurrent walking progression if needed (tournament players not allowed to use carts) (3×/week)**

• Follow general FAI rehabilitation protocol
• Athlete may include cardiovascular activities beginning at 2 weeks postop
  • General recommendations include: swimming with pull buoy, one-leg rowing, upper body exercise
• Athlete may include light upper body conditioning at 2 weeks postop
  • General recommendations include: TRX suspension trainer
• Athlete may initiate rotator cuff maintenance program at 2 weeks
	Begin 3x/week, minimum 2 weeks after weaning off crutches. Add additional day Weeks 4 and 6 if needed.
	Weeks 1–6: Continue general FAI rehabilitation protocol in entirety.
	Week 1: Putting, chipping at 20% (approx. 30 minutes)
	Week 2: Continue putting, chipping, pitching at 40% (approx. 30 minutes)
	Week 3:
	• Continue putting, chipping and pitching
	• Add: Mid irons starting at 50%
	Week 4:
	• Continue putting, chipping and pitching
	• Add: Swing intensity up to 70%
	Week 5:
	• Continue putting, chipping and pitching
	• Add: Woods/driver starting at 50%, irons at 90%
	Week 6:
	• Continue putting, chipping and pitching
	• Add: Woods/driver up to 70%, irons up to 95%
	• Can play holes within intensity levels outlined
	Week 7: Play 9 holes using cart, swinging woods at up to70%, irons up to 95%
	Weeks 8–9: Play 9 holes, walk if there is a need to, swinging woods at 80%, irons at 100%
	Weeks 9–10: Play 18 holes, with cart, swinging woods at 90%, irons at 100%
	Weeks 11–12: Play 18 holes, walk if there is a need to, swinging 100%
	All athletes should prepare to pass sport test between weeks 10 and 12 postoperatively.
		Begin 3x/week, minimum 2 weeks after weaning off crutches. Add additional day Weeks 4 and 6 if needed
		Weeks 1–6: Continue general FAI rehabilitation protocol in entirety.
		Week 1: 0.25-mile walk
		Week 2: 0.33-mile walk
		Week 3: 0.5-mile walk
		Week 4: 1-mile walk
		Week 5: 1.5-mile walk
		Week 6: 2-mile walk
		Week 7: 2.5-mile walk
		Week 8: 3-mile walk or walk nine-hole course
		Week 9: 3.5-mile walk or walk nine-hole course
		Week 10: 4-mile walk
		Week 11: 4.5-mile walk
		Week 12: 5-mile walk
		Week 13: 6-mile walk or walk 18-hole course
		All athletes should prepare to pass sport test between weeks 10 and 12 weeks postoperatively.

cord, and finally live swinging progressions as described in the preceding.
- Additionally, it is our experience that athletes experience greater satisfaction and motivation as these activities are progressively instituted into the rehabilitation/training progression.
- Olympic lifts may be added back into the athlete's strength and conditioning program upon full return to sport activity if the athlete has had previous experience performing the lifts.

Training Principles Used in the Design of the Program

- Progression and specific adaptation to imposed demand are used in the design of the return to sport program.
- As the athlete is able to perform the prescribed sport-specific activities with the appropriate technique and without undue fatigue or increased pain, golf progression can be advanced.
- Progression occurs through activity complexity, speed and intensity of the activity, and the duration the activity is performed. Moreover, the frequency the athlete participates in the prescribed activity may also be increased.

Application of Acute Training Variables

- During each aspect of the return to golf progression several acute training variables are applied.
- Initial movements are performed in a controlled environment with planned movement patterns. Initial golf swings are done in the clinic or pool. As adaptation and acceptance of these movements are made, activities can be moved outdoors to a driving range, and finally to a course where playing surfaces vary such as uneven lies and bunkers are encountered.
- These movements are progressed from basic to complex, while speed and duration of activities are also increased gradually. To this end, club length, repetitions, and intensity are gradually increased. Skills and activities will progress from easy putting, chipping and pitching using submaximal efforts, to the use of irons at gradually increasing swing power, and finally adding drivers and full power.
- In later phases the frequency of training within each week also increases.
- The tempo of the activities is also gradually increased over the training to simulate match conditions before return to unrestricted sporting activity.

Application of Chronic Training Variables

- The goal of return to sport training is to safely return an athlete to sport-specific activities while minimizing the risk of recurrent injury while the body is deconditioned.
- Therefore after successfully returning the athlete safely to sport, their typical training program can be restarted.
- It is important for the athlete, however, to continue a hip specific strengthening program to maintain strength, endurance, and stability of the hip musculature. These may include double and single leg squats, gluteal bridging, single leg RDLs, multidirectional core movements such as resisted wood chops or med ball throws, and core stabilization exercises such as planks and side planks.

Sports Performance Testing

General Information

- The Hip Sports Test is performed around 10 to 12 weeks postoperatively.
- It is intended to ensure adequate hip musculature conditioning necessary to protect the hip during sporting activities. No formal research has been completed to validate its effectiveness in predicting reinjury or readiness for return to sport, but the authors are unaware of any such test. The authors have found it to be an effective clinical tool to test muscular endurance and stability of the hip musculature and also demonstrate what movement patterns may be painful to the athlete. We have found clinically that athletes who go through the process of training for the sport test have high compliance with the overall rehabilitation process and have proved to have high levels of endurance and stability. How this relates specifically to their ability to play golf has yet to be determined.
- If the athlete is not able to pass the test, it also serves as a guide to the type of rehabilitation necessary to optimize the athlete's recovery.

Objective Tests

- Single leg squat (3 min max): 6 pts
  - **Description:** The athlete will perform single knee bends with cord resistance to 60° at a cadence of 1 second up and 1 second down for a goal of 3 minutes. The movement is between 30° to 60° of flexion with the knee never fully straightening past 30° throughout the 3 minutes. To cue the athlete the depth of 60°, the buttocks can lightly touch the seat of a chair or object. Two fingers are allowed for balance on a chair back.
  - **Setup:**
    - With a goniometer, measure a 60° knee bend and place a chair in a position to allow the athlete's buttocks to lightly touch at that depth.
    - The athlete places the heel of the foot on the cord at a position so the D-ring of the handle is aligned with the knee joint line to remove slack from the cord.
    - Tension is set by pulling the cord handle to the waist line and holding. Having the athlete hook his or her thumb around the pant line is helpful in maintaining tension on the cord.
    - Two fingers of the opposite hand are allowed to lightly touch another chair back for balance
  - Technique: The athlete must perform each repetition of a single knee bend without the following:
    - Trendelenburg sign (pelvis must remain level)
    - The knee locking in full extension
    - The knee "collapsing" into medial rotation/adduction
    - The patella extending past the toe.

      Cuing should be provided when one of the following compensations are noted. **If unable to correct, STOP THE TEST.**
  - Scoring: One point is earned for each 30-second increment completed with proper form for a total of 6 possible points.

- Testing is stopped if and when:
  - Form: Once the subject is unable to complete single knee bends without compensation even with cuing.
  - Pain: The patient has pain greater than 3/10 OR reproduces the pain.
  - Endurance: The athlete becomes fatigued.
- Lateral agility test (100s max): 5 pts
  - Purpose: To test the ability of the leg to accept load (absorb) and push off in a lateral direction.
  - Supplies: Sport cord (Topper Sports Medicine, black cord), stopwatch, and tape
  - Description: The athlete will hop laterally with cord resistance from the surgical leg, land momentarily on the nonsurgical leg, only to return onto the surgical leg with the cord pulling him or her back to the starting position for a total test time of 100 seconds. Each repetition of 1 second includes exploding laterally off the surgical side, landing momentarily on the opposite leg, and then returning to the starting position with emphasis on absorbing by bending at the hip and knee with 30° of knee excursion. Excursion is defined as the amount of absorption from knee flexion at landing to max knee flexion.
  - Setup:
    - Place the belt through the sport cord handles and then attach around the waist.
    - Attach the other end of the sport cord to the door jam or secure post.
    - Stand sideways with the involved leg toward the cord attachment.
    - Step away laterally until tension is reached where the athlete slightly compensates with leaning and place a line with tape on the lateral aspect of the involved foot.
    - Measure the distance from the greater trochanter to the floor.
    - Use this measured distance to place a second tape line parallel to the first.
  - Technique: The athlete must perform each lateral hop by landing on or inside the first tape line with the involved foot and on or outside the second tape line with the uninvolved foot. Only one foot should be on the ground at the same time and the athlete must absorb onto the involved leg without the following:
    - Trendelenburg sign (pelvis must remain level)
    - The knee "collapsing" into medial rotation/adduction
    - The patella extending past the toe
    - Losing control or stability

      Cuing should be provided when one of the following compensations are noted. **If unable to correct, STOP THE TEST.**
  - Scoring: One point is earned for each 20 second increment completed with proper form for a total of 5 possible points.
  - Testing is stopped if and when:
    - Form: Once the subject is unable to complete single knee bends without compensation even with cuing.
    - Pain: The patient has pain greater than 3/10 OR reproduces the pain.
    - Endurance: The athlete becomes fatigued.
- Diagonal agility test (100s max): 5 pts
  - Purpose: To test the ability of the leg to accept load (absorb) and push off in a diagonal direction
  - Supplies: Sport cord (Topper Sports Medicine, black cord), stopwatch, and tape
  - Description: The athlete will hop diagonally forward at a 45° angle with cord resistance from the surgical leg, land momentarily on the nonsurgical leg, only to return onto the surgical leg with the cord pulling him or her back to the starting position. The following repetition the athlete will hop diagonally backward at a 45° angle. The goal is 100 seconds total. Each repetition of 1 second includes exploding diagonally forward or backward at 45° angles off the surgical side, landing momentarily on the opposite leg, and then returning to the starting position with emphasis on absorbing by bending at the hip and knee with 30 degrees of knee excursion. Excursion is defined as the amount of absorption from knee flexion at landing to max knee flexion.
  - Setup:
    - Place the belt through the sport cord handles and then attach around the waist.
    - Attach the other end of the sport cord to the door jam or secure post.
    - Stand sideways with the involved leg toward the cord attachment.
    - Step away laterally until tension is reached where the athlete slightly compensates with leaning and place a line with tape on the lateral aspect of the involved foot.
    - Measure the distance from the greater trochanter to the floor.
    - Use this measured distance to place a second tape line at a 45° angle forward and a third tape line at a 45° backward to form a V if connecting the lines.
  - Technique: The athlete must perform each diagonal lateral hop by landing on or inside the first tape line with the involved foot and on or outside the second or third tape line with the uninvolved foot. (Each foot should land parallel with each tape line.) Only one foot should be on the ground at the same time and the athlete must absorb onto the involved leg without the following:
    - Trendelenburg sign (pelvis must remain level)
    - The knee "collapsing" into medial rotation/adduction
    - The patella extending past the toe
    - Losing control or stability

      Cuing should be provided when one of the following compensations are noted. **If unable to correct, STOP THE TEST.**
  - Scoring: One point is earned for each 20-second increment completed with proper form for a total of 5 possible points.
  - Testing is stopped if and when:
    - Form: Once the subject is unable to complete single knee bends without compensation even with cuing.

    - Pain: the patient has pain greater than 3/10 OR reproduces the pain.
    - Endurance: The athlete becomes fatigued.
- Forward single leg lunges (2 min max): 4 pts
  - Purpose: To test the lower extremity strength and endurance into extension.
  - Supplies: Sport cord (Topper Sports Medicine, black cord), stopwatch, and tape
  - Description: The athlete will perform alternating forward lunges onto a box with cord resistance at a cadence of 2 seconds per lunge for a goal of 2 minutes. The movement is a forward lunge with maximum hip extension without compensation at the pelvis or spine throughout the 2 minutes.
  - Setup:
    - Place the belt through the sport cord handles and then attach around the waist.
    - Attach the other end of the sport cord to the door jam or secure post.
    - Stand facing away from the cord attachment.
    - Step forward until tension is reached where the athlete slightly compensates by leaning and tape a line in front of the feet.
    - Measure the distance from the greater trochanter to the floor.
    - Place a stable box or chair the height of the athlete's knees in front of him or her at a distance equal to the measure of the greater trochanter to the floor.
  - Technique: The athlete must perform *alternating* forward lunges onto the box keeping their planted leg behind the line and extending the hip without the following:
    - Trendelenburg sign (pelvis must remain level)
    - Excessive lumbar hyperextension
    - Pelvic rotation

      Correct performance of this activity is through proper extension of the hip.
  - Scoring: One point is earned for each 30-second increment completed with proper form for a total of 4 possible points.
  - Testing is stopped if and when:
    - Form: Once the subject is unable to complete single knee bends without compensation even with cuing.
    - Pain: The patient has pain greater than 3/10 OR reproduces the pain.
    - Endurance: The athlete becomes fatigued.
- A score of greater than 16 is required before return to advanced sporting activities. Points are deducted based on inadequate form (i.e., Trendelenburg, collapse of the leg into internal rotation of adduction, or the use of a chair for support rather than balance) or the lack of endurance (i.e., failure to maintain rhythm or trembling).[1]

Specific Criteria for Progression to the Next Stage to Determine Readiness for Golf

- Progression to any subsequent phase of rehabilitation should not occur until the goals of the previous phase can be completed appropriately and without undue discomfort.
- Golf progression is described in the preceding.
- Sport-specific rehabilitation (apart from general rehabilitation after arthroscopic hip surgery) should not be started until the surgeon and therapist are satisfied that sufficient biological healing has occurred and that the hip musculature has been conditioned to a point the functional sporting activity is not likely to be detrimental to the overall recovery process. This decision is made at the 8 week physician follow-up.
- This typically occurs 6 to 8 weeks postsurgically, although some basic components can be incorporated earlier.
- Each phase of the sport-specific training should be able to be completed without discomfort. If discomfort occurs, the athlete should return to the prior satisfactorily completed phase.

Specific Criteria for Release to Unsupervised Complete Participation in Golf

- Before returning to complete participation without further supervision, several criteria must be present.
- First, each phase of the general femoroacetabular impingement rehabilitation protocol must be completed to ensure appropriate conditioning of the hip musculature.
- As part of this non–sport-specific rehabilitation program, the athlete should be required to pass the hip sports test.
- Second, the athlete should be progressed through a sport-specific training program as detailed below.
- This progression ensures gradual return to functional sport-specific activities to minimize injury risk.
- Ultimately, as part of a return to sport program, the athlete should be able to perform in simulated game situations (driving range and practice rounds) without limitation before full return to sport.

Recommended Ongoing Exercises

- Analogous to the shoulder's rotator cuff, it is important for all athletes to engage in a general hip-conditioning program.
- This is even more important in the postsurgical patient.
- Exercises including single leg squats, stool rotations, standing hip abduction exercises are frequently recommended as maintenance exercises in postsurgical patients. They also serve as a good basic hip program for all athletes. Additionally, gluteal bridges (one- and two-legged), step ups and lateral band walks can be used.

Evidence

Enseki KR, Martin RL, Draovitch P, et al: The hip joint: arthroscopic procedures and postoperative rehabilitation. *J Orthop Sports Phys Ther* 36:516–525, 2006.

This report emphasizes the need for rehabilitation protocols to be individualized based on the principals of soft tissue healing and patient characteristics. These concepts remain

critical in the postoperative rehabilitation of femoroacetabular impingement. (Level V evidence)

Philippon M, Schenker M, Briggs K, et al: Femoroacetabular impingement in 45 professional athletes: associated pathologies and return to sport following arthroscopic decompression. *Knee Surg Sports Traumatol Arthrosc* 15:908–914, 2007.

This retrospective review of professional athletes treated arthroscopically for femoroacetabular impingement indicates 93% of athletes were able to return to sport and 78% remained active in professional sport an average of 1.6 years later. Athletes unable to return to professional sport all demonstrated diffuse osteoarthritis at the time of arthroscopy. This suggests that arthroscopic treatment of hip impingement, coupled with rehabilitation and return to sport training allow athletes to return to a high level of functioning when osteoarthritis is not present (Level IV evidence).

Stalzer S, Wahoff M, Scanlan M: Rehabilitation following hip arthroscopy. *Clin Sports Med* 25:337–357, 2006.

This report describes an early rehabilitation protocol that stresses several important theoretic considerations. These principles include consideration of soft tissue healing constraints, edema control, early passive motion, early neuromuscular control, strengthening and proprioception, and sport-specific rehabilitation. Although rehabilitation after hip arthroscopy continue to evolve, these considerations remain important. (Level V evidence)

Wahoff M, Ryan M: Rehabilitation after hip femoroacetabular impingement arthroscopy. *Clin Sports Med* 30:463–482, 2011.

The phases of a current rehabilitation protocol and their rationale are discussed. Because few evidence-based rehabilitation studies have been reported, current protocols are frequently based on expert opinion. To this end, it is thought that the introduction of early passive circumduction and functional sport progressions will better enable patients to effectively return to sport. (Level V evidence)

REFERENCE

1. Garrison JC, Shanley E, Thigpen C, et al: The reliability of the Vail Sport Test as a measure of physical performance following anterior cruciate ligament reconstruction. *Int J Sports Phys Ther* 7(1):20–30, 2012.

Multiple Choice Questions

QUESTION 1. Maintenance of cardiovascular conditioning should be incorporated into the rehabilitation protocol:

A. As soon as feasible.
B. Six weeks postoperatively.
C. Three months postoperatively.
D. Not until sport-specific training is completed.

QUESTION 2. Sport-specific training should begin:

A. In the immediate postoperative period where appropriate.
B. Six weeks postoperatively.
C. 12 weeks postoperatively.
D. After basic hip rehabilitation is completed.

QUESTION 3. Return to sport principals includes which of the following?

A. Soft-tissue healing rate
B. Individual athlete goals
C. Gradual return to sport-specific activities/situations
D. All of the above

QUESTION 4. The major physiological event of concern to the hip with return to golf progressions is:

A. The deep hip flexion required.
B. Upper body endurance.
C. The repetitive torsional strain placed on the healing hip.
D. Early weightbearing.

QUESTION 5. A hip sport test should be completed 10 to 12 weeks postoperatively and is intended to:

A. Judge hip range of motion.
B. Evaluate for residual impingement.
C. Slow return to sport.
D. Ensure adequate hip musculature conditioning to protect the hip during sport activity.

Answer Key

QUESTION 1: Correct answer: **A** (see Introduction)

QUESTION 2: Correct answer: **A** (see Introduction)

QUESTION 3: Correct answer: **D** (see Introduction)

QUESTION 4: Correct answer: **C** (see Evidence)

QUESTION 5: Correct answer: **D** (see Sports Performance Testing: General Information)

Chapter 27



Stress Fractures of the Femoral Neck and Shaft

INTRODUCTION

Bryan C. Heiderscheit, PT, PhD, and Geoffrey S. Baer, MD, PhD

Epidemiology

- Femoral neck stress fractures account for approximately 11% of stress fractures in athletes; the incidence of stress fractures in the femoral shaft has been reported as approximately 3.5%, but is suspected to be as high as 20% in athletes.
- They are most commonly associated with vigorous weight-bearing activities, such as running, gymnastics, dancing, and marching.
- Females appear to be more prone to this injury.
- The role of age as an independent risk factor is inconclusive, as secondary factors such as training volume and intensity are typically not controlled.
- In athletes, femoral shaft stress fractures are more common in the mid-medial or posteromedial cortex

Pathophysiology

Intrinsic Factors

- Previous stress fracture or family history of stress fracture
- Low bone mineral density
- In women, low aerobic fitness, menstrual dysfunction during the prior year and small calf girth
- Bisphosphonate use in older athletes, most often female
- Poor nutritional status, including low vitamin D status
- Lower extremity alignment, such as rigid medial longitudinal arch of the foot, leg length inequality, and excessive forefoot varus
- Acetabular retroversion

Extrinsic Factors

- A rapid or substantial increase in training volume (i.e., frequency, duration, intensity) with inadequate rest days
- Greater vertical ground reaction force loading rate during running

Classic Pathological Findings

- Periosteal resorption occurs at a faster rate than bone formation, resulting in the cortex becoming weakened and fractured.
- The balance between resorption and bone formation is influenced by the extrinsic and intrinsic risk factors.

Clinical Presentation

History

- Pain is typically nonspecific, insidious, and related to activity.
- Anterior hip, inguinal, and groin pain is common for femoral neck involvement, with diffuse thigh or possibly knee pain if the femoral shaft is involved.
- Pain often persists during rest, particularly with more severe injuries.
- Increased pain with impact type activity
- Increased pain with continued activity
- Patient frequently reports a recent increase in activity level.

Physical Examination

Abnormal Findings

- Antalgic gait may be present
- Fulcrum test can be used to identify femoral shaft stress fractures, which involves the patient being seated with examiner's arm under the involved distal thigh and applying gentle pressure over the knee directed toward the floor. The arm under the thigh is progressively

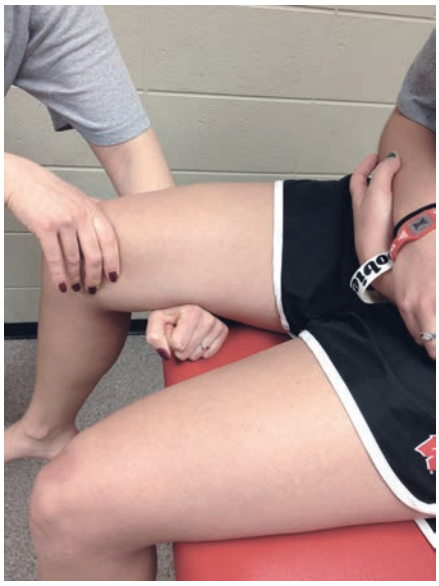

FIGURE 27-1. Fulcrum test.

moved from distal to proximal, with pressure applied at each position, until deep pain is felt by the patient indicating a positive test (Figure 27-1).
- Patrick's test (hip flexion, abduction, and external rotation) or extremes of passive range of motion may provoke pain with involvement of the femoral neck or proximal shaft.
- Hopping on the involved side may elicit pain, although not specific for a femoral stress fracture.

Pertinent Normal Findings

- Bone tenderness may be absent because of the depth of the involved bones.
- Joint range of motion is usually normal, except if the femoral neck is involved.
- Strength is generally normal unless pain is provoked.
- Normal reflexes
- No referred symptoms during testing of lumbar spine

Imaging

- Plain radiographs have poor sensitivity but high specificity. Abnormalities are unlikely unless symptoms have been present for at least 2 to 3 weeks.
- If radiographs show new periosteal bone formation, a visible area of sclerosis, the presence of a callus, or a visible fracture line, the diagnosis of stress fracture is confirmed.
- If radiographs are negative but suspicion of a femoral stress fracture remains, a bone scan or magnetic resonance imaging (MRI) is indicated, with magnetic resonance imaging being the better modality to diagnose femoral neck stress fractures (Figure 27-2).

Differential Diagnosis

- Groin pain: likely to provoke pain with strength testing and palpation
- Hip flexor strain: likely to provoke pain with strength testing and palpation
- Hip osteoarthritis: more gradual onset
- Hip labral tear or femoroacetabular impingement (FAI): MRI demonstrates labral tear or FAI without evidence of femoral neck involvement
- Sports hernia: MRI findings are often normal
- Avascular necrosis: gradual onset with pain in groin, thigh or buttock
- Greater trochanteric pain syndrome: superficial pain with palpation
- Osteosarcoma: swelling and tenderness; unexpected weight loss
- Osteoid osteoma: presence of night pain that can be initially relieved with over-the-counter pain medication; well-demarcated lytic lesion on imaging
- Lumbar spine involvement (i.e., radiculopathy, spinal stenosis, herniated disc, facet syndrome, spondylosis): positive lumbar spine physical exam
- Sacroiliac joint dysfunction: positive sacroiliac joint exam

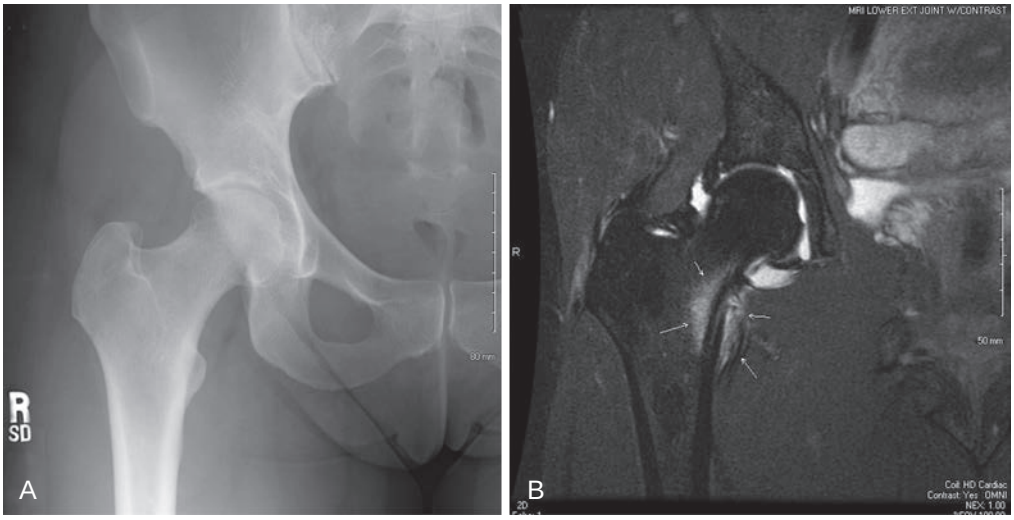

FIGURE 27-2. Femoral neck stress fracture negative on (**A**) radiograph but positive on (**B**) magnetic resonance imaging.

Treatment

Nonoperative Management

- For nondisplaced compression stress reactions involving the femoral shaft, a 1- to 4-week period of limited weight bearing followed by a gradual, progressive return to activity is sufficient for recovery.
- For nondisplaced compression stress fractures involving the femoral shaft, a 4- to 6-week period of limited weight bearing followed by a gradual, progressive return to activity is sufficient for recovery.
- For nondisplaced stress fractures involving the inferior aspect of the femoral neck, a 4- to 6-week period of non–weight bearing is recommended. Radiographic evidence of healing should be evident before beginning a progressive return to weight bearing and activity.
- The gradual return to activity should include exercises to address strength, flexibility, and postural control deficits.
- An analysis of the individual's sports mechanics (i.e., running, gymnastics, dance) should be performed to identify and correct any pathomechanics that may have contributed to the original injury or resulted from it.
- A nutritional assessment should be performed to ensure adequate caloric intake and appropriate vitamins and minerals to maintain adequate bone density.
- Calcium and vitamin D supplementation should be considered, especially for competitive athletes.
- If a metabolic disorder or hormonal imbalance is suspected to contribute to the stress fracture, a more detailed medical evaluation is required.
- Use of an electrical bone stimulator may be considered with stress fractures showing delayed healing or nonunion.

Guidelines for Choosing Among Nonoperative Treatments

- The location (shaft vs neck; compression-sided vs tension-sided) and severity (displaced vs nondisplaced) of the stress fracture determines the extent and duration of non–weight bearing.
- Prolonged non–weight bearing may be recommended if the individual has low bone mineral density.



FIGURE 27-3. Radiograph of right femoral neck stress fracture with displacement.

Surgical Indications

- Displaced fracture (Figures 27-3 and 27-4)
- Tension-sided stress fracture
- Subtrochanteric stress fracture
- Extension of fracture line of compression side femoral neck beyond 50%
- Failure of nonoperative management
- Malunion or nonunion
- Failure of prior fixation
- History of multiple stress fractures (relative)
- Low bone mineral density (relative)

Aspects of History, Demographics, or Exam Findings That Affect Choice of Treatment

- Location of fracture established through physical examination and imaging
- History of multiple stress fractures
- Vitamin D deficiency (serum 25[OH]D status less than 10 ng/ml severe; 10 to 29 ng/ml mild/moderate; 30 to 80 ng/ml optimum; greater than 80 ng/ml toxicity possible) with goal of 60 ng/ml in athletes with stress fractures
- Low bone mineral density
- Patient's relative activity level, more aggressive with more activity (e.g., competitive runner)

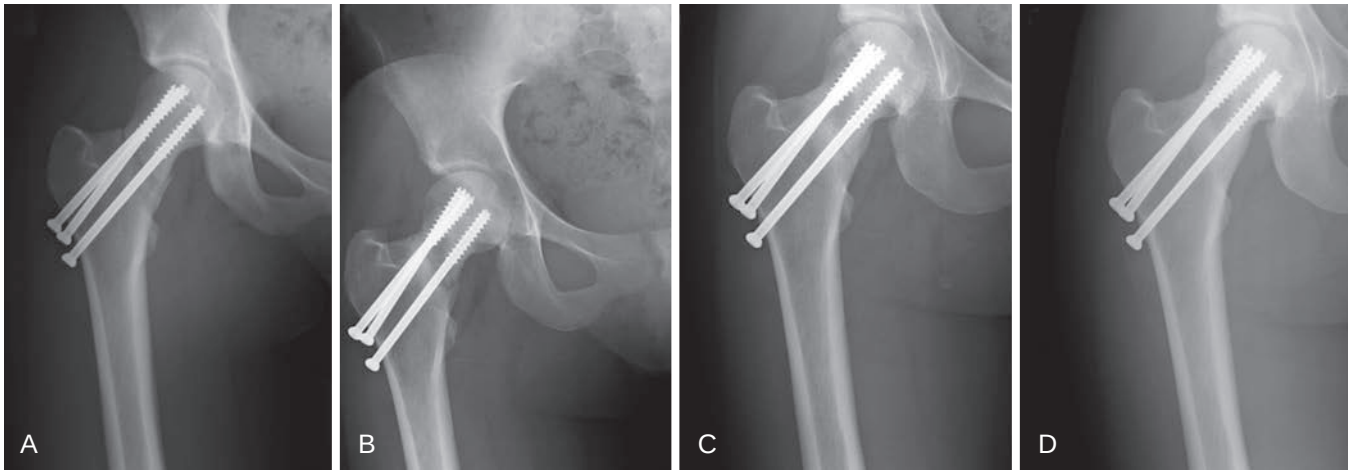

FIGURE 27-4. Postoperative radiographs following closed reduction and internal fixation of displaced right femoral neck fracture shown in Figure 27-3. Minimal healing was evident at (**A**) 1 month postsurgery, with progressive healing present at (**B**) 7 months, (**C**) 14 months, and (**D**) 19 months postsurgery.

Aspects of Clinical Decision Making When Surgery Is Indicated

- Displaced femoral neck fractures often require emergent anatomical open reduction and fixation.
  - Dynamic hip screw of fixed angle plate is often required for stable fixation.
- Osteotomy may be required for varus angulation in malunion or nonunion cases.
- Subtrochanteric fractures can often be treated with intermedullary nails or fixed angle plates.
- Nondisplaced tension-sided (superior) femoral neck stress fractures can be treated with percutaneous fixation.
- Compression-sided femoral neck stress fracture that extend beyond 50% can be treated with percutaneous fixation.

Evidence

Bennell KL, Malcolm SA, Thomas SA, et al: Risk factors for stress fractures in track and field athletes. A twelve-month prospective study. *Am J Sports Med* 24:810–818, 1996.

This prospective cohort study investigated risk factors for stress fractures in 111 track and field athletes. No risk factors were identified for men; however, lower bone density, a history of menstrual disturbance, less lean mass in the lower limb, a discrepancy in leg length, and a lower fat diet were significant risk factors for women. (Level IIb evidence)

Boden BP, Speer KP: Femoral stress fractures. *Clin Sports Med* 16:307–317, 1997.

This expert opinion article reviews common femoral stress fractures and includes a brief case report for each. A summary of presentation, examination, and treatment is provided for each stress fracture location. (Level V evidence)

Kiuru MJ, Pihlajamaki HK, Ahovuo JA: Fatigue stress injuries of the pelvic bones and proximal femur: Evaluation with MR imaging. *Eur Radiol* 13:605–611, 2003.

This retrospective review of 340 consecutive patients with stress-related hip, buttock, or groin pain sought to determine the injury prevalence and distribution based on MRI and radiographs. Bone stress injuries were present in 40% of patient with hip pain, with 60% located in the proximal femur, and 40% in the pelvic bones. The sensitivity of radiography was 37%, specificity 79%, accuracy 60%, positive predictive value 59%, and negative predictive value 61%. The kappa value for agreement between radiography and MRI was poor (0.17, p = .0008). (Level IV evidence)

Kuhn KM, Riccio AI, Saldua NS, et al: Acetabular retroversion in military recruits with femoral neck stress fractures. *Clin Orthop Relat Res* 468:846–851, 2010.

This case-control study compared the anteroposterior radiographs of 54 patients treated for femoral neck stress fractures. The prevalence of a positive cross-over sign was greater in patients with stress fractures than in the control subjects (31 of 54 [57%] vs 17 of 54 [31%], respectively). A greater incidence of acetabular retroversion was present in patients with femoral neck stress fractures. (Level IV evidence)

Pihlajamaki HK, Ruohola JP, Kiuru MJ, et al: Displaced femoral neck fatigue fractures in military recruits. *J Bone Joint Surg Am* 88:1989–1997, 2006.

This descriptive study reported on 21 military recruits that sustained displaced femoral neck stress fracture, with 19 recruits followed for an average of 18 years. Following treatment, six patients had delayed union or nonunion of the fracture; six patients developed osteonecrosis of the femoral head; and eight patients developed severe osteoarthritis. (Level IV evidence)

Multiple Choice Questions

QUESTION 1. Which of the following athletes is at the greatest risk for a femoral shaft stress fracture?

A. Female softball player
B. Female cross country runner
C. Male cross country runner
D. Female basketball player

QUESTION 2. Which of the following is not an intrinsic risk factor for a femoral stress fracture?

A. Poor nutritional status
B. High medial longitudinal arch of the foot
C. Prior stress fracture
D. Rapid or substantial increase in training volume

QUESTION 3. Which clinical test may be useful in detecting a stress fracture of the femoral shaft?

A. Ober's test
B. Fulcrum test
C. Straight leg raise test
D. Scour test

QUESTION 4. To confirm the diagnosis of stress fracture from radiographs, which of the following should be observed?

A. New periosteal bone formation
B. Visible area of sclerosis
C. Visible fracture line
D. Any of the above

QUESTION 5. Which of the following is recommended as part of the recovery process for a nondisplaced, compression-sided femoral shaft stress fracture?

A. Limited weight bearing for 1 to 4 weeks
B. Exercises to address strength, flexibility, and postural control deficits
C. Nutritional assessment
D. All of the above

Answer Key

QUESTION 1. Correct answer: **B** (see Epidemiology)

QUESTION 2. Correct answer: **D** (see Pathophysiology)

QUESTION 3. Correct answer: **B** (see Clinical Presentation—Abnormal Findings)

QUESTION 4. Correct answer: **D** (see Clinical Presentation—Imaging)

QUESTION 5. Correct answer: **D** (see Treatment)

NONOPERATIVE REHABILITATION OF STRESS FRACTURES OF THE FEMORAL NECK AND SHAFT

Bryan C. Heiderscheit, PT, PhD, and Geoffrey S. Baer, MD, PhD

GUIDING PRINCIPLES OF NONOPERATIVE REHABILITATION

- Protection to site of injury to prevent fracture propagation
- Progressive loading to promote bone regeneration
- Maintenance of muscle strength
- This rehabilitation program is designed for nonoperative management of nondisplaced femoral neck and shaft stress fractures.
- Because of risk for significant complications, most tension-sided femoral neck stress fractures are managed surgically. This rehabilitation program is not appropriate for postoperative management because additional restrictions may apply.

Phase I (weeks 1 to 4–6): Limited Weight Bearing

Protection

- Crutches
  - Femoral shaft
    - Toe-touch weight bearing with progression to weight bearing as tolerated over a 1- to 4-week period
  - Femoral neck
    - Non–weight bearing until pain free with radiographic evidence of healing, often 4 to 6 weeks

Techniques for Progressive Increase in Range of Motion

- Femoral neck stress fracture may display limited hip range of motion primarily owing to muscle guarding. Soft tissue mobilization may prove useful in resolving the muscle guarding; however non–weight bearing and activity restriction often produce the same effect.
- Joint mobilization techniques should not be performed with femoral neck stress fractures as they are typically unnecessary and could compromise the fracture healing. Hip range of motion is rarely affected as a result of femoral shaft stress fractures.

Soft Tissue Techniques

- Deep tissue massage, trigger point release and augmented soft tissue mobilization may be considered to resolve associated muscle guarding (gluteals, adductors, quadriceps, hamstrings)

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Gentle to moderate intensity stretching to hamstrings, quadriceps, hip flexors, adductors, and plantar flexors.

Other Therapeutic Exercises

- Easy freestyle swimming
- Deep water running with a flotation belt
- Seated cycling with low to moderate resistance
- Total arm strengthening
- Core stability, as appropriate given limited weight-bearing status

Activation of Primary Muscles Involved

- Vastus medialis and adductor brevis attach at a common site for femoral shaft stress fractures (junction of proximal and middle thirds). Therefore selected exercises should minimize the force production required of these muscles.

TIMELINE 27-1: **Nonoperative Rehabilitation of Femoral Neck and Shaft Stress Fractures**

PHASE I (weeks 1 to 4 to 6)	PHASE II (weeks 4 to 6 to 8)	PHASE III (weeks 8 to 12)
• Crutches • Soft tissue mobilization as needed • Stretching • Cross-training (swimming, cycling) • TAS activities • Core exercises as recommended and tolerated	• Soft tissue mobilization as needed • Stretching • Elliptical • TAS/TLS activities • Core exercises as recommended and tolerated • Balance/proprioception • Weight-bearing lower extremity PREs • Neuromuscular stability exercises • Plyometric exercises as recommended • Begin walk-run program	• Soft tissue mobilization as needed • Stretching • Elliptical • TAS/TLS activities • Core exercises as recommended and tolerated • Balance/proprioception • Weight-bearing lower extremity PREs • Neuromuscular stability exercises • Plyometric exercises as recommended • Complete walk-run program



FIGURE 27-5. Bent knee hip extension in quadruped.

Techniques to Increase Muscle Strength, Power, and Endurance

- For femoral shaft stress fractures:
  - Side-lying hip abduction, 2 × 15
  - Bent knee hip extension in quadruped, 2 × 15 each side (Figure 27-5)
  - One-leg standing (uninvolved side) hip extension with tubing, 2 × 15 with tubing on involved side only, low resistance (Figure 27-6)
  - One-leg standing (uninvolved side) hip abduction with tubing, 2 × 15 with tubing on involved side only, low resistance (Figure 27-7)

Neuromuscular Dynamic Stability Exercises

- For femoral shaft stress fractures:
  - Alternate straight leg and arm raise in quadruped, 2 × 15 each side (Figure 27-8)

Milestones for Progression to the Next Phase

- Pain-free in weightbearing with no antalgic gait
- Radiographic evidence of healing of femoral neck stress fractures

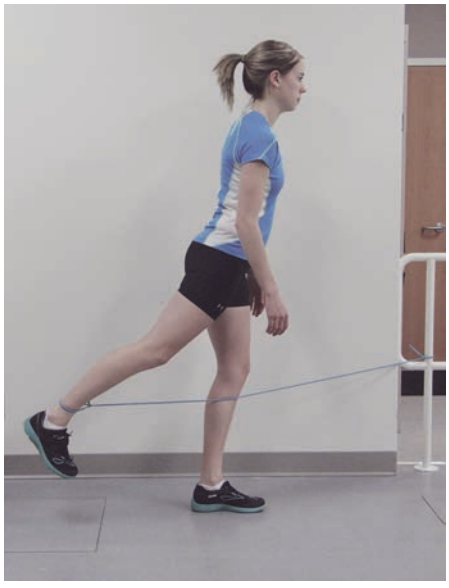

FIGURE 27-6. One-leg standing (uninvolved side) hip extension with tubing on involved side.

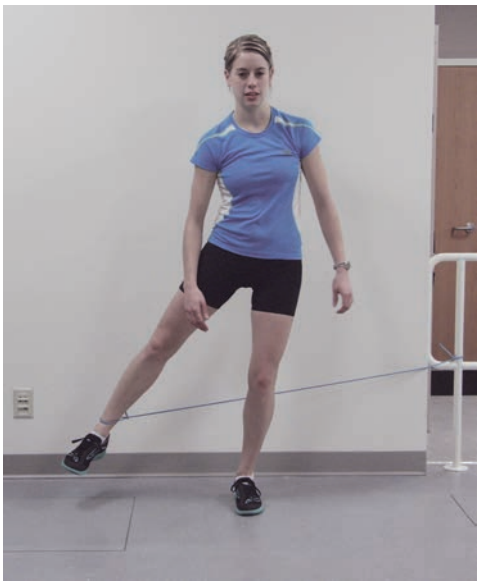

FIGURE 27-7. One-leg standing (uninvolved side) hip abduction with tubing on involved side.

- Full range of motion at hip based on goniometric assessment

Phase II (weeks 4–6 to 8): Low- to Moderate-Impact Activities

- The amount of impact associated with the activities and exercises in this phase is progressively increased. The initial 1 to 2 weeks are typically spent doing low impact activities to determine the bone's tolerance to loading.
- Once the low impact exercises are fully tolerated without any symptom provocation, the moderate impact exercises can be initiated.

Techniques for Progressive Increase in Range of Motion

Soft Tissue Techniques

- Stretching of anterior hip capsule with joint mobilization techniques (posterior to anterior) once femoral neck stress fracture has healed



FIGURE 27-8. Alternate straight leg and arm raise in quadruped.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Moderate to aggressive intensity stretching to hamstrings, quadriceps, hip flexors, and adductors, intensity based on patient's perceived level of stretch; should avoid any symptom provocation

Other Therapeutic Exercises

- Core stability (e.g., planks, side planks, bridging), low (20%) to moderate (50%) intensity relative to estimated maximum effort
- Total arm and leg strengthening
- Elliptical trainer

Sensorimotor Exercises

- One-leg standing on foam with eyes closed, 3 × 30 seconds
- One-leg standing with ball toss, 3 × 30 seconds

Techniques to Increase Muscle Strength, Power, and Endurance

- Wall squats, 3 × 12
- Heel raises, 3 × 12
- Step ups, 3 × 12
- Side stepping with resistance band at ankles, 3 × 30 seconds
- Diagonal forward lunges, 3 × 12
- Dead lifts, 3 × 12

Neuromuscular Dynamic Stability Exercises

- Supine bridging, 2 × 15
- Supine bridging on Physioball, 2 × 15
- Supine bridge on Physioball with leg curl, 2 × 15

Plyometrics

- Two-leg rapid heel raises, 3 × 30 seconds
- Lateral shuffle with ladder, each direction, 2 × 4 ladder lengths
- Two-leg standing hops, 3 × 30 seconds

Sport-Specific Exercises

- Walk-Run program (avoid down hills because of increased impact forces): Self-selected preferred pace for all levels unless indicated. Repeat each level two to three times with a rest day between each and advance only if no pain.
  - Walk 30 minutes
  - Walk 30 minutes at 15% faster pace
  - Walk 4 minutes, Run 1 minutes; repeat six times (30 minutes total)
  - Walk 3 minutes, Run 2 minutes; repeat six times (30 minutes total)

Milestones for Progression to the Next Phase

- Pain-free and able to tolerate moderate-impact activities in Phase II
- Walking 30 minutes moderate pace without pain

phase III (weeks 8 to 12): Moderate-to-High Impact Activities

- As in Phase II, the amount of impact associated with the activities and should continue to increase to a level that is typical of the athlete's sport.
- The duration of this phase should be adjusted for each athlete based upon the specific sport, with the goal of safely increasing impact and training volume.

Techniques for Progressive Increase in Range of Motion

Soft Tissue Techniques

- Same as for Phase II.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Same as for Phase II.

Other Therapeutic Exercises

- Core stability (e.g., planks, side planks, bridging), moderate to high intensity
- Total arm and leg strengthening

Techniques to Increase Muscle Strength, Power, and Endurance

- Diagonal forward lunges with external weight, 3 × 12
- Dead lifts with external weight, 3 × 12 (Figure 27-9)

Neuromuscular Dynamic Stability Exercises

- Two-leg squat-jump-toss with 10 lb medicine ball, 2 × 15

Plyometrics

- Lateral jumps with ladder, each direction, 2 × 4 ladder lengths
- Line jumping
  - Forward-backward, 2 × 30 seconds
  - Side-to-side, 2 × 30 seconds
- Jump on to box (12")
  - Forward, 2 feet jump and 2 feet land, 1 × 10
  - Side, 2 feet jump and 2 feet land, 1 × 5 each side
- Bounding (progress as tolerated)
  - Two-leg, 2 × 6
  - One-leg alternate, 2 × 6 each leg

Sport-Specific Exercises

- Walk-Run program (avoid down hills): Self-selected preferred pace for all levels unless indicated. Repeat

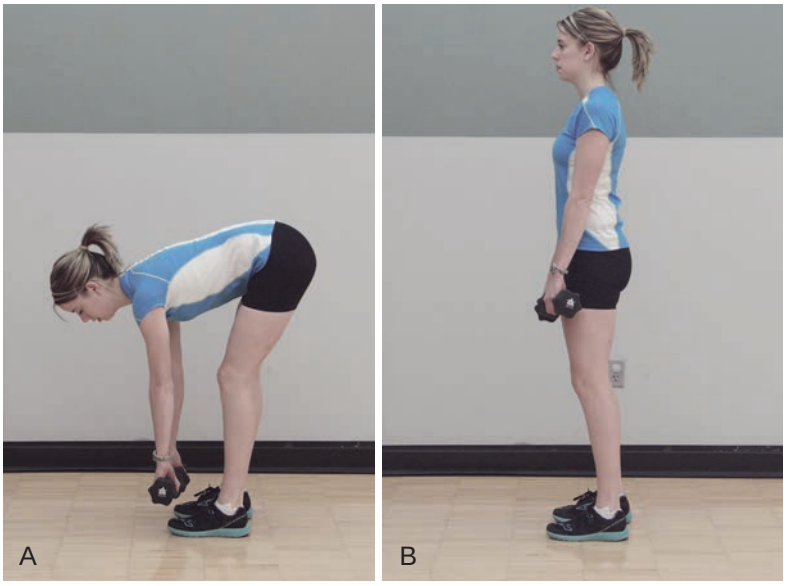

FIGURE 27-9. Dead lifts with external weight.

each level two to three times with a rest day between each and advance only if no pain.
- Walk 2 minutes, Run 3 minutes; repeat six times (30 minutes total)
- Walk 1 minute, Run 4 minutes; repeat six times (30 minutes total)
- Run 30 minutes

Milestones for Progression to Advanced Sport-Specific Training and Conditioning

- No palpable tenderness over involved area
- Pain free and able to tolerate high-impact activities involved in Phase III
- Completion of return to running program without symptom provocation

Criteria for Abandoning Nonoperative Treatment and Proceeding to Surgery or More Intensive Intervention

- Radiographic evidence of delayed union or nonunion
- Propagation of fracture to complete or displaced

Tips and Guidelines for Transitioning to Performance Enhancement

- At this point, the athlete should be completely symptom free and able to tolerate high-impact activities.
- As this type of injury is common in sports involving running, a progressive return to full running volume (approximately 10% per week) is essential to prevent re-injury, as well as re-acclimate tissues to the demands of the sport.
- For those involved in jumping sports, plyometric training needs to be continued and advanced to include box jumps

Performance Enhancement and Beyond Rehabilitation: Training/Trainer and Optimization of Athletic Performance

- Given the time away from sport and limited endurance training during recovery, adequate time should be devoted to cardiovascular training.
- If the athlete is returning to a sport involving running, an assessment of the running gait should be performed to identify pathomechanics that may have contributed to the injury.

Specific Criteria for Return to Sports Participation: Tests and Measurements

- No palpable tenderness over involved area
- Pain free and able to tolerate impact activities reflective of the sport
- Completion of return to running program without symptom provocation

Evidence

Boden BP, Speer KP: Femoral stress fractures. *Clin Sports Med* 16:307–317, 1997.

This expert opinion article reviews common femoral stress fractures and includes a brief case report for each. A summary of rehabilitation treatment is provided for each stress fracture location. (Level V evidence)

Diehl JJ, Best TM, Kaeding CC: Classification and return-to-play considerations for stress fractures. *Clin Sports Med* 25:17–28, 2006.

This expert opinion article reviews the classification and return-to-play criteria of a variety of stress fractures common to athletes. Stress fractures are classified as low or high risk with treatment goals and return-to-play timelines described. (Level V evidence)

Ivkovic A, Bojanic I, Pecina M: Stress fractures of the femoral shaft in athletes: A new treatment algorithm. *Br J Sports Med* 40:518–520; discussion 20, 2006.

This case series of seven athletes with a femoral shaft stress fracture describes nonoperative management using a progressive rehabilitation program. Following a four-phase program with specific testing criteria for advancement, all athletes returned to competition without re-injury over a long-term follow-up period. (Level IV evidence)

Talbot JC, Cox G, Townend M, et al: Femoral neck stress fractures in military personnel: A case series. *J R Army Med Corps* 154(1):47–50, 2008.

This retrospective case series of 20 military recruits with a femoral neck stress fracture describes their injury epidemiology and clinical outcome. Most injuries were nondisplaced (85%) and treated conservatively. (Level IV evidence)

Weishaar MD, McMillian DM, Moore JH: Identification and management of two femoral shaft stress injuries. *J Orthop Sports Phys Ther* 35:665–673, 2005.

This case series of two military cadets with a femoral shaft stress fracture describes the nonoperative management using a progressive rehabilitation program. Both cadets returned to full training and athletic activity without re-injury at approximately 12 weeks. (Level IV evidence)

Multiple Choice Questions

QUESTION 1. Which location of a stress fracture is not appropriate for conservative management?

A. Proximal medial femoral shaft
B. Distal medial femoral shaft
C. Superior femoral neck
D. Inferior femoral neck

QUESTION 2. Progression of a patient with a femoral neck stress fracture from non–weight bearing to weight bearing most often requires

A. radiographic evidence of healing.
B. full range of motion.
C. full strength.
D. pain score of 2 out of 10.

QUESTION 3. To help maintain cardiovascular endurance, which of the following activities is considered safe during Phase I?

A. Elliptical trainer
B. Deep water running with a flotation belt
C. Treadmill walking
D. Step aerobics

QUESTION 4. During Phase II, progression to moderate-impact activities can occur

A. immediately for all types of femoral stress fractures.
B. when low-impact activities are fully tolerated without symptom provocation.
C. if full range of motion is demonstrated at the involved hip.
D. once normal walking mechanics are observed.

QUESTION 5. To promote a safe transition back to running, which of the following return to running programs is recommended?

A. Immediate return to full mileage
B. Progressive return over a period of 1 week
C. Walk-run combination program with progressive increase in running duration over several weeks
D. Individuals with a recent femoral stress fracture should not run for at least 6 months.

Answer Key

QUESTION 1. Correct answer: **C** (see Overview)

QUESTION 2. Correct answer: **A** (see Phase I)

QUESTION 3. Correct answer: **B** (see Phase I)

QUESTION 4. Correct answer: **B** (see Phase II)

QUESTION 5. Correct answer: **C** (see Phase III)

BEYOND BASIC REHABILITATION: RETURN TO RUNNING AFTER OPERATIVE TREATMENT OF A STRESS FRACTURE OF THE FEMORAL NECK

Bryan C. Heiderscheit, PT, PhD, and Geoffrey S. Baer, MD, PhD

Aspects of Running that Require Special Attention in Rehabilitation

- Because of the magnitude and repetition of loading, return to running following surgical treatment of a femoral neck stress fracture should be done so in a progressive yet cautious manner.
- A thorough analysis of running technique should be conducted to identify and correct mechanics that may produce increased loading to the hip region.
- Femoral neck stress fractures most commonly occur with running.
- Although rather uncommon, tension-sided femoral neck stress fractures are particularly concerning as surgical management is often required.
- The likelihood of a full and complete return to running following surgical treatment of a femoral neck stress fracture is fair, with elite runners typically unable to achieve their prior level of performance.
- With radiographic evidence of fracture healing and resolution of hip pain with unassisted walking, consideration should be given to removal of the fixation. A prolonged period (minimum of 3 months) of restricted activity should follow with a gradual return to athletic activity once there is evidence the pin tracks have filled.

Literature

- Johansson and colleagues compiled a case series of 23 athletes (15 of which were runners) who experienced a femoral neck stress fracture. Sixteen of the athletes were initially treated surgically with internal fixation, with the remaining seven treated conservatively.
- Thirty percent of the athletes experienced a complication requiring major surgery, including pseudoarthrosis, avascular necrosis, and refracture. Complications most often occurred in athletes with a displaced fracture.
- At an average follow-up of 6.5 years after injury, none of the elite athletes were able to return to their prior level of performance.

Phase I (weeks 1 to 6)

Goals

- To ensure stability of fracture site and surgical fixation
- To promote healing
- To maintain core and upper body strength

Weight-Bearing Status

- For nondisplaced fractures, weight bearing can be progressive during weeks 1 to 6.
- Displaced fractures after ORIF often require non–weight bearing with crutches for 8 to 10 weeks.

Manual Therapy

- Soft tissue mobilization as needed to hamstring, quadriceps, and gluteal muscles
- Incision scar mobilization as needed

Therapeutic Exercise

- Stretching to knee and ankle of involved and entire noninvolved limb, 2 × 30 seconds each stretch
  - Use stretching positions that minimize compression forces acting on the hip
- AROM initiated at 1 week postop, 2 × 10 reps through pain-free range of motion
  - Flexion, extension, abduction, adduction, internal/external rotation

TIMELINE 27-2: **Return to Running After Surgical Treatment of a Stress Fracture of the Femoral Neck**

PHASE I (postop weeks 1 to 6)	PHASE II (postop weeks 6 to 8)
• Crutches for displaced; progressive weight bearing if nondisplaced • Soft tissue mobilization as needed • Stretching • Aquatic therapy when appropriate • TAS activities • Core exercises as recommended and tolerated	• Soft tissue mobilization as needed • Stretching • Cross-training (swimming, cycling) • TAS activities • Core exercises as recommended and tolerated • Balance/proprioception • Weight-bearing lower extremity PREs • Neuromuscular stability exercises

- Aquatic therapy can be initiated at 2 to 4 weeks postop (with a sealed incision)
  - Same movements as AROM but using resistance of water to increase intensity
- Total arm strengthening
- Core exercises
  - Use positions that minimize hip joint loading

Criteria for Progression to Phase II

- Fully healed incision
- Stable and well-healed fracture site

Phase II (weeks 6 to 8)

Goals

- Promote full weight bearing and normal walking gait
- Full AROM
- Initiate resistance training

Weight Bearing Status

- Full weight bearing, except displaced fractures after ORIF often require non–weight bearing with crutches for 8 to 10 weeks

Joint Mobility

- Joint and soft tissue mobilizations as needed to restore full hip joint ROM.
- Use of self-directed soft tissue mobilization (e.g., foam roller) may be initiated.
- If restricted spinal mobility is present, such as thoracic spine hypomobility or sacroiliac joint restriction, the appropriate manual therapy technique should be employed.

Therapeutic Exercise

- Cross-training (cycling, swimming)
- Gait training—focus on restoration of normal walking mechanics and speed
- Total arm strengthening—unrestricted
- Balance/proprioception
  - Low to moderate intensity steps forward and backward over a tape line while moving sideways, 2 × 1 minutes



FIGURE 27-10. Double leg stand on foam.

  - Double leg stand, progressing from eyes open to eyes closed and with foam, 4 × 20 seconds (Figure 27-10)
  - Partial body weight single leg stand, 3 × 20 seconds
- Progressive resistance exercise
  - Leg press, 3 × 10 repetitions, light to moderate intensity
  - Knee extensions, 3 × 10 repetitions, light to moderate intensity
  - Knee curls, 3 × 10 repetitions, light to moderate intensity
  - Calf raises, 3 ×10 repetitions, light to moderate intensity
  - Hip abduction, 3 × 10 repetitions, light intensity
  - Wall slides, 3 × 15 repetitions
- Core exercises
  - Prone abdominal body bridge (performed by using abdominal and hip muscles to hold the body in a face down straight plank position with the elbows and feet being the only point of contact), 4 × 20 seconds (Figure 27-11)
  - Supine extension bridge (performed by using abdominal and hip muscles to hold the body in a supine hook lying position with the head, upper back, arms and feet being the points of contact), 4 × 20 seconds (Figure 27-12)

TIMELINE 27-2: **Return to Running After Surgical Treatment of a Stress Fracture of the Femoral Neck** (Continued)

PHASE III (postop weeks 8 to 12)	PHASE IV (postop weeks 12 to 16)
• Soft tissue mobilization as needed • Stretching • Cross-training (swimming, cycling) • Elliptical • TAS/TLS activities • Core exercises as recommended and tolerated • Balance/proprioception • Weight-bearing lower extremity PREs • Neuromuscular stability exercises • Mild plyometric exercises as recommended • Begin walk-run program; delayed 2–4 weeks for displaced fractures	• Soft tissue mobilization as needed • Stretching • Cross-training (swimming, cycling) • TAS/TLS activities • Core exercises as recommended and tolerated • Balance/proprioception • Weight-bearing lower extremity PREs • Neuromuscular stability exercises • Moderate plyometric exercises as recommended • Continue walk-run program

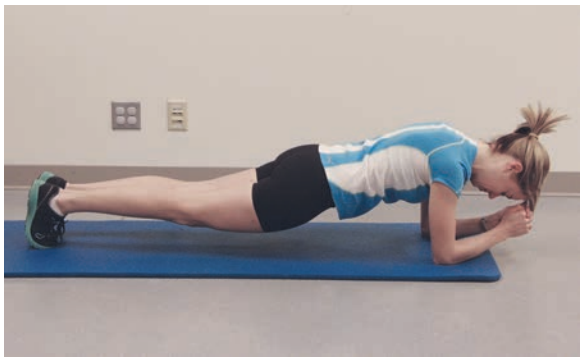

FIGURE 27-11. Prone abdominal body bridge.

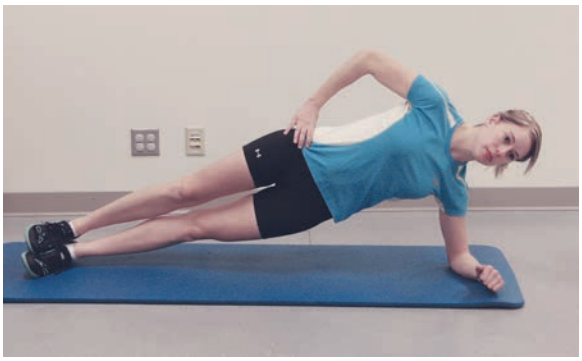

FIGURE 27-13. Side bridge.

- Side bridge (performed by using abdominal and hip muscles to hold the body in a side lying plank position with the lower elbow and feet being the only point of contact), 4 × 20 seconds on each side (Figure 27-13)

Criteria for Progression to Phase III

- Full AROM
- Normal walking mechanics without pain per visual assessment
- Single leg standing for 20 seconds on involved side without pain

Phase III (weeks 8 to 12)

Goals

- Progress resistance training to at least moderate intensity (at least 50% of estimated maximum effort)
- Unrestricted exercise in single leg postures
- Begin walk-run program

Joint Mobility

- Joint and soft tissue mobilizations as needed to maintain full hip joint ROM
- Self-directed soft tissue mobilization (e.g., foam roller) may be used.
- If restricted spinal mobility is present, such as thoracic spine hypomobility or sacroiliac joint restriction, the appropriate manual therapy technique should be employed.



FIGURE 27-12. Supine extension bridge.

Therapeutic Exercise

- Cross-training (cycling, swimming, elliptical)
- Gait training—focus on restoration of normal slow running mechanics
- Total arm/leg strengthening—unrestricted
- Balance/proprioception
  - Moderate to high intensity steps forward and backward over a tape line while moving sideways, 3 × 1 minute, intensity reflective of stepping speed and qualitatively determined
  - Moderate to high intensity grapevine stepping, 3 × 1 minute, intensity reflective of stepping speed and qualitatively determined
  - Single leg stand, progressing from eyes open to eyes closed and with foam, 4 × 20 seconds
- Progressive resistance exercise (moderate [50%] to high [90%] intensity, relative to estimated maximum effort)
  - Leg press, 3 × 6 to 8 repetitions, moderate to high intensity
  - Knee extensions, 3 × 6 to 8 repetitions, moderate to high intensity
  - Knee curls, 3 × 6 to 8 repetitions, moderate to high intensity
  - Calf raises, 3 × 6 to 8 repetitions, moderate to high intensity
  - Hip abduction, 3 × 6 to 8 repetitions, moderate intensity
- Core exercises—continue as in the preceding
- Neuromuscular stabilization
  - Fast feet in place, 3 × 20 seconds
  - Mini hopping on both feet, 3 × 20 seconds
  - Side stepping with moderate elastic resistance around toes, 3 × 30 seconds (Figure 27-14)
  - Supine knee curls on Physioball, 3 × 30 seconds, start with two legs and progress to single leg (Figure 27-15)
  - Single leg windmill touches, 4 × 20 seconds with alternate hand touches (Figure 27-16)
  - Lateral pelvic tilts, 2 × 30 seconds each side (Performed by standing on one leg replicating knee and hip posture during early stance phase of running; keeping trunk erect, raise and lower pelvis in frontal plane through full range) (Figure 27-17)
- Walk-run progression (avoid down hills because of increased impact forces): Self-selected preferred pace

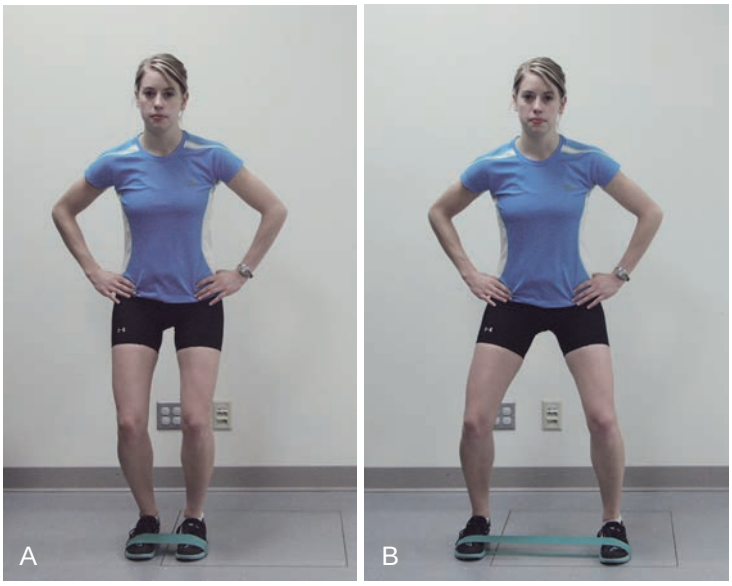

FIGURE 27-14. A,B, Side stepping with elastic resistance around toes.

for all levels unless indicated. Repeat each level two to three times and advance only if no pain.

- Walk 30 minutes
- Walk 30 minutes at 15% faster pace
- Walk 4 minutes, run 1 minute; repeat six times (30 minutes total)
- Walk 3 min, run 2 minutes; repeat six times (30 minutes total)

Criteria for Progression to Phase IV

- No pain in single leg activities
- Normal slow jogging mechanics without pain

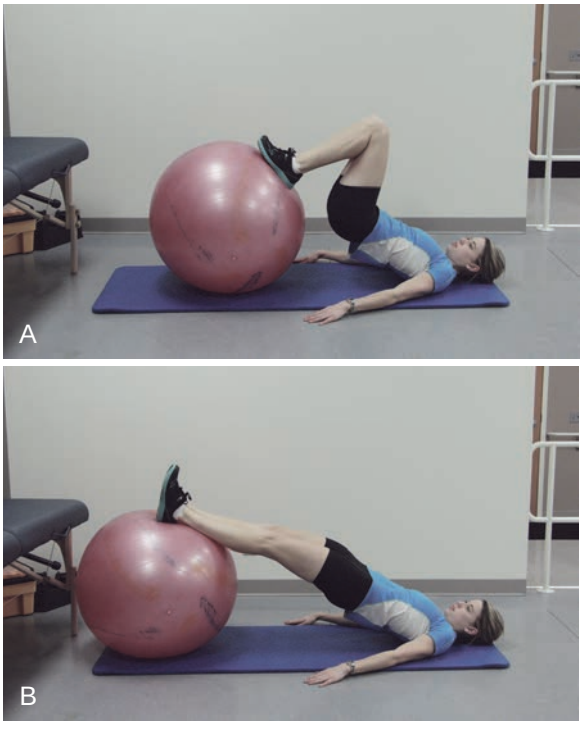

FIGURE 27-15. A,B, Supine knee curls on Physioball.

- 5/5 isometric strength for hip abductors, external rotators and extensors, assessed via manual muscle testing or with handheld dynamometer

Phase IV (weeks 12 to 16)

Goals

- Tolerate low to moderate intensity plyometrics.
- Initiate sports-specific training.
- Complete walk-run program.

Joint Mobility

- Employ joint and soft tissue mobilizations as needed to maintain full hip joint ROM.
- Use of self-directed soft tissue mobilization (e.g., foam roller) may be used.
- If restricted spinal mobility is present, such as thoracic spine hypomobility or sacroiliac joint restriction, the appropriate manual therapy technique should be employed.

Therapeutic Exercise

- Cross-training (cycling, swimming, elliptical)
- Total arm/leg strengthening—unrestricted
- Balance/proprioception
  - Moderate to high intensity steps forward and backward over a tape line while moving sideways, 3 × 1 minute, intensity reflective of stepping speed and qualitatively determined
  - Moderate to high intensity grapevine stepping, 3 × 1 minute, intensity reflective of stepping speed and qualitatively determined
  - One-leg standing with ball toss, 3 × 30 seconds
- Core exercises—continue as in the preceding
- Neuromuscular stabilization
  - Two-leg squat-jump-toss with 10 lb medicine ball, 2 × 15 (Figure 27-18)

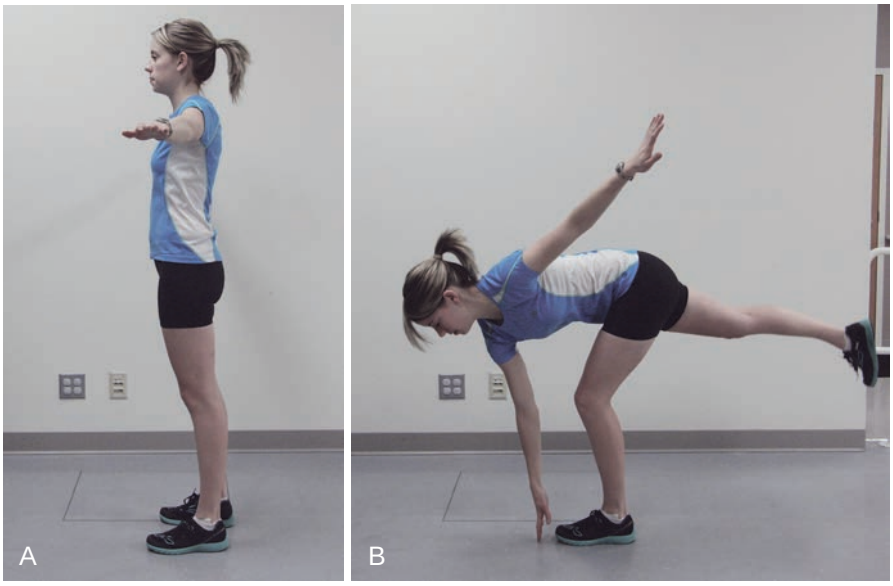

FIGURE 27-16. A,B, Single leg windmill touches.

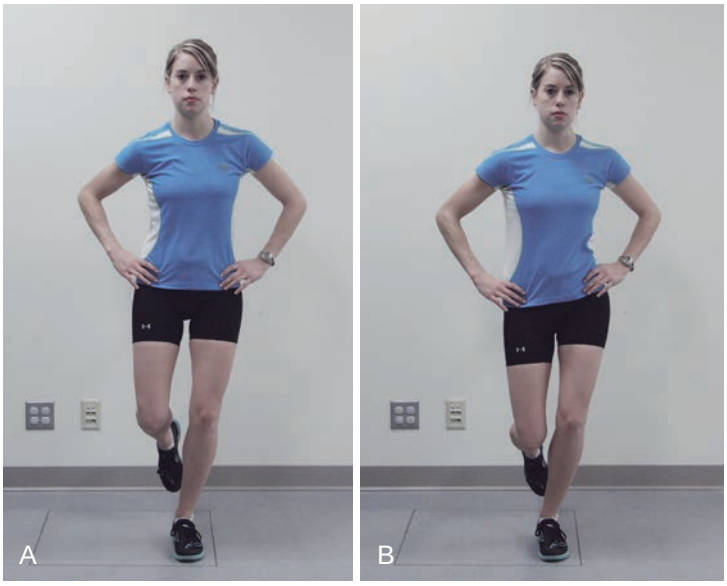

FIGURE 27-17. A,B, Lateral pelvic tilts.

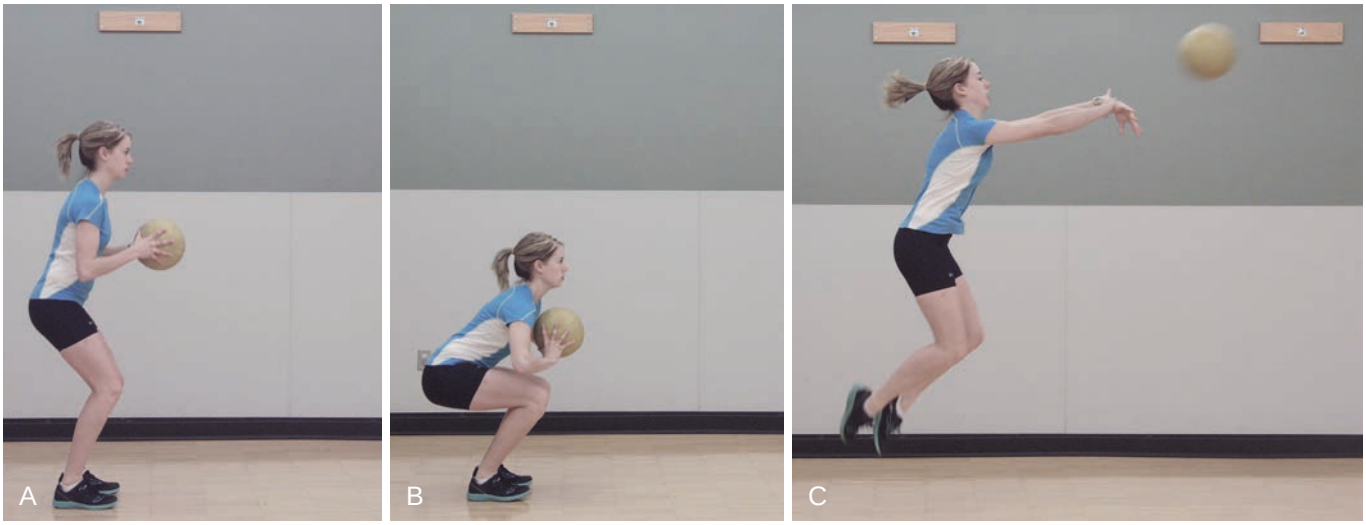

FIGURE 27-18. A–C, Two-leg squat-jump-toss with 10 lb medicine ball.

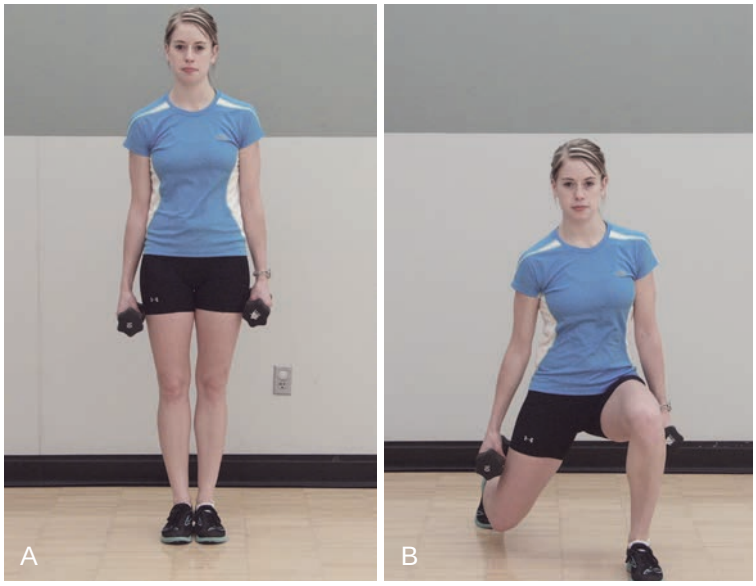

FIGURE 27-19. A,B, Diagonal forward lunge with external weight.

- Diagonal forward lunge with external weight, 3 × 12 (Figure 27-19)
- Dead lifts with external weight, 3 × 12
- Single leg windmill touches, 4 × 20 seconds with alternate hand touches and hand-held weight
- Lateral jumps with ladder, each direction, 2 × 4 ladder lengths (Figure 27-20)
- Jump on to box (12")
  - Forward, 2 feet jump and 2 feet land, 1 × 10 (Figure 27-21)

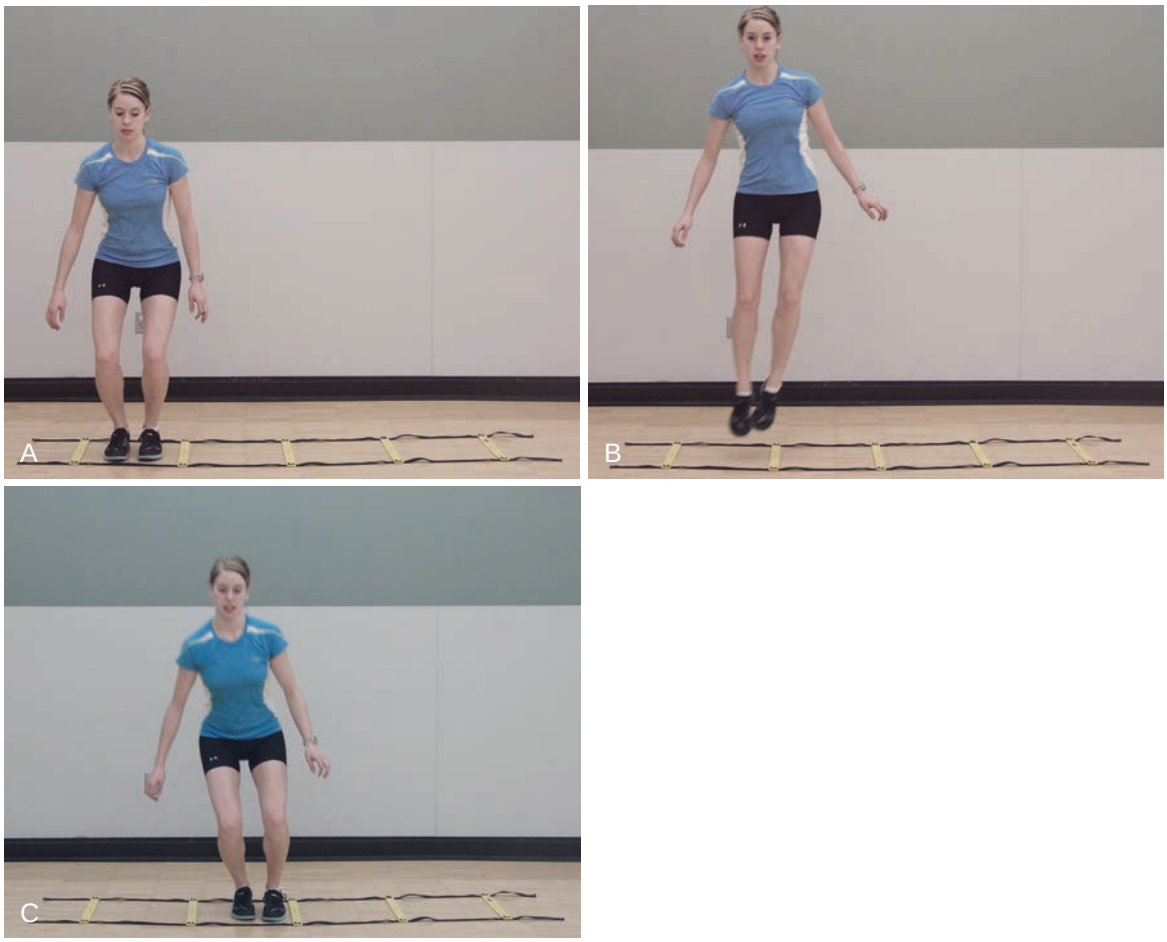

FIGURE 27-20. A–C, Lateral jumps with ladder.

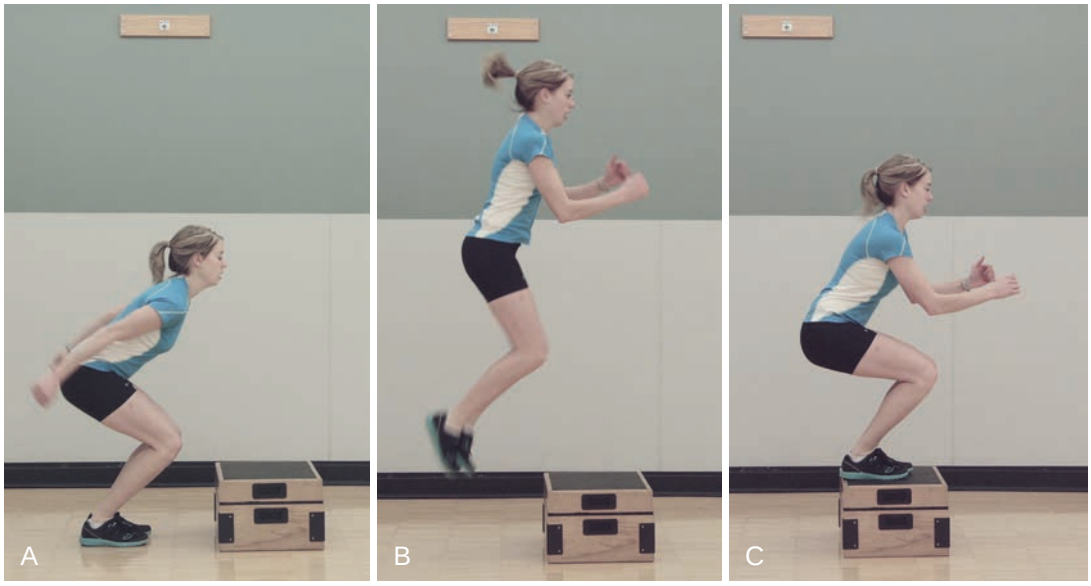

FIGURE 27-21. A–C, Forward box jump.

  - Side, 2 feet jump and 2 feet land, 1 × 5 each side (Figure 27-22)
- Bounding (progress as tolerated)
  - Two-leg, 2 × 6 (Figure 27-23)
  - One-leg alternate, 2 × 6 each leg (Figure 27-24)
- Walk-run progression (avoid down hills because of increased impact forces): Self-selected preferred pace for all levels unless indicated. Repeat each level two to three times and advance only if there is no pain.
  - Walk 2 minutes, run 3 minutes; repeat six times (30 minutes total)
  - Walk 1 minute, run 4 minutes; repeat six times (30 minutes total)
  - Run 30 minutes

Criteria for Progression

- Pain free and able to fully tolerate high-impact activities
- Completion of return to running program without symptom provocation

Advanced Strength and Conditioning Programs

Periodization

- The program is progressed in a linear manner over time.

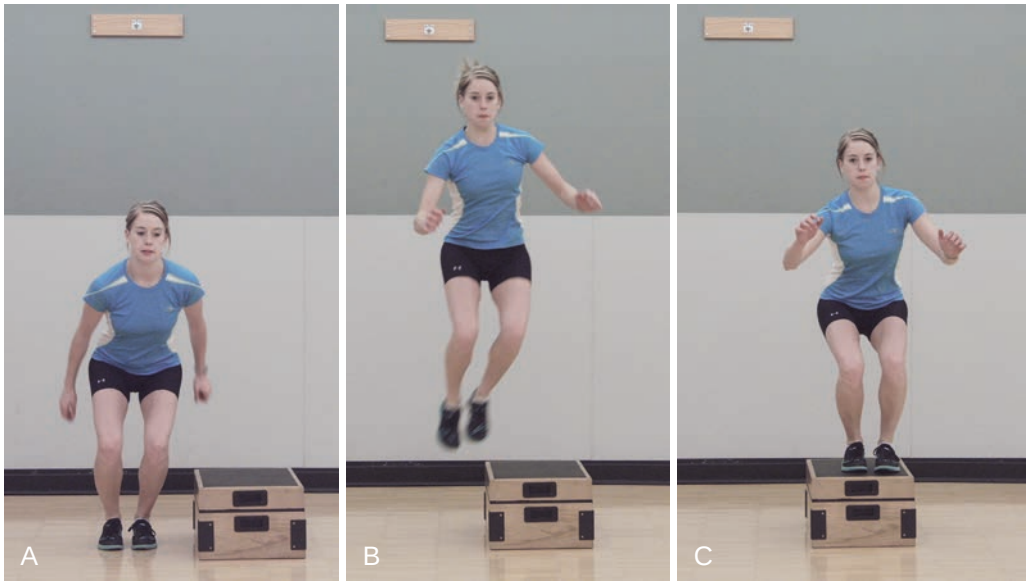

FIGURE 27-22. A–C, Side box jump.

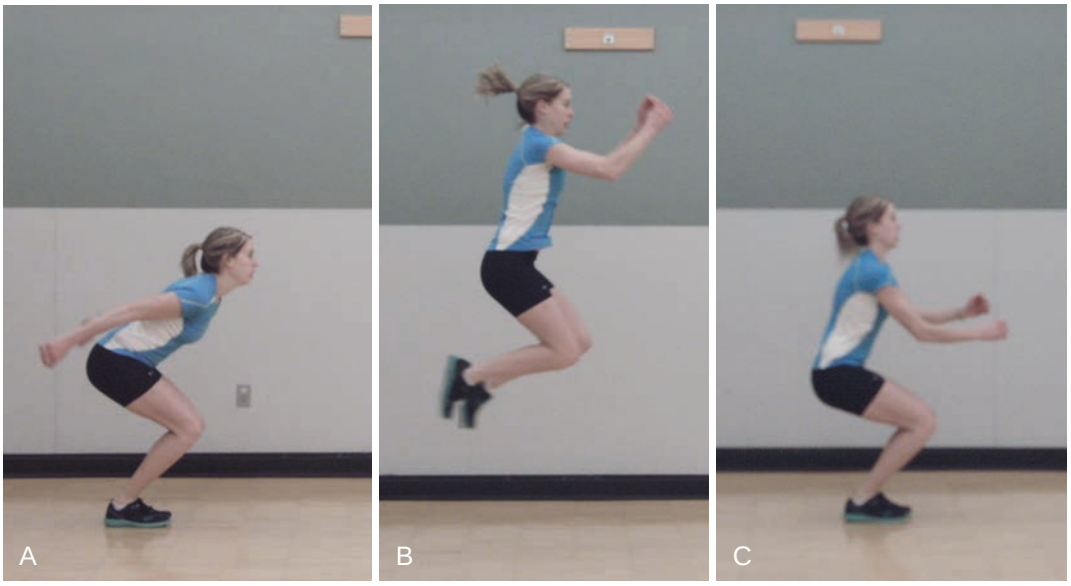

FIGURE 27-23. A–C, Two-leg bounding.

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- Training continuum
- Flexibility/joint mobility for joint stability
- Training with optimum posture
- Sensorimotor and balance training
- Core training
- Cardiorespiratory training
- Multiplanar training activities
- Training for optimum muscle balance
- Training for optimum muscle functional strength
- Training for optimum muscle functional power
- Neuromuscular dynamic stability exercises
- Plyometric training
- Functional training
- Sport-specific training

Training Principles Used in the Design of the Program

- Principle of progression
- Principle of overload
- Principle of variation
- Principle of individualization
- Principles of specificity—specific adaptation to imposed demands (SAID)

Sports Performance Testing

General Information

Specific Criteria for Progression to the Next Stage to Determine Readiness for Running

- This is described in the preceding training program.

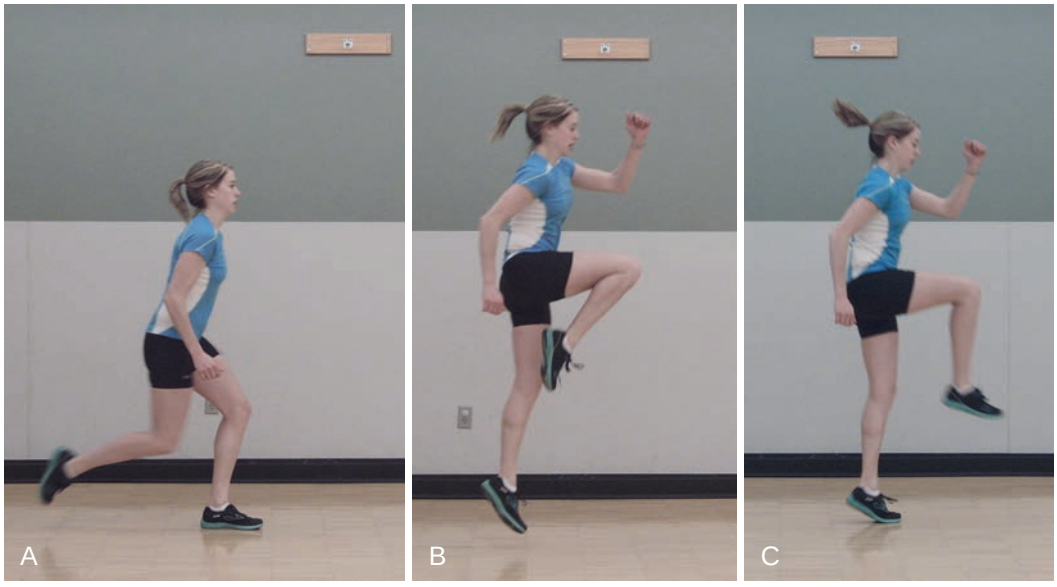

FIGURE 27-24. A–C, One-leg alternate bounding.

Specific Criteria for Release to Unsupervised Complete Participation in Running

- This is described in the preceding training program.

Recommended Ongoing Exercises

- Maintaining strong posterolateral pelvic musculature is important to enable normal hip loading during running.

Evidence

Johansson C, Ekenman I, Tornkvist H, et al: Stress fractures of the femoral neck in athletes. The consequence of a delay in diagnosis. *Am J Sports Med* 18:524–528, 1990.

This case series followed 23 athletes with femoral neck stress fractures for an average period of 6.5 years. Seven (30%) of the athletes experienced complications requiring major surgery, with none of the elite athletes able to return to their prior level of performance. The most important factor influencing complication rate seems to be the severity/type of fracture. (Level IV evidence)

Lee CH, Huang GS, Chao KH, et al: Surgical treatment of displaced stress fractures of the femoral neck in military recruits: A report of 42 cases. *Arch Orthop Trauma Surg* 123:527–533, 2003.

This single prospective cohort study followed 42 patients with displaced femoral neck stress fractures over an average period of 5.6 years. All patients required internal fixation. Ten of the patients developed avascular necrosis of the femoral head with eight treated with prosthetic replacement. Of the 42 patients, 30 (71.4%) had good functional results, four (9.5%) had acceptable, and eight (19%) had poor results. (Level IV evidence)

Niva MH, Kiuru MJ, Haataja R, et al: Fatigue injuries of the femur. *J Bone Joint Surg Br* 87:1385–1390, 2005.

This study described the anatomical location and incidence of femoral stress injuries in 1857 physically active young adults, based on MRI. Of these, 170 individuals had a total of 185 stress injuries, with 57% showing a stress reaction and 22% showing a fracture line. The three most common sites affected were the femoral neck (50%), the condylar area (24%) and the proximal shaft (18%), suggesting femoral neck involvement is more common than previously thought. (Level IV evidence)

Pihlajamaki HK, Ruohola JP, Kiuru MJ, et al: Displaced femoral neck fatigue fractures in military recruits. *J Bone Joint Surg Am* 88:1989–1997, 2006.

This descriptive study reported on 21 military recruits that sustained displaced femoral neck stress fracture, with 19 recruits followed for an average of 18 years. Following treatment, six patients had delayed union or nonunion of the fracture; six patients developed osteonecrosis of the femoral head; and eight patients developed severe osteoarthritis. (Level IV evidence)

Talbot JC, Cox G, Townend M, et al: Femoral neck stress fractures in military personnel: A case series. *J R Army Med Corps* 154(1):47–50, 2008.

This retrospective case series of 20 military recruits with a femoral neck stress fracture describes their injury epidemiology and clinical outcome. Most injuries were nondisplaced (85%) and treated conservatively. (Level IV evidence)

Multiple Choice Questions

QUESTION 1. Which location of a stress fracture is most often managed surgically?

A. Proximal medial femoral shaft
B. Distal medial femoral shaft
C. Superior femoral neck
D. Inferior femoral neck

QUESTION 2. For sub-elite and elite runners, the likelihood of returning to one's prior level of running performance following a surgically managed femoral neck stress fracture is

A. excellent.
B. good.
C. fair.
D. poor.

QUESTION 3. Complications related to a femoral neck stress fracture can include

A. severe osteoarthritis.
B. avascular necrosis.
C. refracture.
D. all of the above.

Answer Key

QUESTION 1. Correct answer: **C** (see Overview)

QUESTION 2. Correct answer: **C** (see Overview)

QUESTION 3. Correct answer: **D** (see Overview and Evidence)

Chapter 28



Patellar Instability

INTRODUCTION

Diego Herrera, MD, Najeeb Khan, MD, Donald C. Fithian, MD, and Christopher M. Powers, PhD, PT

Epidemiology

- The average annual incidence of primary patellar dislocation is 5.8 per 100,000. This incidence increases to 29 per 100,000 in the 10- to 17-year-old age group. The majority of these patients will experience no further instability with reported recurrence rates of 15% to 44% after conservative treatment.[1-3]
- Although recurrence is the exception and not the rule, many patients continue to be symptomatic following their dislocation episode. At 6 months postinjury, 58% of patients continue to have limitations with strenuous activity. Failure to return to sports has been reported in up to 55% of patients.[3]
- There is a slight female predilection.[3,4]

Pathophysiology

Intrinsic Factors

- The medial patellofemoral ligament (MPFL) is the primary ligamentous restraint against lateral patellar displacement.[5-7] In early flexion, the medial retinacular structures (particularly the MPFL) provide the primary restraint to lateral displacement of the patella. As the patella engages the trochlear groove with increasing flexion, trochlear geometry provides increasing constraint to mediolateral patellar motion.
- Deficiency of constraint by the MPFL can be exacerbated by patella alta, which causes the patella to engage late within the trochlea so that the patella spends a greater proportion of early flexion in a precarious state where only the ligaments constrain its mediolateral motion.[8,9]
- A lateralized tibial tubercle, as measured by tibial-tubercle-trochlear groove (TT-TG) distance on CT or MRI, is associated with patellar instability.[10]
- Systemic hypermobility can increase the risk of patellar instability, and articular injury is less likely in this cohort.[11,12]

Extrinsic Factors

- A history of contralateral patellar dislocation would increase the risk of recurrence sixfold, as much as a previous dislocation, even on the index knee.[1]

Traumatic Factors

- The most common mechanisms of patellar dislocation are sports (61%) and dance (9%) injuries.[1]
- The mechanism of injury is most often with the foot planted and internal rotation of the femur, with subsequent tibia external rotation relative to the femur.
- Direct trauma causing patellar translation and ultimately dislocation is also seen.

Classic Pathological Findings

- Injury to the MPFL is a lesion of necessity.[13] Residual laxity of the ligament is primarily responsible for

patellar instability after the initial dislocation event. Injury to the MPFL may occur at more than one location along its length during the dislocation.[14]
- Articular cartilage injuries have been reported in up to 95% of first-time patellar dislocations, although most do not require surgery.[15]
- Imaging studies may also show trochlear dysplasia, patella alta, increased TT-TG distance, and patellar tilt.[10]

Clinical Presentation

History

- For the acute first-time dislocation, knee swelling, and hemarthrosis are nearly always seen. Symptoms associated with the swelling and hemarthrosis, such as pain, decreased range of motion (ROM), and gait changes, can be seen.
- For recurrent dislocators, minimal pain and swelling is seen between episodes of patellar instability. These patients may complain of their knee giving way unexpectedly during activities of daily living and/or sports.
- It is crucial that the clinician distinguish the patient who has true episodic patellar instability from those who primarily complain of pain.

Physical Examination

Abnormal Findings

- For first-time dislocators, a large effusion with tenderness to palpation about the medial retinaculum is a typical finding. If the effusion is large and tense, aspiration can serve as a palliative measure and hasten normalization of ROM and gait.
- Apprehension to lateral patella translation, usually accompanied by pain with straight leg raise and active ROM.
- The Q-angle is rarely helpful, as it is imprecise and changes with patellar mobility. If a patella is subluxed laterally, the Q-angle measurement is falsely low. However, femoral and tibial torsion can play a role in patellar instability, with the largest lateral force placed on the patella when the tibia rotates externally in terminal knee extension. A distance between the tibial tuberosity and the trochlear groove (TT-TG as measured on axial imaging) that exceeds 20 mm is nearly always associated with patellar instability.[10]

Imaging

- Anteroposterior (AP), lateral, and merchant radiographs are used to confirm patellar location, presence of osteochondral fracture, and patellofemoral relationships.
- The lateral view with the knee flexed 30 degrees can help determine patella height. The Caton-Deschamps ratio is the distance between the lower edge of the patellar joint surface to the upper edge of the tibial plateau divided by the length of the patellar articular surface. A ratio greater than 1.2 signifies patella alta (Figure 28-1).
- The lateral view with the posterior condyles aligned can evaluate trochlear dysplasia. The "crossing" sign, where the curve of the trochlear floor crosses the anterior contour of the lateral femoral condyle, represents flattening of the trochlear groove and absence of trochlear constraint against patellar displacement. Trochlear prominence (also called a trochlear "boss," "bump," or "eminence") is represented by the distance between the most anterior point of the trochlear floor and a line drawn along the distal 10 cm of the anterior femoral cortex. The degree of trochlear prominence on a lateral radiograph correlates with the severity of dysplasia (Figure 28-2).
- MRI examination for first-time dislocators, particularly if a hemarthrosis is present, should be considered to assess for osteochondral or chondral injuries that are amenable to surgical intervention.
- Axial MRI images are also used to determine TT-TG offset (Figure 28-3).

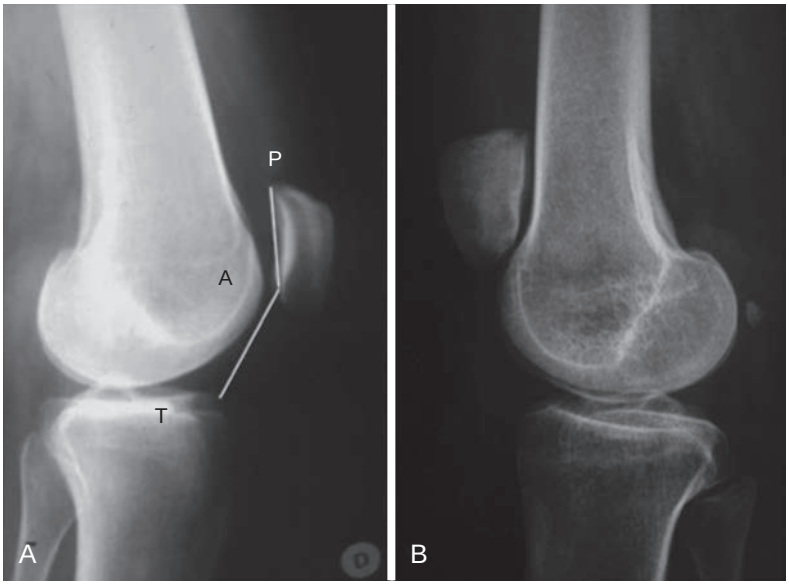

FIGURE 28-1. A, Patellar height. The height of the patella is surprisingly difficult to measure reliably. The Caton-Deschamps ratio is the distance between the lower edge of the patellar joint surface and the upper edge of the tibial plateau (AT) and the length of the patellar articular surface (AP). **B,** Severe patella alta.

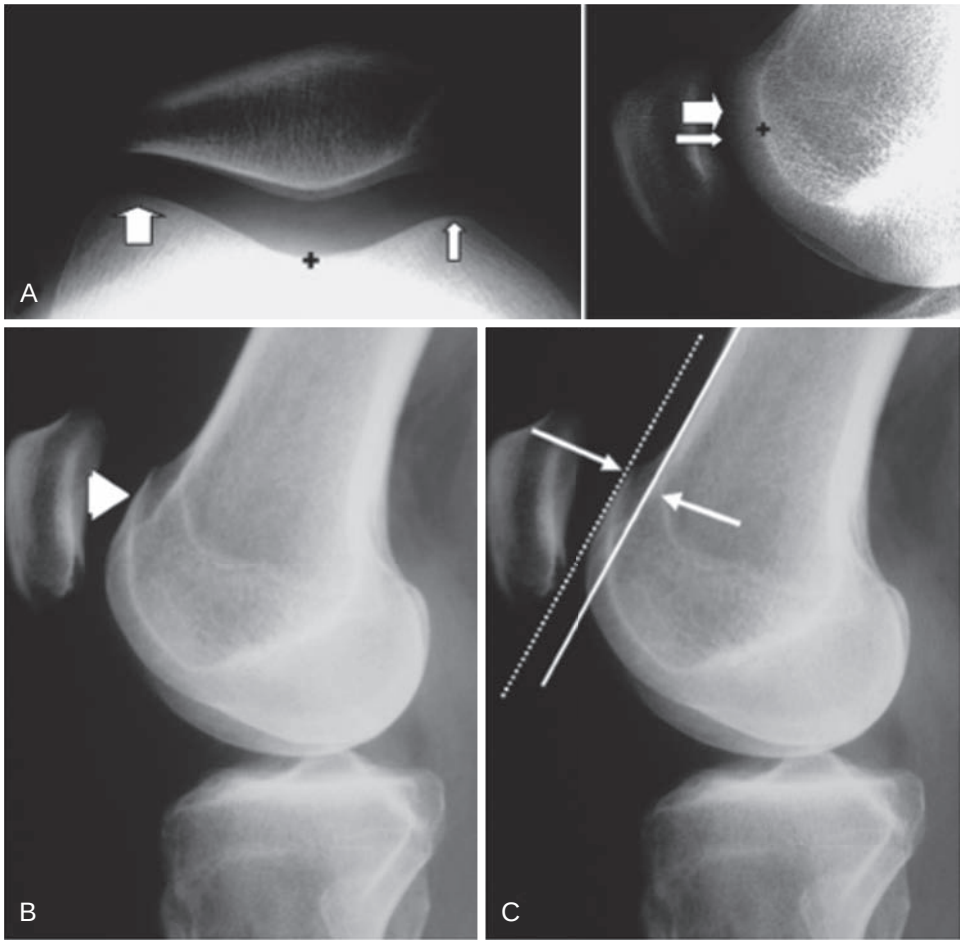

FIGURE 28-2. Crossing sign. **A,** Normal trochlea. On the lateral view, the profile shows a sclerotic curved white line that corresponds to the floor of the trochlea (+). The curves representing the trochlear ridges (*arrows*) do not cross the curve of the trochlear floor. Note that accurate interpretation of the lateral view requires that the posterior condyles be aligned. **B,** The crossing sign is a simple and characteristic image, a qualitative criterion of trochlear dysplasia. The arrowhead indicates the point where the curve of the trochlear floor crosses the anterior contour of the lateral femoral condyle. By definition, the trochlea is flat at this level. This sign is of fundamental importance in the diagnosis. **C,** The prominence (*bump*) is a quantitative characteristic that is particularly significant in trochlear dysplasia. The prominence represents the distance between the most anterior point of the trochlear floor (*dashed line*) and a line drawn along the distal 10 cm of the anterior femoral cortex (*solid line*). The greater the trochlear prominence, the greater the dysplasia.

Differential Diagnosis

- For a primary complaint of instability, it is important to evaluate the cruciates, collaterals, and menisci, as injuries to these structures can accompany patellar dislocations.
- Complaints of anterior knee pain carry a long differential diagnosis, including tumors, Hoffa disease, Osgood Schlatter disease, osteochondritis dessicans, stress fracture, patellofemoral osteoarthritis, bursitis, Sinding-Larson-Johanssen syndrome, symptomatic bipartite patella, meniscal pathology, loose bodies, and others.

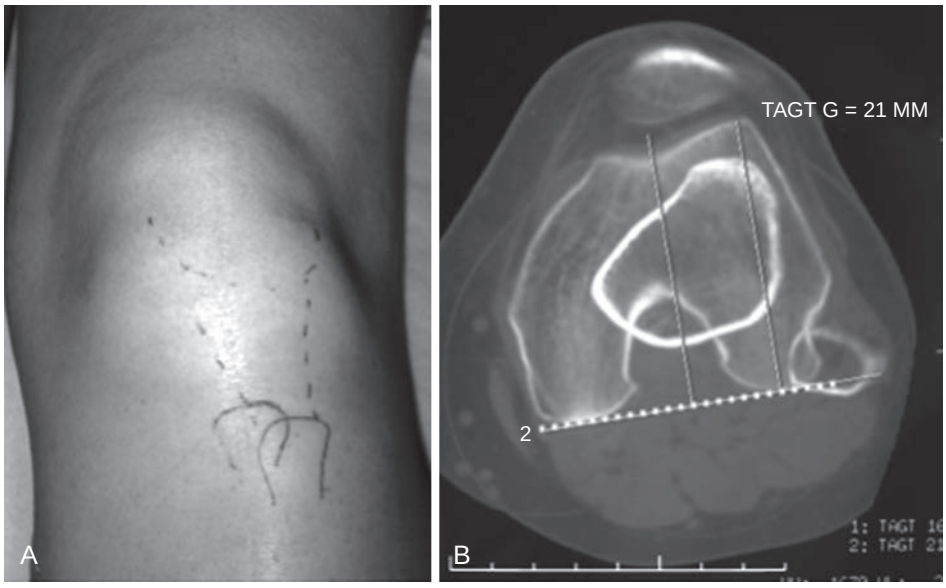

FIGURE 28-3. TT-TG offset. **A,** The lateral offset of the tibial tubercle is suspected clinically, but the analysis is qualitative. A CT scan (or an MRI) allows a reliable and reproducible measurement. **B,** Two axial cuts (*slices*) are superimposed: one through the apex of the tibial tubercle (TT) and the other through the femur at the level where the notch posteriorly resembles a curved "Roman arch" (*arrow*) (trochlear groove [TG]). The TT-TG offset is the distance between the most anterior point of the TT and the apex of the TG along a line parallel to the posterior condylar line (*dashed line*).

Treatment

Nonoperative Management

- Acute first-time patellar dislocations are treated with reduction and measures such as cryotherapy and NSAIDS to reduce pain and swelling. Tense hemarthrosis should be aspirated. Weight bearing as tolerated is encouraged, often with a knee immobilizer if symptoms do not allow sufficient quadriceps control. Physical therapy is started to address pain and swelling, ROM, normalization of gait, and ultimately quadriceps strengthening and proximal lower limb control.
- There is no established standard of care regarding immobilization after first-time dislocation. Whereas a simple knee sleeve was associated with relatively higher rates of recurrent dislocation,[16] strict immobilization can cause muscular atrophy, weakness, and stiffness.

Surgical Indications

- An osteochondral fracture that is visible on conventional radiographs is likely to be a significant lesion that should be followed by an MRI and possible surgical excision or fixation.
- MPFL reconstruction is best used to treat episodic lateral patellar instability due to excessive laxity of medial retinacular patellar stabilizers. The ideal candidate has minimal pain between episodes of patellar instability and seeks medical care primarily to address the occasional dislocation or subluxation. A tibial tubercle osteotomy in addition to MPFL reconstruction is considered in patients with TT-TG > 20 mm, patella alta, or both.

Evidence

Dejour H, Walch G, Nove-Josserand L, et al: Factors of patellar instability: An anatomic radiographic study. *Knee Surg Sports Traumatol Arthrosc* 2:19–26, 1994.

Case control study that identifies relevant radiographic and CT factors in knees with symptomatic patellar instability. The following factors were common findings in the symptomatic knees: Trochlear dysplasia (85%), patellar tilt (83%), tibial tuberosity-trochlear groove distance equal to or greater than 20 mm (56%), patella alta (24%), and very rare findings in nonsymptomatic knees (3% to 6.5%). The identification of these factors can lead to treatments that correct the aforementioned abnormalities. (Level IV evidence)

Desio SM, Burks RT, Bachus KN: Soft tissue restraints to lateral patellar translation in the human knee. *Am J Sports Med* 26:59–65, 1998.

In a biomechanical study that included nine cadaveric knees, it was found that the medial patella femoral ligament was the main restraint to lateral patellar translation at 20 degrees of flexion, contributing 60% of the total restraining force. (Level V evidence)

Fithian DC, Paxton EW, Stone ML, et al: Epidemiology and natural history of acute patellar dislocation. *Am J Sports Med* 32:1114–1121, 2004.

This is a prospective cohort study that identifies risk factors in 189 patients with acute patellar dislocations and a minimum follow up of 2 years (range of 2 to 5 years). Patellar dislocators with a previous history of patellar instability were more likely to be females. These patients also have a higher risk to have subsequent instability episodes than first-time dislocators. (Level I evidence)

Stefancin J, Parker R: First-time traumatic patellar dislocation: A systematic review. *Clin Orthop Relat Res* 455:93–101, 2007.

In a systematic review of 70 Level I to IV studies that included patients with first-time patella dislocation. The authors recommended initial nonoperative management except in specific circumstances, including the presence of an osteochondral fracture, substantial disruption of the medial patellar stabilizers, a laterally subluxated patella with normal alignment of the contralateral knee, a second dislocation, or in patients not improving with appropriate rehabilitation. (Level III evidence)

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Multiple-Choice Questions

QUESTION 1. The primary ligamentous restraint against lateral patellar displacement is the:

A. Medial collateral ligament (MCL)
B. Medial patellomeniscal ligament (MPML)
C. Medial patellofemoral ligament (MPFL)
D. Trochlea

QUESTION 2. The most common mechanisms of patellar dislocation are:

A. Direct trauma
B. Motor vehicle collisions
C. Sports and dance
D. Ehlers-Danlos syndrome

QUESTION 3. How do you measure excessive lateralization of the tibial tubercle?

A. Merchant view
B. Lateral view with the knee flexed 30 degrees
C. Axial imaging; measure tibial tubercle to trochlear groove offset (TT-TG)
D. Q-angle

QUESTION 4. Articular cartilage injuries are seen in up to _____% of first-time patellar dislocators.

A. 0%
B. 20%
C. 95%
D. 100%

QUESTION 5. Choose the best indication for MPFL reconstruction:

A. Patellofemoral pain syndrome
B. First-time patellar dislocation with tense effusion
C. Episodic patellar instability with minimal pain between episodes
D. Patellofemoral osteoarthritis

Answer Key

QUESTION 1. Correct answer: **C** (see Pathophysiology: Intrinsic Factors)

QUESTION 2. Correct answer: **C** (see Pathophysiology: Traumatic Factors)

QUESTION 3. Correct answer: **C** (see Pathophysiology: Intrinsic Factors)

QUESTION 4. Correct answer: **C** (see Classic Pathologic: Intrinsic Factors)

QUESTION 5. Correct answer: **C** (see Surgical Indications)

NONOPERATIVE REHABILITATION OF PATELLAR INSTABILITY

Najeeb Khan, MD, Donald C. Fithian, MD, and Christopher M. Powers, PhD, PT

- Most patients who suffer a first-time patellar dislocation do not have a recurrence. More than half, however, have some limitations with strenuous activities and do not return to sports.[1] The treatment goals after a first-time dislocation are to reduce the patella, diminish pain and swelling, normalize gait patterns, avoid recurrence, return to activities of daily living, and, ultimately, return to sports.
- Patients who have failed nonoperative treatment are considered for surgical intervention. The results of operative treatment, namely, MPFL repair, after primary patellar dislocations generally are not different from nonoperative treatment, although some authors report decreased recurrence with MPFL repair.[2,3] Controversy persists regarding operative treatment of the first-time patellar dislocator. The standard of care at this time is a trial of nonoperative treatment.
- Younger patients and those with predisposing anatomic factors, such as patella alta, trochlear dysplasia, and a high TT-TG offset, may have a higher risk of recurrence and failure of nonoperative treatment.
- Patients with patellofemoral pain, particularly females, may have decreased hip muscular strength in abduction, external rotation, and extension.[4] Once pain and swelling are treated, the ultimate goal is to gain proximal limb control and avoid valgus collapse and dynamic hip internal rotation that comes with weak hip abductors and external rotators.
- Patellofemoral rehabilitation, both for nonoperative and operative treatment of patellar instability, should ultimately address dynamic lower extremity function (Figure 28-4).
- The rehabilitation protocol, following, is somewhat arbitrarily divided into phases. Patients with underlying patellofemoral pathoanatomy (e.g., trochlear dysplasia, patella alta) may achieve goals and progress slower than those without. Athletes who have sustained a patella dislocation caused by direct trauma are generally expected to progress well with therapy, as they may not necessarily have the degree of proximal weakness and imbalance as their counterparts who dislocated caused by indirect trauma. Progression to

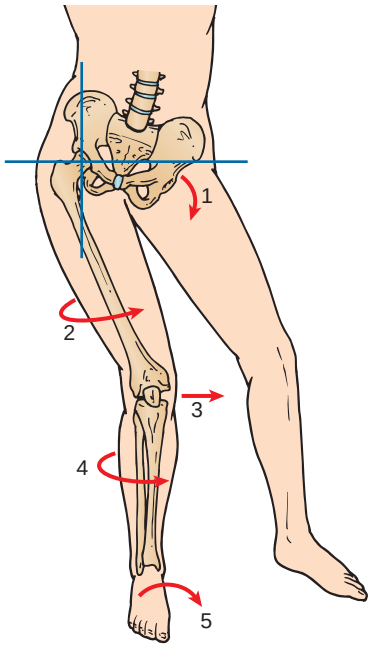

FIGURE 28-4. Schematic of the various potential contributions of limb malalignment and malrotation to increase the dynamic Q-angle: **A,** Hip adduction. **B,** Femoral internal rotation. **C,** Genu valgum. **D,** Tibial external rotation. **E,** Foot pronation.

the next stage is contingent upon achieving the goals of the prior stage.

GUIDING PRINCIPLES OF NONOPERATIVE REHABILITATION

- Reduce pain and swelling
- Normalize ROM
- Normalize gait pattern
- Quadriceps strengthening
- Proximal lower limb control training

Phase I (weeks 0 to 2)

Goals

- The goals of this phase are to reduce pain and swelling, initiate muscular strength and endurance training without pain, and introduce balance training.

Protection

- Encourage weight bearing as tolerated in a hinged knee brace, locked in extension for ambulation. The knee brace is unlocked once appropriate quad strength and control are achieved.
- Crutches may be provided initially, with encouragement to wean from supportive devices as soon as possible.

Management of Pain and Swelling

- Pain and swelling reduction techniques: rest, cryotherapy, NSAIDs.
- Modalities such as E-stim and biofeedback can be used as needed.

Therapeutic Exercises

- Gentle quadriceps strengthening should begin as soon as pain allows. Care should be taken to avoid active terminal knee extension, as this range of motion places high stress on the patellofemoral joint.[5,6] In this early phase, patients also should perform nonweightbearing exercises targeting the hip abductors, external rotators, and extensors. When performing strengthening exercises for the gluteus medius, the patient must take care to minimize the contribution of the tensor fascia lata, as contraction of this muscle contributes to medial rotation of the lower extremity.
- Balance training is introduced as symptoms allow including wobble board, BOSU ball, single-leg squat and reach, and other methods.

Open and Closed Kinetic Chain Exercises

- Care must be taken to avoid open chain active terminal knee extension (15° to full extension), as the stress on the patellofemoral is quite high in this range.[6]

Phase II (weeks 3 to 6)

Goals

- The goals of this phase are to fully treat pain and swelling, enhance leg strength and proximal limb control, normalize gait, and prepare for return to functional activities.

Protection

- Knee brace should be unlocked by Phase II and then exchanged for a neoprene sleeve.[7]

Management of Pain and Swelling

- Treatment of pain and swelling continues with cryotherapy and NSAIDs as needed.

Therapeutic Exercises

- Facilitation of normal gait is an essential component of the overall treatment plan. This is particularly important for the returning athlete (especially runners) in whom even a slight gait deviation can be compounded by repetitive loading. The clinician should pay particular attention to the quadriceps avoidance gait pattern (walking with the knee extended or hyperextended). Because knee flexion during weight acceptance is critical for shock absorption,[8] this key function must be restored to prevent the deleterious effects of high-impact tibiofemoral joint loading.
- Strength training as in Phase I continues. Once the patient can isolate the proximal muscles of interest in nonweightbearing, progression to weightbearing activities can begin.

- The concept of neutral lower extremity alignment is introduced. This involves alignment of the lower extremity such that the anterior superior iliac spine (ASIS) and knee remain positioned over the second toe, with the hip positioned in neutral. Postural alignment and symmetrical strengthening should be emphasized during all exercises.
- If the patient has a difficult time maintaining proper lower extremity alignment during initial weightbearing exercises, femoral strapping can be used to provide kinesthetic feedback and to augment muscular control and proprioception. Also, taping or bracing of the patellofemoral joint may be used if pain is limiting the patient's ability to engage in a meaningful weightbearing exercise program. Partial squats, which may have started already in very controlled environment with supervision, can be advanced to incorporate a BOSU ball or similar device to facilitate proximal control. Close supervision is required to ensure proper execution, as most patients may exhibit abnormal postures or movements during these tasks. Once the patient understands the proper movement and goal of the task, continued performance in front of a mirror provides useful feedback.
- As strength, control, and balance progress, single-leg activities may be initiated. This is the final step before returning to full unrestricted activity.

Phase III (weeks 7 and beyond)

- Rehabilitation from this point onward requires careful assessment and progressive development of proximal lower limb control.
- Patients should be encouraged to return to their sport or activity gradually once they can achieve satisfactory single-limb dynamic control. With competitive or recreational athletes who will be returning to full participation, plyometric training (e.g., jump training) should be considered during this phase of the rehabilitation program. As patients, particularly athletes, return to sport activities, repetitive forces applied through the knee joint must be controlled adequately to allow continued healing of the injured or repaired tissues.

Criteria for Abandoning Nonoperative Treatment and Proceeding to Surgery or More Intensive Intervention

- Surgical management is considered if patellar instability becomes recurrent and interferes with sports and/or activities of daily living.

Specific Criteria for Return to Sports Participation

- Full and painless ROM
- Absence of effusion and swelling
- Satisfactory and symmetric proximal single-limb dynamic control during high-impact activities (e.g., landing from a jump, cutting, etc.)
- Quadriceps, hamstring, and hip strength in at least 90% of the uninjured leg
- Psychologically ready to return to sports

Evidence

Atkin DM, Fithian DC, Marangi KS, et al: Characteristics of patients with primary acute lateral patellar dislocation and their recovery within the first 6 months. *Am J Sports Med* 28:472–479, 2000.

NEEDS ANNOTATION (Level III evidence)

Camanho G, Viegas A, Bitar A, et al: Conservative versus surgical treatment for repair of the medial patellofemoral ligament in acute dislocations of the patella. *Arthroscopy* 25:620–625, 2009.

NEEDS ANNOTATION (Level II evidence)

Christiansen SE, Jakobsen BW, Lund B, et al: Isolated repair of the medial patellofemoral ligament in primary dislocation of the patella: a prospective randomized study. *Arthroscopy* 24:881–887, 2008.

NEEDS ANNOTATION (Level I evidence)

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3. Camanho G, Viegas A, Bitar A, et al: Conservative versus surgical treatment for repair of the medial patellofemoral ligament in acute dislocations of the patella. *Arthroscopy* 25:620–625, 2009.
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Multiple-Choice Questions

QUESTION 1. Which of the following is not a treatment goal after first-time patellar dislocation?

A. Reduce pain and swelling
B. Normalize gait pattern
C. Surgical repair of the medial patellofemoral ligament
D. Return to activities of daily living

QUESTION 2. When are crutches discontinued after primary patellar dislocation?

A. After Phase I
B. After normalization of ROM
C. As soon as possible
D. Never

QUESTION 3. Activation of which muscle groups should be avoided?

A. Hip abductors and external rotators
B. Quadriceps and hamstrings
C. Vastus medialis oblique (VMO) and tensor fascia lata
D. Hip extensors

QUESTION 4. Surgical management is considered for:

A. Pain and swelling
B. Damage to the MPFL
C. Recurrence of patellar instability
D. Quicker return to sports

Answer Key

QUESTION 1. Correct answer: **C** (see Introduction)

QUESTION 2. Correct answer: **C** (see Phase I: Protection)

QUESTION 3. Correct answer: **C** (see Phase I: Therapeutic Exercises)

QUESTION 4. Correct answer: **C** (see Criteria for Abandoning Nonoperative Treatment and Proceeding to Surgery or More Intensive Intervention)

POSTOPERATIVE REHABILITATION AFTER PROXIMAL REALIGNMENT PROCEDURES AND MEDIAL PATELLOFEMORAL LIGAMENT (MPFL) RECONSTRUCTION

Kentaro Suzuki, MD, Matthew Pifer, MD, Najeeb Khan, MD, Donald Fithian, MD, and Christopher M. Powers, PhD, PT

Indications for Surgical Treatment

- Medial patellofemoral ligament (MPFL) reconstruction is best used to treat episodic lateral patella instability because of excessive laxity of medial retinacular stabilizers.
- The ideal candidate has minimal pain between episodes of patella instability and seeks medical care primarily to address the occasional dislocation or subluxation.
- It is imperative that the surgeon document MPFL laxity by physical examination,[1] stress radiography,[2] and/or arthrometry[3] before committing to an MPFL reconstruction. Frequently, an examination under anesthesia is necessary to confirm laxity of the medial retinacular structures because of patient apprehension and discomfort in the clinic.

Brief Summary of Surgical Technique

Major Surgical Steps

- Examination under anesthesia includes an assessment of patella mobility. The diagnosis of patella instability requires that there be a soft or no end point to lateral patella displacement either at full extension or 30° flexion and that the patella be mobile enough during examination under anesthesia to displace it out of the trochlea with the knee at 30° flexion. A diagnostic arthroscopy may be done to diagnose and treat any chondral lesions on the lateral condyle and patella.
- A 3 cm vertical incision is made over the pes anserinus, and a semitendinosis hamstring autograft is harvested. Alternatively, an allograft tendon can be used. A longitudinal incision is made over the medial patella, and the medial patella is exposed subperiosteally. A long curved clamp is then used to develop the interval between the retinaculum and the capsule all the way to the medial femoral epicondyle such that the graft will ultimately lie between the capsular layer and the native MPFL.
- A 4.5 mm drill is used to create two right-angle tunnels in the proximal two-thirds of the patella. A short incision is made over the medial epicondyle, and a blind socket is drilled between the femoral epicondyle and adductor tubercle. Fluoroscopy and intraoperative isometry testing is used to confirm appropriate positioning of the femoral socket.
- The hamstring graft is fixated at the femur, passed deep to the retinacular layer toward the medial patella, and then passed through the patellar tunnels. With the patella centered in the trochlear groove at 30° knee flexion, there is neither slack nor tension in the graft. Each free end of the graft is doubled over and sutured

to itself. Excessive medial constraint should be avoided,[4-6] as overtightening the graft results in increased medial facet compression.

Details and Choices That May Affect Rehabilitation

Surgical

- Postoperative pain can interfere with active quadriceps contraction. Pain can also impede progress with range of motion (ROM). Operating at or near the medial epicondyle of the knee is often associated with postoperative stiffness because of the higher degrees of motion of the injured soft tissues relative to the femur during knee flexion and extension. It is important to address ROM aggressively in the early postoperative phase to avoid stiffness. Once motion has been established, medial pain and knee stiffness as a result of scarring at the femoral attachment of the graft is rarely a problem.
- Swelling, either as free intraarticular fluid (effusion) or as soft tissue edema, can interfere with ROM. In addition, effusion inhibits quadriceps function[7] and may be harmful to articular cartilage.
- If autograft hamstring is harvested and used, avoid excessive hamstring stretching and strengthening for the first 6 weeks.

Anesthesia

- If regional anesthesia is used, await return of full motor function before starting weightbearing exercises.

Before Surgery: Overview of Goals, Milestones, and Guidelines

GUIDING PRINCIPLES OF POSTOPERATIVE REHABILITATION

- The principles of rehabilitation after MPFL reconstruction are similar to those guiding rehabilitation following other ligamentous reconstructions of the knee, such as anterior cruciate ligament (ACL).
- Despite differences between MPFL and ACL reconstruction surgery, there are enough similarities in postoperative neuromuscular deficiencies to suggest that strategies found to be successful after ACL reconstruction should be considered for those who have undergone MPFL reconstruction.
- The keys are to address pain, ROM, quadriceps strengthening, and proximal lower limb control.
- Return of full ROM, pain control, and protected weightbearing are stressed in the early phases of recovery.
- Progression of strength training and return to functional activities follows lines of evidence regarding graft necrosis, remodeling, and tunnel ingrowth, which are most commonly associated with ACL reconstruction.
- It is important to have a thorough preoperative discussion with the patient regarding the potential risks, benefits, goals, and postoperative rehabilitation. The patient should have realistic expectations regarding postoperative pain and the need for active participation in healing, rehabilitation, and return to sports. Passively receiving surgery and then awaiting a desired result can lead to failure of the graft and delay (if not preclude) a return to the activities of daily living and sports.
- Return to sedentary work is usually possible 5 to 7 days after surgery once pain is controlled and narcotic usage is minimal. Family and/or friends should also be recruited to help during the postoperative period. Driving can be considered once off narcotics, weightbearing is comfortable, and distal neuromuscular control allows for normalized reaction time.[8] This can take up to 6 weeks.

Phase I: Immediate Postoperative Period (days first 14)

Goals

- Pain control
- Reduce swelling and effusion
- Normalize ROM
- Return of quadriceps activation

Clinical Pearls

- If regional anesthesia is used, await return of motor function before starting weightbearing exercises.
- Use leg elevation, circumferential wrap, and cryotherapy to reduce swelling and effusion.
- Early ROM is critical to reduce stiffness.
- Avoid hamstring stretches (if autograft is selected).

Management of Pain and Swelling

- Pain and swelling need to be addressed immediately postoperatively and controlled over the long term. Strict elevation of the limb and limited activity in the first 1 to 2 days postoperatively allows the acute inflammatory phase to pass without further perturbation by overaggressive therapy. During that time, cryotherapy is helpful,[9] whether in the form of ice packs or commercially available cold therapy units.

Details of the Following Treatments That Are Appropriate to the Phase of Rehabilitation

- The patient is allowed to bear weight as tolerated with crutches with a hinged knee brace locked in extension. Unlock the hinged knee brace at 2 to 3 weeks as quad strength and control returns. MPFL reconstruction is not affected by axial loading of the joint. For this reason, weightbearing is encouraged after surgery as

long as axial rotation of the limb is not allowed. The limb should be in a brace during weightbearing activities for 4 to 6 weeks postoperatively or at least until limb control is sufficient to prevent falls and rotational stress on the knee. Early weightbearing should follow a gradual progression from full protection in a rigid brace locked at full extension to an unlocked brace with crutches. Gradual increase to full weightbearing should be permitted as quadriceps strength is restored.

- Immediate, controlled ROM is not detrimental to fixation or graft development in well-positioned and securely fixed MPFL grafts.
- An early goal of rehabilitation after MPFL reconstruction is to reestablish full knee extension. Unlike ACL reconstruction, return of passive knee extension does not guarantee full active extension. For that to occur, attention must be focused on quadriceps strengthening. Pain and swelling can be mitigated with electrical stimulation, cold therapy, and compression wraps. Passive patellar glides should be instituted as soon as tolerated to reestablish normal passive patellar mobility within the trochlear groove in all directions (superiorly, inferiorly, medially, and laterally).
- Early application of neuromuscular electrical stimulation in combination with volitional contraction is used to minimize strength loss after surgery.[11]
- Treatment to enhance proximal control can be started preoperatively and then immediately after surgery. Postoperatively, patients should perform nonweightbearing exercises targeting the hip abductors, external rotators, and extensors. When performing strengthening exercises for the gluteus medius, the patient must take care to minimize the contribution of the tensor fascia lata, as contraction of this muscle contributes to medial rotation of the lower extremity. Once the patient can isolate the proximal muscles of interest in nonweightbearing, progression to weightbearing activities can begin.

Phase II: Postoperative (weeks 2 to 6)

Goals

- Normalize ROM
- Discontinue crutches
- Discontinue brace

Clinical Pearls

- ROM should be normalized in this phase.
- Quadriceps and hip muscle activation exercises in weightbearing should be emphasized.
- Return of quadriceps function should allow the clinician to unlock the brace.

Details of the Following Treatments That Are Appropriate to the Phase of Rehabilitation

- Return of passive flexion can be limited by poor surgical technique (e. g., misplaced graft) and by pain associated with dissection around the medial epicondyle. The goal is to exceed 90° flexion within 6 weeks postoperatively. If that goal is achieved, then it has been our experience that limited knee flexion will not be a problem. On the other hand, delay in achieving greater than 90° of knee flexion may allow scar tissue proliferation and formation of adhesions around the graft and within the medial knee soft tissues. Manipulation may be required to regain full knee motion if flexion past 90° is not accomplished by Week 6.
- Exercises to enhance proximal control in weightbearing should be emphasized. As with the nonweightbearing exercises, the patient must take care to minimize the contribution of the tensor fascia lata, as contraction of this muscle contributes to medial rotation of the lower extremity.

Phase III (weeks 6 to 10)

Goals

- Normalize gait pattern
- Normalize hip strength
- Improve quadriceps strength

Clinical Pearl

- As pain and swelling subsides and function returns, athletes are often tempted to return to their sport before clearance by their medical team (surgeon, therapist). Advise the patient to complete their rehabilitation before returning to sports.

TIMELINE 28-1: **Postoperative Rehabilitation After Proximal Realignment Procedures and Medial Patellofemoral Ligament (MPFL) Reconstruction**

PHASE I (weeks 0 to 4)	PHASE II (weeks 4 to 6)

• Weight-bearing as tolerated (WBAT) with crutches; brace locked in extension
• Unlock brace at 2–3 weeks as quad strength and control returns
• Passive ROM as tolerated
• Start nonweightbearing exercises targeting hip abductors, external rotators, and extensors
• Modalities, including cryotherapy and electrical stimulation
• Home exercises:
  • Passive knee extension (knee sags)
  • Passive knee flexion (heel slides)
  • Gentle quadriceps sets
  • Patellar mobilization
	• Gradually discontinue crutches
	• Discontinue brace at 6 wk
	• Normalize ROM

Details of the Following Treatments that Are Appropriate to the Phase of Rehabilitation

- Surgery of the extensor mechanism is particularly prone to causing quadriceps inhibition and dysfunction, and every effort should be made to regain quadriceps control, strength, and endurance. Gentle quadriceps setting exercises should be started immediately after the surgery to keep the patellar tendon and infrapatellar fat pad stretched to their full length and to restore neuromuscular control. Care must be taken to avoid open-chain active terminal knee extension (15° to full extension), as the stress on the patellofemoral is quite high in this range.[10] Resisted quadriceps and hamstring strengthening should be progressively employed as the initial pain subsides.
- The primary causes of quadriceps avoidance are pain, effusion, and quadriceps muscle weakness. As these impairments are addressed in other aspects of treatment, the clinician should keep in mind that resolution of symptoms may not readily translate into a normalized gait pattern. This is particularly evident in a patient with long-term pain and dysfunction. Movement patterns can be learned, and the patient may need to be reeducated with respect to key gait deficiencies. Electromyography (EMG) biofeedback can be an effective tool for this purpose (Figure 28-5).
- When postoperative quadriceps weakness and neuromuscular inhibition are superimposed on poor proximal control, unprotected weightbearing can result in abnormal forces on the healing graft. Assuming that 8 to 12 weeks are required for tendon-to-bone healing within tunnels to support graft tension without risk of slippage[13] care is needed to avoid any rotational activity during the first three postoperative months. Unprotected single-leg stance on the operated knee should be avoided until satisfactory proximal limb control has been achieved. The postoperative brace should be removed for resisted flexion and extension strengthening and other controlled rehabilitative exercises that do not cause knee valgus or axial rotational torque that would jeopardize the graft fixation.
- Care should be taken during weightbearing to prevent dynamic knee valgus and hip internal rotation, which can cause abnormal loads on the healing graft. This is important, as many patients with patellofemoral disorders have preexisting deficiencies in proximal limb control that can contribute to these motions.[12]
- Facilitation of normal gait is an essential component of the overall treatment plan. This is particularly important for the returning athlete (especially runners) in whom even a slight gait deviation can be compounded by repetitive loading. The clinician should pay particular attention to the quadriceps avoidance gait pattern (walking with the knee extended or hyperextended). Because knee flexion during weight acceptance is critical for shock absorption,[14] this key function must be restored to prevent the deleterious effects of high-impact tibiofemoral joint loading.

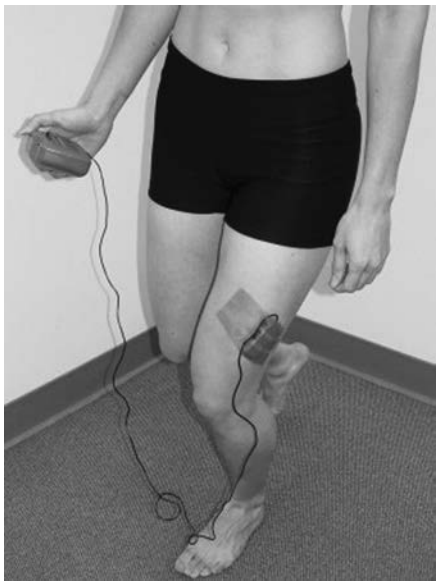

FIGURE 28-5. Electromyography biofeedback can be used to facilitate quadriceps recruitment during functional tasks. *(From Powers CM, Souza RB, Fulkerson JP. Patellofemoral joint. In Magee DJ, Zachazewski JE, Quillen WS, editors: Pathology and intervention in musculoskeletal rehabilitation. St Louis: Saunders Elsevier; 2008.)*

TIMELINE 28-1: **Postoperative Rehabilitation After Proximal Realignment Procedures and Medial Patellofemoral Ligament (MPFL) Reconstruction** (Continued)

PHASE III (weeks 6 to 10)	PHASE IV (weeks 10 to 14)	PHASE V (weeks 14 to 24)
• Normalize gait • Normalize hip strength • Improve quadriceps strength	• Functional and proximal control training • Weightbearing strength training of quadriceps, core, and hip stabilizers • Single-leg strength, balance, and control exercises • Plyometrics and sport-specific training	• Normalize strength and power of all major muscle groups • Dynamic limb control during sport-specific activities • Movement activities that simulate demands of their sport • Return to their sport or activity gradually • Plyometric training (e.g., jump training) • Maintain quadriceps and hip muscle strength (e.g., maintenance program)

Phase IV: Postoperative (weeks 10 to 14)

Goals

- Symmetric and normalized dynamic limb stabilization and control (single leg)
- Normalized quadriceps strength

Clinical Pearls

- Focus on functional training, dynamic limb stabilization, and control.
- Perform closed-chain quadriceps strengthening; avoid open-chain knee extension exercises.
- Unprotected single-leg stance on the operated knee should be avoided until satisfactory proximal limb control has been achieved.

Details of the Following Treatments That Are Appropriate to the Phase of Rehabilitation

- Functional training of the limb can begin in earnest 3 months after surgery. At this time, the patient should be introduced to the concept of neutral lower extremity alignment. This involves alignment of the lower extremity such that the anterior superior iliac spine (ASIS) and knee remain positioned over the second toe, with the hip positioned in neutral. Postural alignment and symmetrical strengthening should be emphasized during all exercises (see previous section of this chapter).
- Femoral strapping can be used to provide kinesthetic feedback and to augment muscular control and proprioception. Taping or bracing can also be used if pain is limiting the patient's ability to engage in a meaningful weight-bearing exercise program.
- Partial squats, which may have started already in a very controlled environment with supervision, can be advanced to incorporate a BOSU ball, or similar device, to facilitate proximal control. Close supervision is encouraged to ensure proper execution of these exercises. Once the patient understands the proper movement and goal of the task, continued performance in front of a mirror provides useful feedback.
- As strength, control, and balance progress, single-leg activities may be initiated. This is the final step before returning to full unrestricted activity. Considering that most patients are conditioned by their preoperative apprehension caused by patellar instability and some patients may not have performed single-leg squats on the operated leg for years before the operation, the patient may not progress to this stage before 5 to 6 months after the reconstruction. In any case, rehabilitation from this point onward requires careful assessment and progressive development of proximal lower limb control.

Phase V: Postoperative (weeks 14 to 24)

Goals

- Normalized strength and power of all major muscle groups
- Dynamic limb control during sport-specific activities
- No evidence of hip internal rotation or dynamic knee valgus during sport-specific activities

Clinical Pearls

- The athlete should begin to engage in movement activities that simulate demands of their sport.
- The athlete should be closely monitored for poor lower limb mechanics during this phase of rehabilitation.

Details of the Following Treatments That Are Appropriate to the Phase of Rehabilitation

- Patients are encouraged to return to their sport or activity gradually once they can achieve satisfactory single-limb dynamic control. With competitive or recreational athletes who will be returning to full participation, plyometric training (e.g., jump training) should be considered during this phase of the rehabilitation program. As patients, particularly athletes, return to sport activities, repetitive forces applied through the knee joint must be controlled adequately to allow continued healing of the injured or repaired tissues. Quadriceps and hip muscle strength should be maintained (e.g., maintenance program).

Criteria for Return to Sport

- Return to sport criteria:
  - Full and painless ROM
  - Absence of effusion and swelling
  - Satisfactory and symmetric proximal single-limb dynamic control during high-impact activities (e.g., landing from a jump, cutting, etc.)
  - Quadriceps, hamstring, and hip strength in at least 90% of uninjured leg
  - Psychologically ready to return to sports
- Patients can expect to return to unrestricted activities 6 months to 1 year postoperatively.

Evidence

Chen V, Chacko AT, Costello FV, et al: Driving after musculoskeletal injury. Addressing patient and surgeon concerns in an urban orthopaedic practice. *J Bone Joint Surg Am* 90:2791–2797, 2008.

The authors report on two surveys (one administered to patients, one to surgeons) regarding return to driving and the impact of musculoskeletal injury on driving. Overall, 73% of

patients reported that the inability to drive presented a minor or major difficulty, and greater than 35% of patients either began driving while still on narcotics or did not consult their doctor before driving. The authors highlight the medicolegal ramifications regarding the issues around returning to drive and describe the process that their institution used to develop standardized guidelines. The need for standardized guidelines from a large professional organization was emphasized. (Level V evidence)

Nomura E, Hoiuchi Y, Kihara M: A mid-term follow up of medial patellofemoral ligament reconstruction using an artificial ligament for recurrent patellar dislocation. *Knee* 7:211–215, 2000.

Case series of 27 MPFL reconstructions at average follow-up of 5.9 years. A double-staple fixation method was used to fix the artificial ligament at 60° of knee flexion with a minimal amount of tension (a tension spacer was placed to ensure that it was not overtightened). The authors report 96% good to excellent results, with only one case of recurrent patellar subluxation/dislocation and two cases with positive apprehension tests. Symptomatic implants (staples) were the most frequent complication. (Level IV evidence)

Palmieri-Smith RM, Kreinbrink J, Ashton-Miller JA, et al: Quadriceps inhibition induced by an experimental knee joint effusion affects knee joint mechanics during a single-legged drop landing. *Am J Sports Med* 35:1269–1275, 2007.

Laboratory study involving nine active subjects in which four experimental knee conditions were tested in the same subjects with a washout period: no effusion, subcutaneous lidocaine injection, low effusion (30 ml), and high effusion (60 ml). Using electromyographic, motion analysis, and force measurements, the subjects were analyzed doing drop landings. Both the high- and low-effusion conditions had significantly impaired vastus lateralis and vastus medialis muscle activity, but only the high-effusion condition had a significant increase in net ground reaction force and corresponding decreases in net knee extension moment and peak knee flexion angle. The results indicate that larger effusions lead to altered biomechanics, muscle activation, and landing forces. (Level V evidence)

Rodeo SA, Arnoczky SP, Torzilli PA, et al: Tendon-healing in a bone tunnel. A biomechanical and histological study in the dog. *J Bone Joint Surg Am* 75:1795–1803, 1993.

This is a study of 20 dogs that underwent bilateral transplantation of the long digital extensor tendon from the lateral femoral condyle into a tunnel through the proximal tibial metaphysis, with fixation on the medial tibia. At 2, 4, 8, 12, and 26 weeks, biomechanical and histologic analysis was performed after sacrifice. Over the postoperative period, the tendon–bone interface transformed from fibrous tissue to more organized collagen fibers with significant remodeling of the trabecular bone. The most dramatic increase in the strength of the interface occurred during the first 4 weeks. All specimens through 8 weeks failed at the tendon–bone interface, whereas at 12 and 26 weeks, failure occurred from slippage at the clamp or from midsubstance rupture. The authors recommend protecting a healing tendon–bone interface for 8 to 12 weeks postoperatively. (Level V evidence)

Shelbourne KD, Gray T: Anterior cruciate ligament reconstruction with autogenous patellar tendon graft followed by accelerated rehabilitation. A two- to nine-year followup. *Am J Sports Med* 25:786–795, 1997.

This study is a case series of 1057 patients with ACL reconstructions with 76% objective follow-up and 90% subjective follow-up at an average of 4 years postoperatively. The patients underwent an accelerated rehabilitation protocol with strengthening and functional agility occurring at weeks 2 to 5 and return to sport-specific activities at 5 weeks if quadriceps strength was sufficient. Mean time to completing at 100% was 6.2 months. Graft ruptures occurred in 2.6% of the patients, and 97% to 98% of patients (both acute and chronic) had KT arthrometry side-to-side differences of less than 5 mm. (Level IV evidence)

Souza RB, Powers CM: Differences in hip kinematics, muscle strength, and muscle activation between subjects with and without patellofemoral pain. *J Orthop Sports Phys Ther* 39:12–19, 2009.

This is a laboratory study comparing the hip biomechanics of 20 asymptomatic females with 21 females with patellofemoral pain. Motion analysis and EMG of the gluteus maximus and gluteus medius were used to analyze the biomechanics during running, drop jumps, and step-downs. Hip abductor and hip extension isometric strength was also tested using a dynamometer. Subjects with patellofemoral pain had a higher degree of peak hip internal rotation during the tests and lower peak hip abduction and extension torques in strength testing. The authors conclude that an assessment of hip kinematics and strength is critical in patients with patellofemoral pain. (Level V evidence)

Steinkamp LA, Dillingham MF, Markel MD, et al: Biomechanical considerations in patellofemoral joint rehabilitation. *Am J Sports Med* 21:438–446, 1993.

This is a biomechanical study of 20 patients comparing patellofemoral joint forces performing leg extension exercises versus incline leg presses. At 0° and 30°, knee moments, patellofemoral joint reaction forces, and patellofemoral joint stress values were higher during leg extensions than during leg presses. At 60° and 90°, patellofemoral stress, joint reaction force, and knee moments were higher for leg presses. The crossover points were between 46° and 51°, with the intersection occurring at 48.4° for patellofemoral joint stress. Leg presses are recommended for rehabilitation of patellofemoral pain because of the lower patellofemoral joint stress values at lower (functional) ranges of motion. (Level V evidence)

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Multiple-Choice Questions

QUESTION 1. Choose the best indication for MPFL reconstruction:

A. Patellofemoral pain
B. First-time lateral patellar dislocation
C. Episodic lateral patellar instability
D. Episodic medial patellar instability

QUESTION 2. If an autograft hamstring is harvested and used to reconstruct the MPFL, avoid:

A. Regional anesthesia
B. Immediate ROM
C. Excessive hamstring stretching and strengthening for the first 6 weeks
D. Quad setting for the first 12 weeks

QUESTION 3. The principles that guide rehabilitation after MPFL reconstruction are similar to those guiding rehabilitation after which type of surgery?

A. Tibial tubercle osteotomy and anteromedialization
B. Lateral retinacular release and medial reefing
C. Anterior cruciate ligament reconstruction
D. Total knee arthroplasty

QUESTION 4. ROM exercises after MPFL reconstruction should start:

A. Three weeks after surgery to avoid detrimental effects to MPFL fixation at the patella
B. Six weeks after surgery to avoid detrimental effects to MPFL fixation at the femur
C. Immediately but must be controlled
D. Once proximal single-limb dynamic control has been attained

QUESTION 5. The final step before return to full unrestricted activity is:

A. Normalized gait pattern
B. Absence of effusion and swelling
C. Single-leg activities to achieve symmetric proximal single-limb dynamic control during high-impact activities
D. Removal of postoperative bandages

Answer Key

QUESTION 1. Correct answer: **C** (see Indications for Surgical Treatment)

QUESTION 2. Correct answer: **C** (see Brief Summary of Surgical Technique)

QUESTION 3. Correct answer: **C** (see Postoperative Rehabilitation: Overview of Goals, Important Milestones, and Guidelines)

QUESTION 4. Correct answer: **C** (see Postoperative Rehabilitation: Overview of Goals, Important Milestones, and Guidelines [Range of Motion])

QUESTION 5. Correct answer: **C** (see Postoperative Rehabilitation: Overview of Goals, Important Milestones, and Guidelines [Dynamic Limb Stabilization and Control])

POSTOPERATIVE REHABILITATION AFTER ANTEROMEDIALIZATION OF THE TIBIAL TUBERCLE

John Pryor Fulkerson, MD, Craig Alver, PT, and Erin L. Ives, PT, MS, OCS, CertMDT

Indications for Surgical Treatment

- Excessive lateral patella compression syndrome
- Lateral patellofemoral arthrosis
- Lateral patella tracking with lateral articular breakdown
- Painful distal and/or lateral patella chondral articular softening that has not responded to nonoperative or arthroscopic treatment

Brief Summary of Surgical Treatment

Major Surgical Steps

- Oblique osteotomy behind the tibial tubercle, tapered anteriorly at the distal aspect[1]
- Transfer the tibial tubercle anteriorly and medially by rotation of the osteotomy through a distal hinge of bone



FIGURE 28-6. Surgical incision.

- Secure fixation with two cortical lag screws into the posterior tibial cortex with compression (Figure 28-6)

Factors That May Affect Rehabilitation

Anesthetic

- Regional block will impair early motion in the first 24 to 48 hours but will be very helpful for immediate postoperative pain control

Surgical

- Fixation that is less secure or bone graft added in the osteotomy may require a longer period of limited motion and therefore impede the rehabilitation process

GUIDING PRINCIPLES OF POSTOPERATIVE REHABILITATION

- Understand the process of the surgical reconstruction
- Protect and progress ROM as appropriate for the healing bone and soft tissues
- Identify and correct lower extremity (LE) muscle imbalances

Phase I: Immediate Postoperative Period (days 0 to 14)[1]

Clinical Pearl

It is important during the immediate postoperative period to emphasize to the patient the importance of regaining full range of motion as quickly as possible. The patient needs to be instructed to bend the knee to a point that produces some level of discomfort that subsides once the stretch is completed. Stretching needs to be performed often (2 to 3 times a day) to gain the best results. Surgical fixation should permit this early motion.

Goals

- Protect the reconstruction
- Minimize pain and swelling in the lower extremity
- Initiate ROM exercises to promote healthy scar tissue

Protection

- Protection of the reconstructed knee includes the use of bilateral axillary crutches with a knee immobilizer.
- Weightbearing status is touch-toe weightbearing (TTWB) with a maximum of 20 lb exerted through the affected LE.

Management of Pain and Swelling

- Modalities including cryotherapy, TENS, and IFC stimulation; oral pain medications
- Cryotherapy, elevation, high-volt electrical stimulation, Kinesio taping (Figure 28-7)

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Mobilize the patella in inferior and superior directions along with correcting for any positional faults that may be present, such as lateral tilt

Soft Tissue Techniques

- Myofascial release and soft tissue mobilization around incision when proper healing has occurred



FIGURE 28-7. Kinesio tape positioning for edema reduction.

[1]*Prehabilitation, if appropriate, is described in the Nonoperative Rehabilitation section of this chapter.*

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Gastrocnemius, hamstring, iliotibial band (ITB), and hip flexor stretches to promote knee extension and quadriceps stretching to promote knee flexion; ankle pumps for thrombosis prevention

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Quadriceps, gluteal, and hamstring setting exercises should be initiated

Milestones for Progression to the Next Phase

- Achieve 0° to 90° of knee active range of motion (AROM) by 6 weeks from the date of surgery and full motion by 8 to 10 weeks
- Demonstrate independence with thrombosis prevention measures and ROM exercises
- Independent use of bilateral axillary crutches with TTWB through affected LE

Phase II: Postoperative (weeks 2 to 6)

Clinical Pearl

During this phase, OKC exercises for the hip are initiated, and correct form is crucial to good outcomes. Compensations in the form of faulty movement patterns will occur and need to be noted and corrected by the therapist. During side-lying abduction, the therapist needs to be sure that the patient is actually abducting from the hip joint and not compensating with lumbar side bending. During the side-lying clamshell exercise, the therapist also needs to be sure that the movement occurring is hip rotation and not lumbar spine rotation. These compensations may result in low back pain and a prolonged recovery for your patient.

Goals

- Continue to protect the reconstruction
- Minimize pain and swelling in the lower extremity
- Achieve full knee extension to flexion ROM
- Initiate open-chain LE strengthening exercises

Protection

- Protection continues with the use of bilateral axillary crutches
- Weightbearing can increase to partial weightbearing (PWB) 50% of body weight

Management of Pain and Swelling

- For pain: modalities including cryotherapy, TENS, and IFC stimulation
- Oral pain medications.
- For swelling: modalities including cryotherapy, high-volt electrical stimulation, and Kinesio taping

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Mobilize the patella in superior and inferior directions progressing the inferior glide with varying angles of knee flexion to promote full knee flexion AROM

Soft Tissue Techniques

- Myofascial release and soft tissue mobilization around the incision is continued in this phase to help promote return of full extension to flexion knee range of motion (ROM)

Stretching and Flexibility Techniques for the Musculotendinous Unit

- The stationary bike is a great tool for working flexion ROM at this time. The patient will begin with a rocking motion, inducing a flexion stretch in both forward and reverse directions until a complete revolution is possible.

TIMELINE 28-2: **Postoperative Rehabilitation After Anteromedial Tibial Tubercle Transfer**

PHASE I (weeks 0 to 2)	PHASE II (weeks 2 to 6)	PHASE III (weeks 6 to 10)
• Knee immobilizer • TTWB with bilateral axillary crutches • PT modalities • ROM (goal of 90°) • Patella mobilization as needed • TBS/TAS/TLS as recommended and tolerated • Thrombosis prevention	• Weightbearing can increase to PWB 50% of body weight with bilateral axillary crutches • PT modalities • Patella mobilization as needed • Achieve full knee extension-to-flexion ROM • Initiate OKC LE strengthening exercises	• FWB without assistive device with normal gait pattern • PT modalities • Patella mobilization as needed • Initiate CKC exercises for strength, balance, and proprioception • Maintain full knee extension-to-flexion ROM

- LE stretches are continued, including the hamstring, gastrocnemius, quadriceps, and hip flexor muscle groups, until full ROM is achieved at the knee.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Quadriceps, hamstring, and gluteal setting exercises continue and progress to open-chain exercises outlined in the following sections

Open and Closed Kinetic Chain Exercises

- OKC exercises, including straight leg raise (SLR) into flexion, abduction, adduction, and extension
- OKC and CKC exercises to address the hip muscles, including the clamshell and bridge

Milestones for Progression to the Next Phase

- Full knee extension to flexion ROM
- SLR in four directions without extension lag
- Effective use of crutches with PWB at 50%

Phase III: Postoperative (weeks 6 to 10)

Clinical Pearls

It has been documented that there is a correlation between hip ER weakness and patellofemoral dysfunction.[2] As strengthening is progressed with CKC activity in this phase, it is important to be aware of the patient's movement patterns. A common faulty movement pattern includes IR of the femur with a valgus movement at the knee. Correct activation of the hip ER can decrease this faulty movement pattern.

Goals

- Normalize gait without assistive devices
- Initiate CKC exercises for strength, balance, and proprioception
- Maintain full knee extension to flexion ROM

Protection

- The patient should be weaning from crutches at this point, with an emphasis placed on normalizing the gait pattern by the end of this phase. The patient will now be weightbearing as tolerated (WBAT) through the affected LE with the use of bilateral axillary crutches progressing to one crutch WBAT and finally to fulll weightbearing (FWB) at 10 weeks.

Management of Pain and Swelling

- Cryotherapy after therapy interventions to mitigate inflammation and soreness
- If swelling persists into this phase, the use of cryotherapy with high-volt stimulation can be effective

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Continue to monitor movement of the patella; at this point, grade 1 to 4 mobilizations of the knee for flexion or extension can be initiated

Soft Tissue Techniques

- Soft tissue mobilizations and myofascial release would be beneficial for any remaining adhesions

Stretching and Flexibility Techniques for the Musculotendinous Unit

- The stationary bike is continued at this time, with the patient making full revolutions with increasing resistance

TIMELINE 28-2: **Postoperative Rehabilitation After Anteromedial Tibial Tubercle Transfer** (Continued)

PHASE IV (weeks 10 to 14)	PHASE V (weeks 14 to 24)	PHASE VI (weeks 24 to 52)
• PT modalities as needed • Mobilizations as needed (patellofemoral and tibiofemoral) • Achieve normal gait pattern if not yet achieved • A/PROM to full if not yet achieved • Initiate prone quadriceps stretching • CKC: Leg presses and squats • OKC: May begin lightweight knee extensions at 10 to 12 weeks • OKC: Hamstrings and hip PREs • Controlled balance and proprioception exercises • Begin upper-body strengthening and endurance activities • Aquatic therapy may start as long as incision is healed	• Continue modalities and mobilizations as needed • Initiate partial lunges • Initiate walk-run program at 4 months • Initiate SLB exercises on even and uneven surfaces • Initiate plyometrics at 5 months • Initiate slide board activity at 16 to 20 weeks • Slow-speed sport-specific exercise at 20 weeks • Continue with OKC and CKC exercises	• Maintain full ROM • Continue OKC and CKC exercises as appropriate • Progress to full lunges with varying directions • Progress plyometrics • Increase speed of sport-specific exercises • Increase jogging time speed • Progress in-line running speed • Return to in-line running full speed • Return to limited sports with warning of risks • Full torsional sport (plant and cut) usually delayed until 1 yr after osteotomy

Sensorimotor Exercises

- Initiate balance and proprioception exercises for the LE seated on a therapy ball, then progress to single-leg stance (SLS) with the contralateral LE in a toe-touch position and, finally, SLS on the affected LE with a goal of maintaining the position for 30 seconds

Open and Closed Kinetic Chain Exercises

- Continuation of SLR in four positions of hip flexion, extension, abduction, and adduction with the addition of an ankle weight once extension lag is no longer present
- Clamshell with a weight above the knee for an added challenge
- Bridge progression to bridge with marching

Techniques to Increase Muscle Strength, Power, and Endurance

- The stationary bike at this point can be used for endurance with increasing resistance as tolerated

Functional Exercises

- Sit to stand from chair
- Two-inch step exercises, including anterior step-up, lateral step-up, and retro step-up

Milestones for Progression to the Next Phase

- FWB without assistive device with normal gait pattern
- Full extension to flexion ROM of the knee is maintained
- SLS with eyes open for 30 seconds

Phase IV: Postoperative (weeks 4 to 6)

Clinical Pearl

The literature has demonstrated improved knee function as a result of LE stretching, specifically at the hip.[3] As early as possible in this phase, prone quadriceps stretching should be initiated. Stretching the quadriceps in this position helps to stabilize the hip and decrease the potential for tortional forces on the knee. It also makes it easier to detect any rotation at the hip (ER/IR), which should be avoided. Passive knee flexion of 90° in prone by the therapist should be achieved before having the patient stretch independently. For comfort, a folded towel may be put under the thigh, raising it slightly off the table/floor.

Goals

- Normal gait if this has not been achieved
- Full pain-free ROM if this has not been achieved
- Strength MMT 4/5 for quadriceps and hamstrings
- Climb stairs reciprocally without pain

Management of Pain and Swelling

- Cryotherapy after interventions to mitigate inflammation and soreness
- If swelling persists into this phase, the use of cryotherapy with high-volt stimulation can be effective

Techniques for Progressive Increase in Range of Motion

- If ROM in the knee is not yet full, then it will continue to be addressed.

Manual Therapy Techniques

- Joint mobilization if needed for flexion and extension
- Patella mobilization if needed
- Often times, ROM is WNL and the patella is moving well by this point in rehabilitation

Soft Tissue Techniques

- If the incision remains tight, scar mobilization can be used

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Quadriceps stretching (in prone) (Figure 28-8)
- Hamstring, gastrocnemius, and hip musculature self-stretching

Other Therapeutic Exercises

- Increase LE closed-chain strengthening
- Slowly progress to proprioceptive activities in standing
- Begin upper-body strengthening and endurance exercises

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Leg presses/partial squats for quadriceps strengthening are introduced



FIGURE 28-8. Prone quadriceps self-stretch using a strap.

- Begin step-ups/step-downs
- Increase knee, hip, and calf strengthening

Sensorimotor Exercises

- Single-leg balance with eyes open and contralateral LE in toe-touch position
- Progress to single-leg balance (SLB) with eyes open and no contralateral involvement with the goal of maintaining position for 30 seconds

Open and Closed Kinetic Chain Exercises

- OKC: Continuation of SLR in four positions and other previous OKC exercises with increasing weight
- OKC: Open-chain light quadriceps strengthening can be started at 10 to 12 weeks postop. Open-chain quadriceps exercises should be initiated with light weight, 10 to 15 reps, and should be pain free
- OKC: Hamstring curls, seated
- CKC: Leg presses/partial wall squats, hip extension, calf raises. Advance to single-leg squats and calf raises as tolerated. Squats should initially be stopped at 50° to 60° of knee flexion, as research suggests that there is less patellofemoral joint force in this range and that it increases between 60° and 90°.[4]
- Also, because the goal is to restore quadriceps strength and correct patella tracking, there is research to support using isometric hip adduction with squats to help elicit the VMO and promote patella tracking.[5] (Figure 28-9)
- CKC: Step-ups/step-downs, usually starting with a 4-inch step. With step work, care should be taken to have the patient adduction and internal rotation of the hip
- CKC: Terminal knee extension with foot on ground, resistance behind knee
- Pool-based exercises for the UE and LE may be started at this point as long as the incision is healed

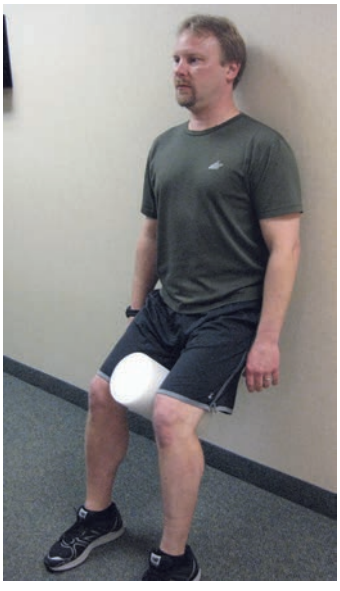


FIGURE 28-9. Wall squat with isometric hip adduction.



FIGURE 28-10. Hamstring curl with legs on therapeutic ball.

Techniques to Increase Muscle Strength, Power, and Endurance

- Increase resistance and time on bike as tolerated
- May begin using elliptical machine
- Increase walking time and speed slowly

Neuromuscular Dynamic Stability Exercises

- In standing, begin SLR in four directions with resisted tubing on surgical leg. This will improve balance and will facilitate core recruitment for total body stability.
- Also, exercises such as bridges on a Thera-Ball and hamstring curls on a Thera-Ball can be started, as they will also introduce core stability while working on LE strength (Figure 28-10).

Functional Exercises

- Step-ups and step-downs on stairs (start with 4-inch step)
- Make sure that technique is monitored
- Avoid hip adduction and internal rotation of the hip

Sport-Specific Exercises

- UE sport-specific drills for coordination can be started in a controlled environment, either sitting or standing on both legs

Milestones for Progression to the Next Phase

- Pain-free normal gait
- Able to climb stairs reciprocally without pain
- 4/5 quadriceps and hamstring strength
- Single-limb balance greater than 1 minute

Phase V: Postoperative (weeks 14 to 24)

Clinical Pearls

With the patient advancing to balance activities and increased dynamic stabilization exercises such as

lunges, great care needs to be placed on educating the patient in proper technique. Good alignment of the knee in relation to the hip and foot must be stressed. For instance, research has shown that a longer step with the lunge produces less patellofemoral joint force.[6]

Additionally, when higher-level dynamic stability exercises are initiated, it is imperative that form be monitored. In weightbearing, hip IR and adduction should be avoided when balancing, squatting, and jumping, as this can lead to lateral patella tilt and displacement.[7]

Goals

- 5/5 strength in quadriceps, hamstrings, and all hip musculature
- Single-limb balance of 2 minutes
- Return to jogging

Management of Pain and Swelling

- Ice after exercise

Techniques for Progressive Increase in Range of Motion

- Patients should have achieved full ROM by now. If not, follow previous guidelines.

Manual Therapy Techniques

- Continue previous techniques as needed

Soft Tissue Techniques

- Scar mobilization if required

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Continue with previous stretching of lower extremities bilaterally

Other Therapeutic Exercises

- Progress previous LE strengthening
- Progress UE strengthening
- Initiate neuromuscular dynamic stability exercises
- Initiate walk/run program at 4 months
- Initiate plyometric exercises at 4 months

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- As before with progressive resistance

Sensorimotor Exercises

- Initiate SLB activities on uneven surfaces at 16 weeks.
- Initiate SLS exercises with a progression of opposite LE reach, bilateral UE reach, and weighted bilateral UE reach as tolerated, focusing on good control of the knee in relation to the foot and hip (Figure 28-11).



FIGURE 28-11. Single-leg stance with bilateral upper extremity reach.

- Add SLS with UE weighted ball toss against rebounder, standing on flat surface.
- Slide board activity may be started between 16 and 20 weeks postoperatively. Balance on uneven surfaces, such as Airex foam or DynaDisc and exercises on a BOSU ball may also be initiated at this time (Figure 28-12).

Open and Closed Kinetic Chain Exercises

- OKC: Progress to standing hip exercises with resistance from bands or machines
- OKC: Progress hamstring curls
- OKC: Progress knee extension exercises. Stay with 10 to 15 reps for three sets and continue to lower resistance
- CKC: Lunges, starting forward and progressing as tolerated. Oftentimes, it is necessary to start with partial



FIGURE 28-12. Squat on BOSU ball.

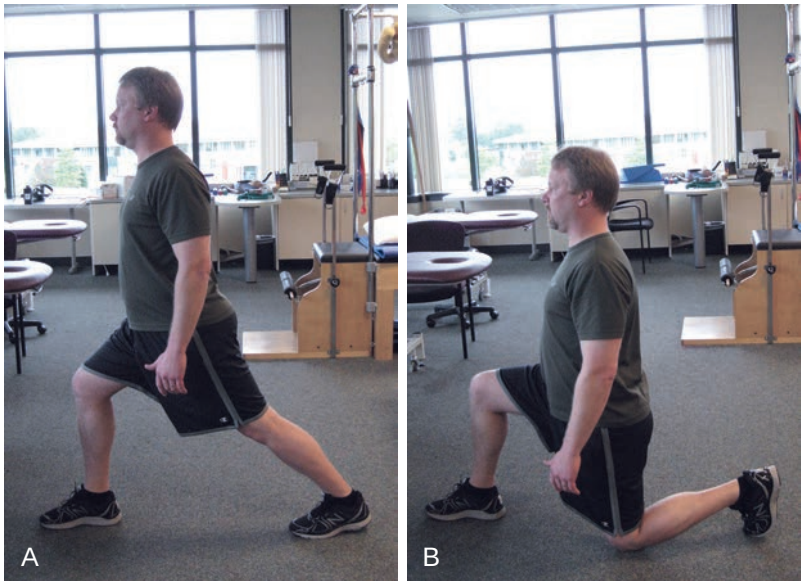


FIGURE 28-13. **A**, Partial lunge. **B**, Full lunge with long stride.

lunges (Figure 28-13). Of note: research supports a longer stride when performing a lunge to decrease the patellofemoral compressive force. Over time, a medicine ball with upper extremity reaching may be added to the lunge to incorporate core stabilization (Figure 28-14).
- CKC for upper body and core, such as pushups and planks, may be started

Techniques to Increase Muscle Strength, Power, and Endurance

- Increase weight on resistance exercises
- Initiate a walk/run program at 4 months. To do this, the patient must be pain free during a fast walk (at least 3.5 mph)

Neuromuscular Dynamic Stability Exercises

- Forward and sideways lunge on BOSU ball
- SLS with ball toss on uneven surfaces (Figure 28-15)
- Squats on BOSU ball; SLB on BOSU ball

Plyometrics

- Begin light plyometrics at 5 months as long as patient is pain free. Focus first on technique. Make sure the landing is soft and that the femur is not internally rotating or adducting (Figure 28-16).
- Slowly progress plyometrics, always focusing on form.
- Begin with bilateral jumps, progressing to toe taps on steps, step-ups, and step-overs and progress to one leg only as patient's control allows.



FIGURE 28-14. Lunge with upper extremities holding medicine ball.



FIGURE 28-15. Single-leg balance on DynaDisc with ball toss against rebounder.



FIGURE 28-16. **A**, Correct landing. **B**, Incorrect landing with right hip slightly adducted and internally rotated.

Functional Exercises

- Begin step-ups and step-overs, starting on a step and progressing to BOSU ball.
- Begin a walk/run program at 20 to 24 weeks as long as the patient is pain free.

Sport-Specific Exercises

- Continue sport-specific exercises for UEs
- May initiate slow-speed agility activities at 20 weeks if jogging and plyometrics have been pain free. These may include side shuffling, figure-eights, side-to-side carioca, etc.

Milestones for Progression to the Next Phase

- 5/5 strength throughout lower extremity
- Pain-free jogging
- Single-leg balance of 2 minutes
- Able to jump and land with good control pain free

Phase VI: Postoperative (weeks 24 to 52)

Clinical Pearl

Progression in this phase varies widely. It is not uncommon for an athlete who plays a contact sport to be out a full year before returning to the game. It is important to explain this to the patient early on and to set goals appropriately. Progression during this phase with regard to jumping, cutting, and speed/agility exercises must be slow and controlled.

Goals

- Return to in-line running full speed
- Return to limited sports with warning of risks
- Full torsional sport (plant and cut) usually delayed until 1 year after osteotomy

Management of Pain and Swelling

- Ice as needed after exercise

Techniques for Progressive Increase in Range of Motion

- ROM should be full and pain free at this point.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Patient should be instructed in the necessity of continuing LE stretching before and after exercise

Other Therapeutic Exercises

- The focus in this phase should be to get UE and LE strength back to preinjury levels.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Continue to strengthen quadriceps, hamstring, and hip musculature, progressing weight as tolerated.

Sensorimotor Exercises

- Advance balance and proprioceptive exercises to tolerance

Open and Closed Kinetic Chain Exercises

- OKC: Continue open-chain quadriceps, hamstring, and hip exercises
- CKC: Progress squats and leg presses to tolerance

Techniques to Increase Muscle Strength, Power, and Endurance

- Increase jogging time and speed
- Progress in-line running time and speed to tolerance

Neuromuscular Dynamic Stability Exercises

- Single-leg stance with UE band pulls, increasing resistance as control and balance allow

Plyometrics

- Advance plyometric exercises to tolerance, still focusing on good control of the knee in relation to the foot and hip

Sport-Specific Exercises

- During this phase, sport-specific exercises should be initiated, starting at slow speed and then increasing speed in a slow, progressive manner

Milestones for Progression to the Next Phase

- If isokinetic testing is available, less than 10% deficit of the involved side when compared to the noninvolved side
- No pain with agility/speed training activities

Criteria for Return to Sport

General

- Full motion and strength return
- Solid evidence of radiographic consolidation of the osteotomy
- Perform full-speed, sport-specific agility drills without pain

Sport-Specific

- The rehabilitation specialist and athletic trainers should, at this point, be able to develop a series of tests to ensure that the patient is ready to return to preinjury levels of activity.

After Return to Sport

Continuing Fitness or Rehabilitation Exercises

- General conditioning
- Continued LE strength and motion exercise

Exercises and Other Techniques for Prevention of Recurrent Injury

- As above

Evidence

Escamilla RF, Zheng N, Macleod TD, et al: Patellofemoral joint force and stress between a short and long step forward lunge. *J Orthop Sports Phys Ther* 38:681–690, 2008.

Research study using 18 subjects and 12 repetition max weight while performing forward lunge exercises. The study used EMG, ground reaction force, and kinematic variables to calculate patellofemoral joint force and stress as a function of knee angle. Patellofemoral joint force and stress were found to be significantly greater when performing a forward lunge with a short step versus a long step. Lunge with stride also produced greater force and stress than did the lunge without a stride. (Level II evidence)

Escamilla RF, Zheng N, Macleod TD, et al: Patellofemoral joint force and stress during the wall squat and one-leg squat. *Med Sci Sports Exerc* 41:879–888, 2009.

Research study using 18 subjects and 12 repetition max weight while performing wall squat short and long, as well as one leg squat. The study used EMG, force platform, and kinematic variables to calculate patellofemoral compressive forces and stress as a function of the knee angle. Results of the study found that patellofemoral force and stress were greater with these exercises between 60° and 90°, with differences depending on the exercise. (Level II evidence)

Farr J, Schepsis A, Cole B, et al: Anteromedialization, review and technique. *J Knee Surg* 20:120–128, 2007.

In this article, the authors share their extensive experience with the procedure to present the proper use and implementation of tibial tubercle ateromedialization. In essence, the procedure is best used to realign a chronically lateral overloaded patella that has led to lateral and/or distal patella articular breakdown and pain. The procedure effectively unloads the lateral and distal patella, thereby affording substantial pain relief and patellofemoral balance to the patient when the surgery and rehabilitation are properly performed. (Level III evidence)

Ireland ML, Willson JD, Ballantyne BT, et al: Hip strength in females with and without patellofemoral pain. *J Orthop Sports Phys Ther* 33:671–675, 2003.

This is a cross-sectional design study involving 30 females, 15 with knee pain and 15 without knee pain. Hip ER and ABD strength were measured using a hand-held dynamometer. The subjects with knee pain demonstrated 26% to 36% less knee strength than the control group.

Irish SE, Millward AJ, Wride J, et al: The effect of closed-chain exercises and open-kinetic chain exercise in muscle activity of vastus medialis oblique and vastus lateralis. *J Strength Cond Res* 24:1256–1262, 2010.

Research study comparing the effect of two closed-chain exercises and one open-chain exercise on VMO and VL activity. The study had 22 subjects and used surface EMG to compare VL and VMO activity while performing three different quadriceps strengthening exercises. Double-leg squat with isometric hip adduction was shown to produce the highest VMO : VL ratio, and the lunge produced the closest idealized ratio of VMO : VL. Open-chain knee extension was shown to produce significantly more VL activation than either of the closed-chain exercises. (Level II evidence)

Souza RB, Draper CE, Fredericson M, et al: Femur rotation and patellofemoral joint kinematics: a weightbearing magnetic resonance imaging analysis. *J Orthop Sports Phys Ther* 40:277–285, 2010.

This is a cross-sectional research study involving 15 females without knee pain and 15 females with patellofemoral pain. The study used weightbearing kinematic magnetic resonance imaging to compare patellofemoral joint kinematics and femoral rotation and patella rotation between the groups. The females in the patellofemoral group demonstrated both significantly greater medial (internal) femoral rotation and more lateral tilt than that of the pain-free group. (Level II evidence)

Tyler TF, Nicholas SJ, Mullaney MJ, et al: The role of hip muscle function in the treatment of patellofemoral pain syndrome. *Am J Sports Med* 34:630–636, 2006.

Thirty-five subjects with patellofemoral pain were evaluated and placed in a 6-week treatment program including hip abduction, flexion, and adduction strengthening along with iliopsoas and ITB stretching. The subjects that reported the most improvement demonstrated increased hip flexion strength and iliopsoas and ITB flexibility. (Level II evidence)

REFERENCES

1. Farr J, Schepsis A, Cole B, et al: Anteromedialization: review and technique. *J Knee Surg* 20:120–128, 2007.
2. Ireland ML, Willson JD, Ballantyne BT, et al: Hip strength in females with and without patellofemoral pain. *J Orthop Sports Phys Ther* 33:671–675, 2003.
3. Tyler TF, Nicholas SJ, Mullaney MJ, et al: The role of hip muscle function in the treatment of patellofemoral pain syndrome. *Am J Sports Med* 34:630–636, 2006.
4. Escamilla RF, Zheng N, Macleod TD, et al: Patellofemoral joint force and stress during the wall squat and one-leg squat. *Med Sci Sports Exerc* 41:879–888, 2009.
5. Irish SE, Millward AJ, Wride J, et al: The effect of closed-chain exercises and open-kinetic chain exercise in muscle activity of vastus medialis oblique and vastus lateralis. *J Strength Cond Res* 24:1256–1262, 2010.
6. Escamilla RF, Zheng N, Macleod TD, et al: Patellofemoral joint force and stress between a short and long step forward lunge. *J Orthop Sports Phys Ther* 38:681–690, 2008.
7. Souza RB, Draper CE, Fredericson M, et al: Femur rotation and patellofemoral joint kinematics: a weight-bearing magnetic resonance imaging analysis. *J Orthop Sports Phys Ther* 40:277–285, 2010.

Multiple-Choice Questions

QUESTION 1. Initial protection of reconstructed knee includes the use of bilateral axillary crutches with a knee immobilizer. Weight-bearing status is TTWB with a maxim of:

A. 0 lb exerted through the affected LE
B. 5 lb exerted through the affected LE
C. 10 lb exerted through the affected LE
D. 20 lb exerted through the affected LE

QUESTION 2. Sensorimotor exercises such as balance and proprioception should be initiated:

A. Never
B. During Phase II
C. During Phase III
D. During Phase IV

QUESTION 3. Robert's postrehabilitation of anteromedial tibial tubercle transfer should include:

A. Only open-chain exercises
B. Only closed-chain exercises
C. Both A and B
D. Neither A nor B

QUESTION 4. Which manual and soft tissue techniques are permitted in Phase I s/p anteromedial tibial tubercle transfer?

A. Patella mobilization superiorly and inferiorly
B. Myofascial release
C. Soft tissue mobilization
D. All are correct

QUESTION 5. As long as the patient is pain free, you can begin a walk-run program at weeks:

A. 28 to 32
C. 24 to 28
D. 16 to 20
D. 20 to 24

Answer Key

QUESTION 1. Correct answer: **D** (see Phase I: Protection)

QUESTION 2. Correct answer: **C** (see Phase III)

QUESTION 3. Correct answer: **C** (see Phase IV)

QUESTION 4. Correct answer: **D** (see Phase I)

QUESTION 5. Correct answer: **D** (see Phase V)

Chapter 29



Patellar and Quadriceps Tendinopathy

INTRODUCTION

Christopher C. Kaeding, MD

Epidemiology

Age

- 16 to 35 years

Sex

- Occurs in both males and females, with a predilection for males

Sport

- Basketball
- Lacrosse
- Soccer
- Football

Position

- Positions requiring sudden start/stop and or jumping movements

Pathophysiology

Intrinsic Factors

- Enthesis is at risk for tendinosis.
- This junction of tendon/bone joins materials with different modulus of elasticity.
  - This causes an area of stress concentration.
  - Thus producing peak loads at the enthesis.
  - These peak loads place enthesis at risk for overload pathological processes.

Extrinsic Factors

- A high volume of high loading episodes without required periods of rest/recovery
  - In positive adaptive environment, a tenocyte will produce growth factors such as TGF beta 1 and ILGF 1.
  - This can result in increased tendon fiber size and number and thus greater tendon tensile strength.
  - If loading surpasses threshold of a positive adaptive response, degenerative process can start.
- Plyometric loading of tendon
  - Tendons are viscoelastic and more stiff at higher loading rates.
  - Thus plyometric exercise can result in significant higher tendon loads.

Traumatic Factors

- Overuse injury that occurs from:
  - High volume (frequency, duration + intensity) of explosive, plyometric type of quadriceps contractions
  - Without required recovery period
  - Puts enthesis at highest risk for tendinosis
- Tenocyte de-differentiates into a more generic mesenchymal cell
  - Loses spindle shape, becomes round
- This cell produces catabolic signals that lead to tendon matrix degeneration.
  - These include substance P, calcitonin related gene peptide, and matrix metalloproteases.
  - Inflammation does not have a significant role during this process.
  - Prostaglandin E, a marker for inflammation, is not found in tendinosis.
- Early in the process there is a ingrowth of neovasculature and neurofilaments.
  - Neurofilaments/substance P may be source of pain.
  - No evidence for inflammation as source of pain.
- Once established, tendinosis cell/function appears to be recalcitrant

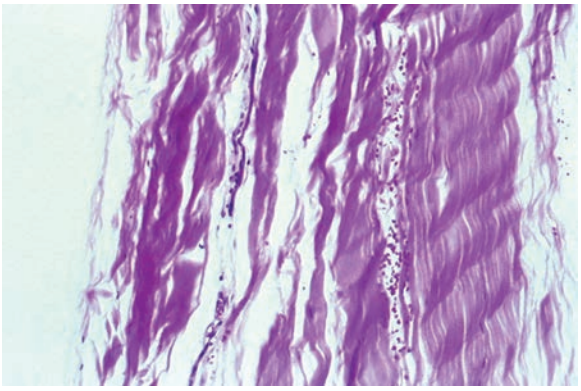


FIGURE 29-1. Normal tendon histology.

- Understimulation theory
  - Because of overloading there is a yet to be defined disruption of normal mechanotransduction by tenocyte.
  - Unable to detect tensile loads, the tenocyte starts to function more and more like a tendinosis cell, which does not support normal tendon matrix.
  - With lose of support of normal tenocyte and catabolic signals from the tendinosis cell, the matrix degenerates.

Classic Pathological Findings

- Normal tendon (Figure 29-1)
  - Tightly packed collagen fibers in longitudinal alignment
  - Slight waving pattern
  - Difficult to see spindle-shaped tenocytes
  - No discernible ground substance
- Tendinosis lesion (Figure 29-2)
  - Disorganized /fragmented/widely spread collagen
  - Mucoid ground substance
  - Sparse spindle shaped tenocytes
  - Hypercellularity
  - Round plump cells
  - Increased vascularity
  - Increased nerve filaments

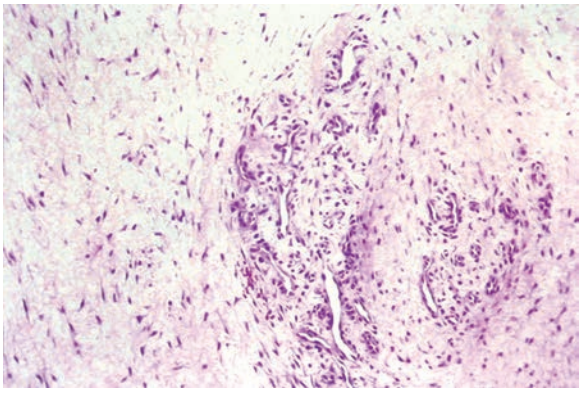


FIGURE 29-2. Tendinosis lesion histology.

Clinical Presentation

History

- Typically insidious onset of symptoms
- Patient localizes pain to inferior pole of patella
- Pain is typically increased with loading of the patella tendon
- Clinical classification of severity
  - Type 1: Sore after activity, but does not notice pain while playing
  - Type 2: Pain with activity, but not enough to affect play
  - Type 3: Pain impairs athlete's ability to train and perform.

Physical Examination

Abnormal Findings

- Tenderness of proximal patella tendon at the inferior pole of the patella
- May have some mild swelling or fullness in the area
- Pain on significant active quadriceps loading of tendon

Pertinent Normal Findings

- No effusion
- Ligaments stable
- No joint line tenderness
- Patella tracking is symmetrical
- Full range of motion
- No erythema or warmth to touch

Imaging

- Ultrasound will reveal an anechoic area
- MRI (Figures 29-3 and 29-4)
  - Area most often involved is proximal, posterior tendon in mid/medial portion or tendon



FIGURE 29-3. Sagittal MRI image of normal patella tendon.



FIGURE 29-4. Sagittal MRI image of patella tendinosis.

- Tendon is thickened
- Increased signal within the thickened portion of tendon

Differential Diagnosis

- Patella-femoral pain syndrome
  - Pain is typically described in more generalized fashion about anterior knee
  - There is no point tenderness at inferior pole of patella
  - May not have history of high volume of ballistic quadriceps contractions
- Patella-femoral chondrosis
  - Likely to have patella-femoral crepitus
  - May have mechanical symptoms of catching, clicking or locking
  - Imaging (x-ray/MRI) likely to demonstrate chondral erosions
  - Does not have point tenderness at inferior pole of patella
- Osgood Schlatter's disease
  - Occurs during the adolescent growth spurt. Patella tendinosis is rare in this age group.
  - Point of maximal tenderness is at the distal patella tendon insertion, as opposed to the proximal patella tendon origin in tendinosis.
  - Typically has prominence and tenderness over tibial tubercle.

Treatment

Nonoperative Management

- All of the following have been reported in the literature as treatment options for "chronic tendinitis" or tendinosis.
- Most have been reported to have 80% to 95% success rates.
- Very few, if any, have supportive high-quality controlled studies.
  - Rest
  - Diathermy
  - Deep friction massage
  - Extracorporal shock wave
  - Electric stimulation
  - Ultrasound
  - Magnets
  - Hyperbaric oxygen
  - Free radical scavengers
  - Sclerotherapy
  - Platelet-rich plasma (PRP) injection
  - Corticosteroids
  - Needling
  - Autologous blood injection
  - Nitric oxide
  - Eccentric exercise
  - Prolotherapy
  - Unloading devices
  - Pulsed electromagnetic fields
  - Acupuncture
  - NSAIDs (nonsteroidal antiinflammatory drugs)
  - DMSO (dimethylsulfoxide)
  - Cold laser
  - Radiofrequency ablation
  - Matrix metalloproteinase inhibitors
  - Stem cell injection
- A summary of several of the more common nonoperative treatments follows:
- Rest
  - Has been shown to be effective in acute overuse situation
  - Has not been shown to be effective in established tendinosis lesions
- NSAIDs/corticosteroids
  - May be of benefit in acute injury, if used for only a short period
  - Have not been shown to be effective in resolving established tendinosis
  - High or prolonged use may impair tendon healing
- Nitric oxide
  - Lab studies have shown some beneficial effects on tendon healing
  - Clinical studies mixed
  - Need further controlled trials and assessment of optimal dosing protocol
- Extracorporeal shock wave therapy (ECSW)
  - Conflicting evidence of clinical efficacy
  - Need more controlled trials and evaluation of optimal treatment protocols
- Platelet-rich plasma
  - Basic science studies have demonstrated beneficial effects on tendon healing in lab
  - Clinical studies mostly poorly controlled and mixed in results
  - Strongest evidence of clinical efficacy is for lateral epicondylar lesions
- Matrix metalloproteinase (MMP) inhibitors
  - Work by inhibiting catabolic effects of matrix metalloproteases
  - Some initial encouraging clinical results

  - Need further studies on efficacy and optimal treatment protocols
- Sclerotherapy
  - Aims to sclerose blood vessels of tendinosis lesion, often using ultrasound guidance
  - Some evidence of efficacy in producing pain relief
    - May be related to ablation of neurofilaments accompanying blood vessels
  - Has not been shown to reverse tendinosis pathology
- Eccentric exercises
  - Strongest evidence of efficacy in treating tendinosis
  - Best studied for Achilles lesions
  - Continuing to establish optimal treatment protocols

Guidelines for Choosing Among Nonoperative Treatments

- No good evidence that rest, corticosteroids, or NSAIDs are likely to provide lasting relief of an established patella tendinosis lesion.
- Eccentric exercises have the strongest level of evidence of clinical efficacy.
- ECSW, nitric oxide, sclerotherapy, and PRP have encouraging evidence, but further studies are needed.
- MMP inhibitors and stem cells are early in the evaluation process.

Surgical Indications

- Surgery is indicated when
  - There is a well-defined and well-established lesion.
  - Pain is significantly impairing the desired activity level.
  - Nonoperative measures have failed.
  - The patient understands expected outcomes and risks.

Aspects of History, Demographics, or Exam Findings That Affect Choice of Treatment

- Factors favoring operative treatment include
  - Longstanding lesion
  - High level of pain/disability
  - Well-established and well-defined lesion on MRI
  - Failure of nonoperative treatments
- Factors favoring nonoperative treatment
  - Recent onset
  - Poorly delineated on MRI
  - Lower levels of pain/disability

Aspects of Clinical Decision Making When Surgery Is Indicated

- The patient decides to proceed with surgery after understanding risks and expected outcomes of surgical treatment.
- Decision regarding timing of surgery
  - Patient expectations
  - Schedule and priority of competitions and training regimens
- Should an arthroscopy also be performed?
- Should excision of bone from the inferior patella be included in the procedure?
- Should a biological adjuvant treatment be added?
  - Stem cells, platelet rich plasma, etc.?

Evidence

Alfredson H, Pietila T, Jonsson P, et al: Heavy-load eccentric calf muscle training for the treatment of chronic Achilles tendinosis. *Am J Sports Med* 26:360–366, 1998.

This study provides evidence of the efficacy of eccentric exercise in treating tendinosis lesions. (Level IV evidence)

Arnoczky SP, Lavagnino M, Egerbacher M, et al: Matrix metalloproteinase inhibitors prevent a decrease in the mechanical properties of stress-deprived tendons: An in vitro experimental study. *Am J Sports Med* 35(5):763–769, 2007.

This study outlines the theory that it is the understimulation of tenocytes that results in their transforming into tendinosis type of cells.

Cook J, Feller J, Bonar S, et al: Abnormal tenocyte morphology is more prevalent than collagen disruption in asymptomatic athletes' patellar tendons. *J Orthop Res* 22:334–338, 2004.

This study supports theory that the primary change in tendinosis is in the tenocyte and not in the collagen matrix. (Level IV evidence)

Hoksrud A, Ohberg L, Alfredson H, et al: Ultrasound-guided sclerosis of neovessels in painful chronic patellar tendinopathy. *Am J Sports Med* 34(11):1738–1746, 2006.

This study provides evidence of the efficacy of sclerotherapy in the treatment of Patella tendinosis. (Level IV evidence)

Kaeding C, Best T: Tendinosis: Pathophysiology and nonoperative treatment. *Sports Health* 1(4):284–292, 2009.

This paper provides an overview of the pathophysiology and treatment options for tendinosis lesions. (Level V evidence)

Kane T, Ismail M, Calder J: Topical glyceryl trinitrate and noninsertional Achilles tendinopathy: A clinical and cellular investigation. *Am J Sports Med* 38(6):1160–1163, 2008.

This study, a randomized and controlled trial, did not demonstrate a benefit of topical glyceryl trinitrate patches in tendinopathy. (Level I evidence)

Magnussen R, Dunn W, Thomson A: Nonoperative treatment of midportion Achilles tendinopathy: A systematic review. *Clin J Sport Med* 19(1):54–64, 2009.

This paper provides a review of the level of evidence of various nonoperative treatments of tendinosis of the Achilles. (Level IV evidence)

Orchard J, Massey A, Brown R, et al: Successful management of tendinopathy with injections of the MMP-inhibitor aprotinin. *Clin Orthop Relat Res* 466(7):1625–1632, 2008.

This study is one of the first to report positive results with treating tendinosis with an MMP inhibitor. (Level IV evidence)

Paoloni J, Appleyard R, Nelson J Murrell G: Topical glyceryl trinitrate treatment of chronic noninsertional Achilles tendinopathy. *JBJS Am* 86:916–922, 2004.

This study demonstrated a beneficial effect of nitric oxide on tendinosis(Level II evidence)

Popp J, Yu J, Kaeding C: Recalcitrant patellar tendonitis. Magnetic resonance imaging, histologic evaluation, and surgical treatment. *Am J Sports Med* 25:218–222, 1997.

This study provides an over view of the MR imaging, histologic appearance and surgical treatment of patella tendinosis. (Level IV evidence)

Schyber T, Weidler C, Lerch K, et al.: Achilles tendinosis is associated with sprouting of substance P positive nerve fibres. *Ann Rheum Dis* 64:1083–1086, 2005.

This study is one of several studies that document the presence of substance P and new nerve filament growth in tendinosis lesions (Level IV evidence)

Van Leeuwen M, Zwerver J, Van den Akker-Scheek I: Extracorporeal shockwave therapy for patellar tendinopathy: A review of the literature. *Br J sports Med* 2008 [epub ahead of print].

This paper provides an overview of the literature regarding the efficacy of ECSW as treatment of tendinosis. (Level V evidence)

Multiple Choice Questions

QUESTION 1. Tendinosis is a chronic overuse condition of tendon that is characterized by

A. chronic inflammation with high PGE levels.
B. decreased number and size of cells.
C. decreased vascularity and innervation.
D. increased number of abnormal cells.

QUESTION 2. The nonoperative treatment of tendinosis with the least amount of evidence of efficacy is

A. rest and NSAIDs.
B. sclerotherapy.
C. shockwave therapy.
D. eccentric exercises.

Answer Key

QUESTION 1. Correct answer: **D** (see Classic Pathological Findings)

QUESTION 2. Correct answer: **A** (see Nonoperative treatments)

NONOPERATIVE REHABILITATION OF PATELLAR TENDINOPATHY

John DeWitt, PT, DPT, SCS, ATC, and Christopher C. Kaeding, MD

GUIDING PRINCIPLES OF NONOPERATIVE REHABILITATION

- Identify intrinsic and external risk factors for patellar tendinopathy.
- Evaluate efficacious nonoperative treatment interventions.
- Discuss appropriate return to sport criteria to prevent recurrence.
- Pain
  - Progress eccentrics if less than 5/10 pain.
  - Progress all other interventions if pain-free only.

Phase I (weeks 0 to 2)

Protection

- No running or jumping
- Can do non-bounding exercise (elliptical, bike, swimming) if pain free to maintain cardiopulmonary endurance.

Management of Pain and Swelling

- Ice massage

Techniques for Progressive Increase in Range of Motion

- Five-minute bike warmup
- Lumbosacral mobility (i.e., cat/camel exercise)
- Hip flexor and quadriceps flexibility (before and after activity)
  - Assisted: Prone with opposite hip flexion to isolate soft tissue
  - Self: Use belt or stand
- Patellar tendon mobility (before activity)
  - Instrument assisted soft tissue mobilization[1]
  - Cross-friction mobilization

Neuromuscular Dynamic Stability Exercises

- Activation exercise
  - Gluteal activation (Figure 29-5)
    - Bilateral activation
    - Reciprocal activation (frog leg-position)



FIGURE 29-5. Frog-leg gluteus activation.



FIGURE 29-6. A,B, Functional rolling to activate lumbosacral stabilizers.

- Transversus abdominis
  - Bilateral activation
- Functional roll patterns (Figure 29-6)
- Posterior weight shifts against wall

- Eccentrics (assist with concentric phase) (Figure 29-7)
  - Squats on decline board, partial weight bearing (Shuttle, Total Gym)
  - Progress from partial to full weight-bearing resistance able to complete if <5/10 pain
  - Three sets × 15 repetitions (reps)
- Stability exercise with correct mechanics (i.e., no pelvic drop, knee valgus, or excessive anterior weight)
  - Strengthening
    - Balance on stable surface
    - Side lying abduction/clam shell series (Figure 29-8)
    - Hip hike on single leg

TIMELINE 29-1: **Nonoperative Rehabilitation of Patellar Tendinopathy**

PHASE I (weeks 0 to 2)

- 5-min bike warmup
- Lumbosacral mobility (i.e., cat/camel exercise)
- Hip flexor and quadriceps flexibility (before and after activity)
  - Assisted: Prone with opposite hip flexion to isolate soft tissue
  - Self: use belt or stand
- Patellar tendon mobility (before activity)
  - Instrument assisted soft tissue mobilization
  - Cross-friction mobilization
- Neuromuscular interventions
  - Activation exercise
    - Gluteal activation
      - Bilateral activation
      - Reciprocal activation (frog leg-position)
    - Transversus abdominis
      - Bilateral activation
    - Functional roll patterns
    - Posterior weight shifts against wall
  - Eccentrics (assist with concentric phase)
    - Squats on decline board, partial weight bearing (Shuttle, Total Gym)
    - Begin at 30% and progress resistance if <5/10 pain
    - Three sets × 15 repetitions
  - Stability exercise (i.e., no pelvic drop, knee valgus, or excessive anterior weight)
    - Strengthening
      - Balance on stable surface
      - Side-lying abduction/clamshell series

PHASE II (weeks 2 to 4)

- Mobility
  - Lumbosacral mobility (i.e., cat/camel exercise)
  - Hip flexor and quadriceps flexibility (before and after activity)
    - Assisted: prone with hip in flexion to isolate soft tissue
    - Self: progress to half-kneel with knee flexed
  - Patellar tendon mobility (before activity)
    - Instrument assisted soft tissue mobilization
    - Cross-friction mobilization
- Neuromuscular interventions
  - Activation exercise
    - Gluteal activation
      - Add tall knee and half-kneel position
  - Transverse abdominis
    - Add UE/LE movements. use feedback device
    - Functional roll patterns
  - Eccentrics (assist with concentric phase)
    - Squats on decline board - partial weight bearing (Shuttle, Total Gym)
    - Progress 50%–75% resistance if <5/10 pain
    - Three sets × 15 repetitions
  - Stability exercise (i.e. no pelvic drop, knee valgus or excessive anterior weight)
    - Posterior weight shifts (if needed)
    - Lumbopelvic stability exercise
      - Double leg support
    - Strengthening
      - Advance balance to unstable surface/add perturbations
      - Single leg squat (Romanian deadlift)
      - Advance side-lying abduction/clamshell series
      - Hip hike on single leg with unstable surface
    - Bounding (appropriate landing mechanics)
      - Begin jump squats and jogging on Shuttle



FIGURE 29-7. Partial weight-bearing decline eccentrics on Shuttle.

Milestones for Progression to the Next Phase

- Appropriate gluteal maximus, transversus abdominis, and multifidi activation patterns. Tactile cueing, observation and external feedback devices can be used to ensure appropriate activation[2] (i.e., no knee flexion with prone leg extension to assess appropriate gluteal activation).
- No compensatory movements with stability exercise (i.e., no pelvic drop, knee valgus or excessive anterior weight).
- Complete weight bearing eccentrics with less than 5/10 pain.

Phase II (weeks 2 to 4)

Protection

- Begin jogging, jumping on Shuttle.
- No full weight-bearing running

Management of Pain and Swelling

- Ice massage

Techniques for Progressive Increase in Range of Motion

- Lumbosacral mobility (i.e., cat/camel exercise)
- Hip flexor and quadriceps flexibility (before and after activity)
  - Assisted: Prone with hip in flexion to isolate soft tissue
  - Self: Progress to half-kneel with knee flexed (Figure 29-9)
- Patellar tendon mobility (before activity)
  - Instrument-assisted soft tissue mobilization (Figure 29-10)
  - Cross-friction mobilization

TIMELINE 29-1: Nonoperative Rehabilitation of Patellar Tendinopathy (Continued)

PHASE III (weeks 4 to 8)

- Protection: begin FBW jogging, alternate with non-bounding intervention
- Mobility
  - Dynamic warmup
    - Inchworms, Spidermans, walking lunges (10 repetitions each)
    - Patellar tendon mobility (before activity if needed)
  - Instrument-assisted soft tissue mobilization
    - Cross-friction mobilization
- Neuromuscular interventions
  - Activation exercise
    - Progress functional roll patterns
  - Eccentrics (lowering phase only phase)
    - Squats on decline board, FWB
      - Progress 5-10 lb/week beginning at 10% BW if <5/10
    - Begin stepdowns
    - 4″ step at 4 weeks
    - 6″ step at 6 weeks
    - Three sets × 15 repetitions
  - Stability exercise (i.e., no pelvic drop, knee valgus, or excessive anterior weight)
  - Advance lumbopelvic stability exercise
    - Single leg support
  - Strengthening
    - Advance balance on unstable surface/add perturbations
    - Single leg squat (Romanian deadlift)
      - Add resistance, unstable surface
    - Split lunge with chop and lift
    - Resisted band walking
    - Step-up 12 onto plyo box
  - Bounding (appropriate landing mechanics)
    - Begin double leg jumping on Shuttle or Total Gym
      - Three sets × 15 repetitions
  - Initiate walk jog progression

PHASE IV (weeks 8 to 12)

- Protection
  - Progress jog progression, alternate with nonbounding exercise
  - Begin sports-specific activity if nor worsening of symptoms
- Treatment for pain/swelling: ice massage is needed
- Mobility
  - Dynamic warmup
    - Inchworms, Spidermans, walking lunges, 10 repetitions each
  - Patellar tendon mobility (before activity if needed)
  - Instrument-assisted soft tissue mobilization
  - Cross-friction mobilization
  - Neuromuscular interventions
    - Activation exercise
  - Progress functional roll patterns
    - Eccentrics (lowering phase only phase)
    - Squats on decline board, FWB
      - Progress 5-10 lb/week if <5/10
      - Three sets × 15 repetitions
    - Step downs
      - 8″ step three sets × 15 repetitions
      - Stability exercise (i.e., no pelvic drop, knee valgus or excessive anterior weight)
    - Strengthening
      - Step-up 24 inch ploy box—go onto toe
      - Progress all LE strengthening exercise
    - Bounding (appropriate landing mechanics)
      - Single leg jumping on Shuttle or Total Gym
        - Three sets × 15 repetitions
      - Begin double leg hop down on 4″
        - Progress to 6″ to 12″ step as form improves
        - Three sets × 15 repetitions
    - Sports-specific drills
    - Progress walk jog progression

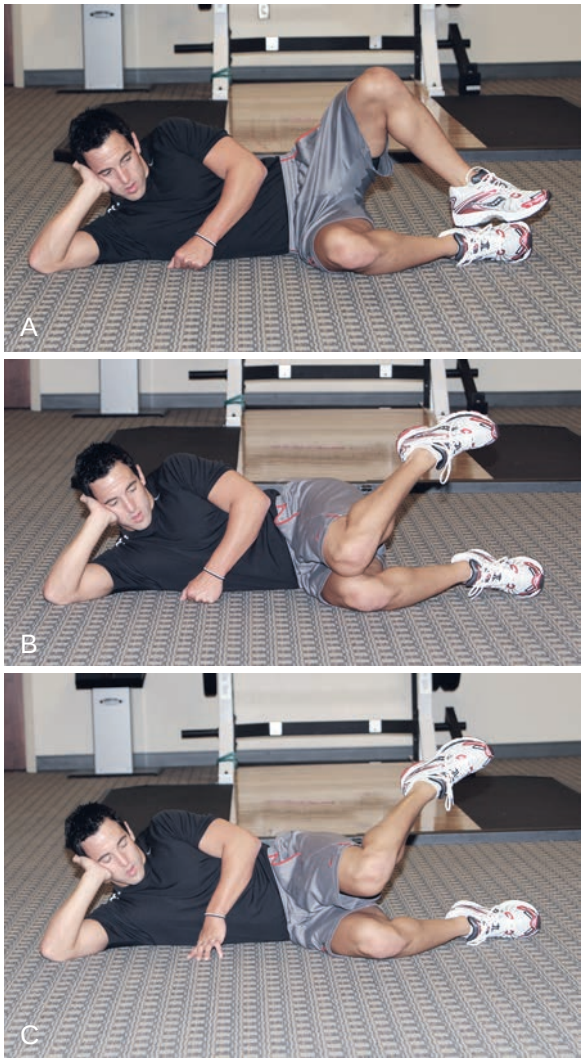


FIGURE 29-8. A–C, Clamshell series.



FIGURE 29-9. Prone hip flexor stretching.



FIGURE 29-10. Instrument-assisted cross-friction mobilization.

Neuromuscular Dynamic Stability Exercises

- Activation exercise
  - Gluteal activation
  - Progress to functional positions (i.e., tall kneel [Figure 29-11] and half-kneel positions)
  - Transverse abdominis/multifidi
    - Add UE/LE movements with pelvic stability exercise. Use internal (isometric cueing) and external (dynamic stabilizer, electronic) feedback device.
  - Functional roll patterns (see Figure 29-6)
  - Eccentrics (assist with concentric phase)
    - Squats on decline board—partial weight bearing less than 5/10 pain (Shuttle, Total Gym)
    - Progress 50% to 75% resistance if less than 5/10 pain
    - Three sets × 15 repetitions

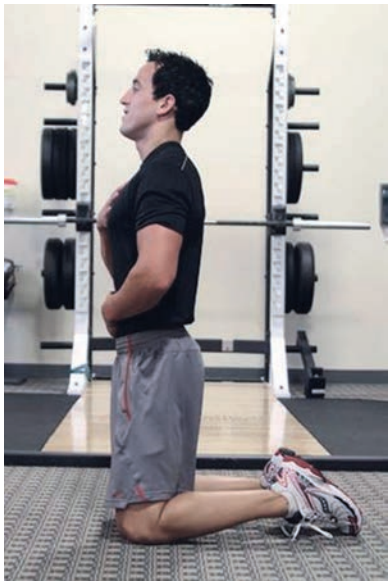


FIGURE 29-11. Tall kneel.

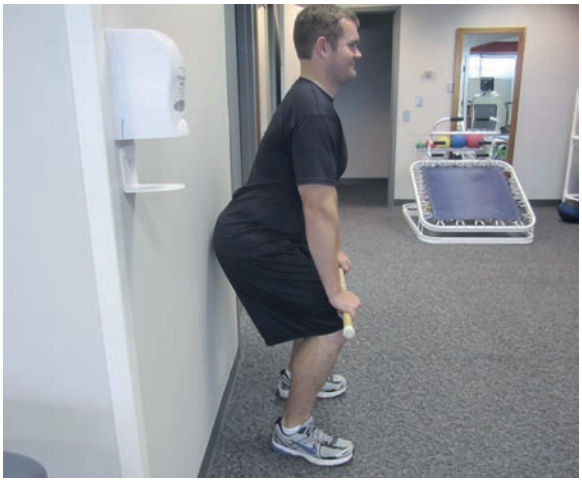


FIGURE 29-12. Posterior weight shifts.

- Stability exercise (avoid pelvic drop, hip add, knee valgus, or excessive anterior weight)
- Posterior weight shifts (if needed) (Figure 29-12)
- Lumbopelvic stability exercise
  - Advance to unsupported double leg work (three sets 10 to 15 repetitions)
  - Planks (two to three sets × 60 seconds)
  - Chop/lift activities (three sets 10 to 15 repetitions)
  - Strengthening
  - Add unstable surface/foam to exercise
- Bounding (avoid pelvic drop, knee valgus, or excessive anterior weight) (Figure 29-13)
  - Jogging on Shuttle (1 to 2 minutes × 5 to 10 sets with no exacerbation of symptoms)

Milestones for Progression to the Next Phase

- Appropriate gluteal maximus, transversus abdominis and multifidi activation patterns. Tactile cueing, observation, and external feedback devices can be used to ensure appropriate activation[2] (i.e., no knee flexion with prone leg extension to assess appropriate gluteal activation).
- No compensatory movements with stability exercise (i.e., no pelvic drop, knee valgus, or excessive anterior weight)
- Complete weight-bearing eccentrics with less than 5/10 pain.

Phase III (weeks 4 to 8)

Protection

- Begin FBW jogging.
- May utilize nonbounding exercise 20 to 30 minutes if unable to complete jogging (bike, elliptical, swimming, etc.).

Management of Pain and Swelling

- Ice massage

Techniques for Progressive Increase in Range of Motion

- Dynamic warmup
  - Inchworms, Spidermans, walking lunge (10 repetitions each) (Figure 29-14)
- Patellar tendon mobility (before activity if needed)
  - Instrument assisted soft tissue mobilization
  - Cross-friction mobilization

Neuromuscular Dynamic Stability Exercises

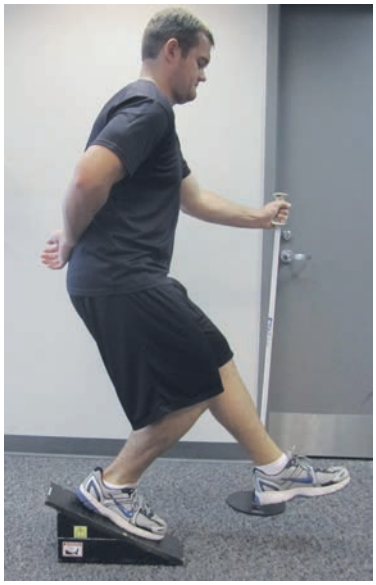
- Activation exercise
  - Progress functional roll patterns
- Eccentrics (lowering phase only phase)
  - Squats on decline board, FWB (Figure 29-15)
    - Progress 5 to 10 lb/week if less than 5/10
  - Three sets × 15 repetitions



FIGURE 29-13. A,B, Bounding exercises.



FIGURE 29-14. Dynamic warmups. **A,** Inchworm. **B,C,** Spiderman. **D,** Walking lunge.



.**FIGURE 29-15.** Full weight-bearing squats on decline board



FIGURE 29-16. Step downs.

- Begin step downs (Figure 29-16)
  - 4" step at 4 weeks
  - 6" step at 6 weeks
  - Three sets × 15 repetitions
- Stability exercise (Advance with good mechanics: no pelvic drop, hip add, knee valgus or excessive anterior weight)
  - Lumbopelvic stability exercise
  - Advance from double to single leg support if appropriate mechanics are maintained.
- Strengthening
  - Advance balance on unstable surface/add perturbations (three sets 10 to 15 repetitions)
  - Single leg squat
    - Add resistance, unstable surface (three sets 10 to 15 repetitions)
  - Split lunge with chop and lift (three sets 10 to 15 repetitions)
  - Resisted band walking (three sets 10 to 15 repetitions)
  - Step-up 12 onto ploy box (three sets 10 to 15 repetitions)
- Bounding (appropriate landing mechanics)
  - Begin double leg jumping on Shuttle or Total Gym
    - Three sets × 15 repetitions
- Initiate walk/jog progression
  - The Walk/Jog program (Table 29-2) is to be performed in a step-by-step fashion. The program can be varied to meet individual situations. The patient should be progressing at a minimum of 1 day on, 1 day off basis with increased time off between bouts given on individual basis.
  - If painful, stop jogging. Once pain-free restart at the previous level to avoid re-aggravation.

Phase IV (weeks 8 to 12)

Protection

- Only advance with jogging and sports specific-activity (speed and agility drills) if pain free.
- Eccentrics can be continued if less than 5/10 pain.

Management of Pain and Swelling

- Ice massage is needed

Techniques for Progressive Increase in Range of Motion

- Dynamic warmup
  - Inch worms, Spidermans, walking lunge
    - Ten repetitions each (see Figure 29-14)
- Patellar tendon mobility (before activity if needed)
  - Instrument assisted soft tissue mobilization
  - Cross-friction mobilization

Neuromuscular Dynamic Stability Exercises

- Activation exercise
  - Progress functional roll patterns (see Figure 29-6)
- Eccentrics (lowering phase only phase)
  - Squats on decline board, FWB
    - Progress 5 to 10 lb/week if less than 5/10
    - Three sets × 15 repetitions
  - Step downs
    - 8" step
    - Three sets × 15 repetitions
- Stability exercise (i.e., no pelvic drop, hip add, knee valgus, or excessive anterior weight)
  - Strengthening
    - Step-up 24-inch plyo box—go onto toe
    - Progress all LE strengthening exercise
    - Bounding (ensure good mechanics with symmetrical landing and avoid jump/hop down off plyo boxes)
    - Single leg jumping on Shuttle or Total Gym
    - Three sets × 15 repetitions
    - Begin double leg hop down on 4"
    - Progress to 6" to 12" step as form improves
    - Three sets × 15 repetitions
    - Sports-specific drills (multidirectional, agility and speed activities such as dot and ladder drills) (Figure 29-17)
    - Progress walk/jog progression (Table 29-1)

Milestones for Progression to Advanced Sport-Specific Training and Conditioning

- Demonstrate no greater than Blazina's Phase I criteria.
- Hip flexor/quadriceps flexibility symmetry
- No compensatory movements with functional testing (i.e., no pelvic drop, hip add, knee valgus, or excessive anterior weight)
- Victorian Institute of Sport Assessment scale—Patellar tendinopathy (VISA-P) score of 60 or better



FIGURE 29-17. A–C, Sports-specific drills (dot and ladder drills).

Criteria for Abandoning Nonoperative Treatment and Proceeding to Surgery or More Intensive Intervention

- Lack of progression or exacerbation with rehabilitation program
- Blazina Phase III greater than 3 to 4 months without change (Table 29-2)
- Unable to change from Kennedy's Phase IV criteria (see Table 29-1)

Tips and Guidelines for Transitioning to Performance Enhancement

- Athletes need to be reminded on appropriate warm-up and corrective mobility techniques before sports-specific training to help correct and prevent compensatory movement patterns.
- Sports-specific training can be progressed only if pain is felt after activity; however, no symptoms should be noted before or during activity.

Table 29-1 The Walk-Jog Program

	Warm-up	Jog	Walk	Repetitions	Cool Down
Step I	5 min	1 min	3 min	5	5 min
Step II	5 min	1 min	2 min	7	5 min
Step III	5 min	2 min	1 min	7	5 min
Step IV	5 min	3 min	1 min	5	5 min
Step V	5 min	5 min	1 min	4	5 min
Step VI	5 min	20 min continuous		1	5 min
Step VII	5 min	Jog every other day reaching 30 min and increase pace			5 min

Adapted from OSU Sports Medicine walk/jog progression (www.sportsmedicine.osu.edu).

Table 29-2 A Guide to Progression and Criteria to Modify Sport

	Blazina's Tendinopathy Stages	Kennedy's Tendinopathy Stages
Phase I	No significant pain during athletic activity, but discomfort afterward	Pain after activity
Phase II	Pain before and after activity, but not enough during activity to alter their performance	Pain at the beginning and after activity
Phase III	Pain is severe enough that performance is affected and the athlete's volume of activity has to be modified	Pain at the beginning, during, and after activity, but performance is no affected
Phase IV	Tendon rupture	Pain at the beginning, during, and after activity, and the performance is affected

For the purposes of these guidelines, Blazina's classification is used.
Adapted from Rutland.

Performance Enhancement and Beyond Rehabilitation: Training/ Trainer and Optimization of Athletic Performance

- It is important to recognize intrinsic and extrinsic risk factors of patellar tendinopathy to prevent re-injury.
- The following should be considered when designing a performance enhancement program:
  - Intrinsic factors
    - Thigh weakness
    - Thigh hypomobility
    - Ankle DF hypomobility
    - Higher waist to hip ratio
  - Extrinsic factors
    - Sex (male)
    - Competition level (elite)
    - Sport (volleyball and basketball)
    - Hard surface
    - Lifting weights
    - Higher jumping performance

Specific Criteria for Return to Sports Participation: Tests and Measurements

- Demonstrate no greater than Blazina's Phase I criteria.
- Less than 10% side to side difference with isokinetic quadriceps strength
- Less than 10% side to side difference with functional testing (single leg, triple, crossover hopping)
- Restore symmetrical hip flexor/quadriceps and ankle DF joint mobility and muscle-tendon flexibility
- No compensatory movements with functional testing (hopping, FMS, single leg squat, etc.)
- VISA-P score of 70 or greater

Evidence

Alfredson H, Pietila T, Jonsson P, et al: Heavy-load eccentric calf muscle training for the treatment of chronic Achilles tendinosis. *Amer J Sports Med* 26(3):360–366, 1998.

Prospective study of 15 recreational athletes with average age of 44.3 ± 7.0 years of age treated with 12-week eccentric training program. At 6 months all 15 patients returned to preinjury running levels. A comparison group of 15 athletes treated with conventional therapy (no eccentrics) showed no improvement. (Level II evidence)

Gaida JE, Cook JL, Bass SL, et al: Are unilateral and bilateral patellar tendinopathy distinguished by difference in anthropometry, body composition, or muscle strength in elite female basketball players. *Br J Sports Med* 38:581–585, 2004.

This cross-sectional design studied 39 elite female basketball players to determine risk factors associated with unilateral and bilateral patellar tendinopathy. Unilateral tendinopathy has identifiable risk factors, whereas bilateral did not include body composition and eccentric strength. (Level III evidence)

Van der Worp H, van Ark M, Zwerver J, et al: Risk factors for patellar tendinopathy in basketball and volleyball players: A cross-sectional study. *Scand J Med Sci Sports* 1–8, 2011.

Cross-sectional study of 53 Dutch basketball and volleyball players ranging from 18 to 35 years of age. Risk factors for patellar tendinopathy included being male, age, playing at an elite level, and playing volleyball. Within the volleyball subset, being an outside hitter and middle blocker increased risk of patellar tendinopathy. (Level III evidence)

Young MA, Cook JL, Purdam ZS, et al: Eccentric decline squat protocol offers superior results at 12 months compared with traditional eccentric protocol for patellar tendinopathy in volleyball players. *Br J Sports Med* 39:102–105, 2005.

Prospective randomized control design of 17 elite volleyball players with imaging-confirmed patellar tendinopathy. Players were randomly designed to a 12-week eccentric or step up protocol and monitored and each showed significant improvement from baseline at the 12-week and 12-month time period using VISA-P and VAS measures. There was a greater likelihood of clinical improvement in the decline group at 12 weeks, suggesting great clinical gains throughout rehabilitation. VAS scores did not differ between groups at 12 months. (Level I evidence)

REFERENCES

1. Loughmani MT, Warden SJ: Instrument-assisted cross-fiber massage accelerates knee ligament healing. *Orthop Sports Phys Ther* 39(7):506–514, 2009.
2. Lewis CL, Sharman SA: Muscle activation and movement patterns during prone hip extension exercise in women. *J Athletic Training* 44(3):238–248, 2009.

Multiple Choice Questions

QUESTION 1. Which extrinsic risk factor is a potential contributor to patellar tendinopathy?

A. Female gender
B. Ankle dorsiflexion hypomobility
C. Sport (volleyball and basketball)
D. Quadriceps weakness

QUESTION 2. Which bonding exercise should be avoided to limit deleterious stress through the patellar tendon?

A. Hop/jump done from elevated surface
B. Agility drills
C. Broad jumping
D. Hop/jump ups onto elevated surface

QUESTION 3. What pain response recommendations should be used when performing eccentric exercise to treat patellar tendinopathy?

A. Pain-free only
B. Less than 3/10
C. Less than 5/10
D. Greater than 7/10

QUESTION 4. Which criteria should be used before returning to sport?

A. 10% limb symmetry index with hop testing
B. 25% quadriceps difference with isokinetic strength testing
C. Moderate compensation with functional movements
D. Less than 5/10 with sports-specific tasks

QUESTION 5. Which exercise provides the most stress to facilitate soft tissue healing for a patient suffering patellar tendinopathy?

A. Single leg squat on a flat surface
B. Single leg squat on an incline surface
C. Single leg squat on decline surface
D. Single leg squat on an unstable surface

Answer Key

QUESTION 1. Correct answer: **C** (see Guiding Principles of Nonoperative Rehabilitation box)

QUESTION 2. Correct answer: **D** (see Phase IV)

QUESTION 3. Correct answer: **C** (see Phase I)

QUESTION 4. Correct answer: **A** (see Phase IV).

QUESTION 5. Correct answer: **C** (see Phase I)

POSTOPERATIVE REHABILITATION AFTER PATELLAR TENDINOPATHY DEBRIDEMENT

John DeWitt, PT, DPT, SCS, ATC, and Christopher C. Kaeding, MD

Indications for Surgical Treatment

- Lack of progression or exacerbation with rehab program
- Blazina Grade III greater than 3 to 4 months without change (see Nonoperative Rehabilitation)
- Unable to change from Kennedy's Phase IV criteria (see Nonoperative Rehabilitation)

Brief Summary of Surgical Treatment

Major Surgical Steps

- Localize lesion on MRI
- Expose lesion via anterior tendon splitting approach
- Excise abnormal tissue
- Excise any inferior patella spurring
- Repair defect
- Perform multiple longitudinal tenotomies
- Close peritenon, subcutaneous tissue, and skin

Factors That May Affect Rehabilitation

- The size of the lesion and the subsequent extent of the excision may result in significant compromise of the patella tendon integrity. If tendon is significantly compromised (greater than 30%) the patient would require more and longer protection from loading and a longer time to recover and reconstitute full strength to minimize risk of complete tendon rupture postoperatively.

Other Surgical Techniques and Options

- May consider adding platelet-rich plasma to the defect at the end of the procedure. This would not affect postoperative rehabilitation.

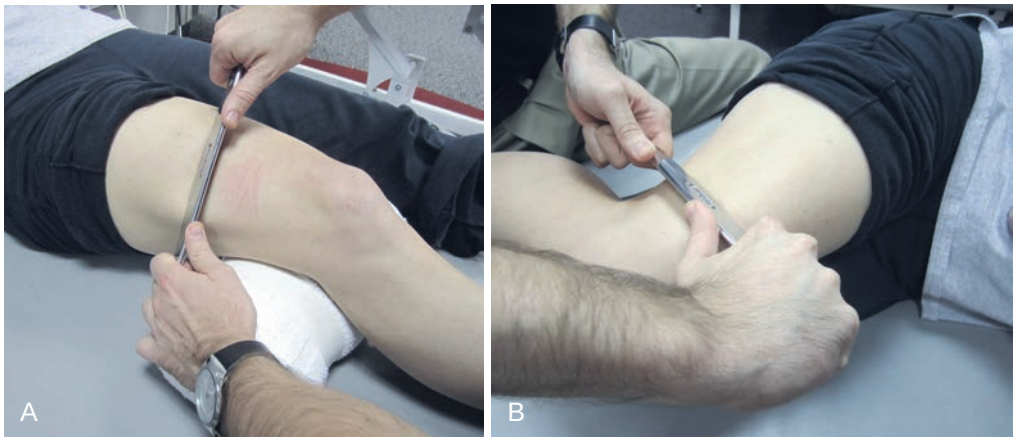


FIGURE 29-18. ITB (**A**) and quad ST (**B**) mobilizations.

GUIDING PRINCIPLES OF POSTOPERATIVE REHABILITATION

- Understand surgical procedure and soft tissue healing parameters.
- Protect surgical site and ensure soft tissue healing.
- Correct proximal stability and mobility impairments.
- Avoid exercise that place excessive load on the patellar tendon (leg extension, squatting beyond 90°, excessive jumping).
- Phases are both time- and criterion-based.

Phase I (days 0 to 14)[1]: Immediate Postoperative Period

Clinical Pearl

Early mobilization in a protected range is essential to facilitate soft tissue healing and prevent scarring. Non-resistance biking can be progressed 10–20 min/day after 14 days.

Goals

- Normalize gait without brace or crutches
- Knee ROM 0° to 90°
- Symmetrical quad contraction with heel lift
- No exacerbation of symptoms with ADLs

Protection

- Week 1: Hinged brace locked in extension WBAT with crutches.
- Week 2: Brace can be unlocked to 90° if good quad activation and no pain with ADLs. Brace can be removed once gait is normalized by day 14 if good quad control.

[1]Prehabilitation, if appropriate, is described in the Nonoperative Rehabilitation section of this chapter.

Management of Pain and Swelling

- Ice, NSAIDs, modalities

Techniques for Progressive Increase in Range of Motion

- Increase ROM:
  - Week 1: 0° to 60°
  - Week 2: 0° to 90°

Manual Therapy Techniques

- Gentle patellar mobilization (grades I to II).

Soft Tissue Techniques

- Quad/ITB soft tissue mobilization after week 1 (Figure 29-18)

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Mobility techniques for the musculotendinous unit; hamstring/ITB stretching
- AAROM knee flexion per preceding range restrictions

Other Therapeutic Exercises

- UE ergometry

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Progress quad activation emphasizing heel off. Begin gluteal and transversus abdominis activation exercises (see Figure 29-5).

Open and Closed Kinetic Chain Exercises

- Hip abduction and extension straight leg raise with brace
- May discontinue brace at day 7 if good quad control (no extensor lag)

Milestones for Progression to the Next Phase

- No pain at 90° degrees of flexion
- Normalization of gait

- Good quad control with exercise
- No exacerbation with ADLs

Phase II (weeks 2 to 4 postoperatively)

Clinical Pearl

Activation of lumbopelvic stabilizers and gluteals are important to facilitate proximal stability, prevent distal compensatory motion (especially excessive anterior weight shift), and avoid excessive stress through the patellar tendon.

Goals

- 120° knee flexion without pain
- No compensatory movement patterns with weight bearing exercise
- No pain after activity or physical therapy

Protection

- Discontinue brace and crutches if no gait deviation and good quad control.

Management of Pain and Swelling

- Ice, modalities if needed for pain
- Vasocompression device if needed for swelling

Techniques for Progressive Increase in Range of Motion

- Progress knee flexion ROM per tolerance.

Manual Therapy Techniques

- Continue patellar mobilizations (mobs) if quad set is painful

Soft Tissue Techniques

- Continue ITB and quad/hip flexor mobilizations

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Begin pain-free quad/hip flexor stretches; continue ITB and hamstring stretches.

Other Therapeutic Exercises

- Increase biking to 20 minutes without resistance.
- Deep water jogging
- Swimming with pull buoy
- Progress neuromuscular lumbopelvic stability program
- Begin UE strength training in seated position.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Gluteus maximus activation progression (frog-leg progress, standing). Avoid kneeling positions.
- Teach posterior weight shifting in squat position (see Figure 29-12)
- Begin total body rolling activities (see Figure 29-6)

Sensorimotor Exercises

- Single leg balance
  - Progress from stable to unstable surface
  - Include opposite LE movements (touch toe, resistance band, etc.)

TIMELINE 29-2: **Postoperative Rehabilitation After Arthroscopic Patellar Tendon Debridement**

PHASE I (weeks 1 to 2)	PHASE II (weeks 2 to 6)
• Brace locked in extension WBAT • ROM: 0–60 week 1, 0–90 week 2 • PT modalities for pain control • Gentle patellar mobilizations • Gentle quad sets • ITB/quad soft tissue mobilization • Transversus abdominis and gluteus activation • Abduction SLR in brace	• D/C brace if good quad control and no pain with ADLs • PT modalities • ROM: 0°–120° and progress per tolerance • Biking without resistance/deep water jogging 10–20 minutes • Continue soft tissue and joint mobs as needed • Begin single-leg balance exercise • CKC partial weight bearing strengthening, progress to full weight bearing (emphasis on posterior weight shift and avoid going below 60°) • Progress to heel touch off 4″ step if good form • Heel/toe raise • OKC/CKC hip strengthening

Open and Closed Kinetic Chain Exercises

- OKC
  - Progress SLR in all directions
  - Initiate clamshell progression (see Figure 29-8)
- CKC
  - Partial weight-bearing squats (Shuttle, Total Gym, Ex)
  - Begin wall squat
  - Bridge progression
    - Double leg, marching, single leg
  - Progress to heel touch on 4" step if good form
  - Heel/toe raises

Milestones for Progression to the Next Phase

- No pain during or after activity and/or physical therapy
- Restore normal ROM.
- Restore quad strength to 4+/5.
- Restore hip abduction strength to 5/5.
- No compensatory movement with CKC activity

Phase III (weeks 6 to 12 postoperatively)

Clinical Pearl

Exercises should be progressed to increase neuromuscular balance and stability by adding unstable surfaces and/or single leg positions. Excessive strain to the patellar tendon should be avoided by correcting LE compensations (especially excessive anterior weight shift).

Goals

- Complete 20 heel touches on 6" to 8" step without compensation.
- Begin walk/jog progression without pain.
- Begin sport-specific and cutting drills without pain or compensation.
- Progress to strengthening and balance activities without exacerbation.

Management of Pain and Swelling

- Ice cup if needed for pain
- Compression stocking or knee sleeve may be used if needed to control swelling.

Techniques for Progressive Increase in Range of Motion

Soft Tissue Techniques

- Use roller to mobilize ITB and quads after warmup.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Advanced quad/hip flexor and ankle DF stretches should be performed before and after activity.

Other Therapeutic Exercises

- 10 to 20 minutes of biking with mild resistance
- Swimming
- Normal UE strength training can be resumed

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Progress core stability and functional rolling

TIMELINE 29-2: **Nonoperative Rehabilitation of Long Head of Biceps Tendinitis/Tendinosis** (Continued)

PHASE III (weeks 6 to 12)	PHASE IV (weeks 12 to 16)

• PT modalities as needed
• Quad/hip flexor and ankle DF stretching
• Biking/elliptical (no stair climbing) 20–30 minutes
• Progress balance exercise, use unstable surface or rhythmic stabilization
• CKC strengthening using single leg and multidirectional/lateral positions
• Single leg squat
  • Avoid going below 60°
  • Avoid pelvic drop, knee valgus, and anterior weight shift compensation
• Begin jogging on shuttle
• Practice landing mechanics on even ground
• Begin walk/jog progression if the following criteria are met
• 20 single leg squats on 4" step with good form
• No gait asymmetries or pain with jogging
• No pain with PT or ADL activity
	• PT modalities if needed
	• Initiate dynamic warmup and self-stretching program
	• Progress CKC strengthening and balance in functional patterns (chop/lift)
	• Single leg squat
	  • 60° to 90°
	  • Avoid pelvic drop, knee valgus, and anterior weight shift compensation
	• Reverse leg press
	• Single leg jumping on shuttle/Total gym or in pool
	• Double and single leg jumping with good mechanics
	• Single leg hop ups onto step
	  • Begin with 4" and increase height until symmetrical with uninvolved leg
	  • Only progress if good mechanics
	• Advance jogging progression
	• Begin ladder and cutting/change of direction drills
	  • 50%–75% intensity (weeks 12–14)
	  • 75%–100% intensity (weeks 14–16)
	• May return to sport is the following criteria are met:
	  • Less than 10% quad difference with isokinetic testing
	  • Less than 10% difference limb symmetry index with SL hopping tests
	• No pain during or after bounding or sports-specific exercise

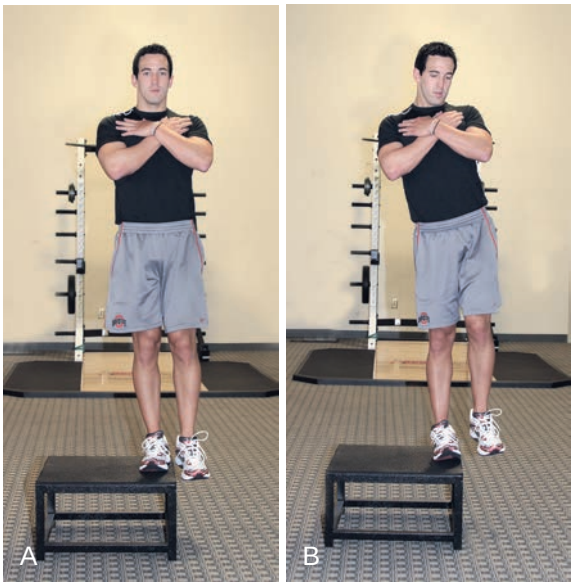


FIGURE 29-19. Hip hikes.

Sensorimotor Exercises

- Advance strengthening to single leg positions and use unstable surfaces

Open and Closed Kinetic Chain Exercises

- Heel touch beginning with 4" step (progress to 6" to 8")
- Single balance/strengthening
  - Hip hikes (Figure 29-19)
  - Romanian dead lifts (Figure 29-20)
  - Lower extremity clocks
- Step up and step downs (pain free and with good control) (Figure 29-21)
- Resisted lateral side-stepping

Techniques to Increase Muscle Strength, Power, and Endurance

- Advance endurance and strengthening exercise if good form and no pain during or after activity.

Neuromuscular Dynamic Stability Exercises

- Practice landing mechanics on even surface



FIGURE 29-20. Romanian dead lift.



FIGURE 29-21. Step up.

Plyometrics

- Begin partial weight bearing jogging on Shuttle or Total Gym.
- Criteria to begin jogging program
  - 20 single leg squats on 4" step with good form
  - No gait asymmetries or pain with jogging
  - No pain with PT or ADL activity

Milestones for Progression to the Next Phase

- No lower extremity compensation with strengthening exercise
- Symmetrical restoration of muscle length
- Restore normal strength
- No pain with walk-jog progression or cutting activity

Phase IV (weeks 12 to 16 postoperatively)

Clinical Pearl

Exercises to promote quad strength and flexibility should be advanced to include sports-specific and bounding components if no pain and good form. Exercise or activity causing compensatory movement patterns should be modified to correct motion.

Goals

- Less than 10% quad difference with isokinetic testing
- Less than 10% difference limb symmetry index with SL hopping tests
- No pain during or after bounding or sports-specific exercise
- No lower extremity compensatory movement patterns with activity and bounding activity



FIGURE 29-22. Split lunge with lift.

Management of Pain and Swelling

- Ice cup if needed for pain
- Knee sleeve if needed for swelling

Techniques for Progressive Increase in Range of Motion

- 5- to 10-minute warm up (light jog or bike) followed by dynamic warmup (see the following) before activity (see Figure 29-14).
  - 10 inchworms
  - 10 walking knee to chest stretches
  - 10 walking lunges (no excessive anterior weight shift)
  - 10 skipping bounds

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Continue gluteus activation progression if needed.
- Continue rolling if unable to complete correctly.

Open and Closed Kinetic Chain Exercises

- Add unstable surface and/or rotational movements to strengthening program in previous phase
- Advance step-up/down height
- Chop/lifts in half-kneel or split lunge position (Figure 29-22)
- Slide board (Figure 29-23)
- Single leg squat 60° to 90° (Figure 29-24)
- Leg press and reverse leg press (Figure 29-25)

Clinical Pearl

Improving quadriceps strength and proximal stability are important to help prevent risk factors for reinjury.

Plyometrics

- Single leg jumping on shuttle/Total gym or in pool
- Double and single leg jumping with good mechanics
- Single leg hop ups onto step (14 weeks)
  - Begin with 4" and increase height until symmetrical with uninvolved leg
  - Only progress if good mechanics

Functional Exercises

- Begin ladder and cutting/change of direction drills (see Figure 29-13)
  - 50% to 75% intensity (12 to 14 weeks)
  - 75% to 100% intensity (14 to 16 weeks)
- Advance jogging activity (see Table 29-3)

Sport-Specific Exercises

- Begin sports-specific exercise
  - 50% to 75% intensity (12 to 14 weeks)
  - 75% to 100% intensity (14 to 16 weeks)



FIGURE 29-23. Slide board.



FIGURE 29-24. Single-leg deep squat (60° to 90°).

Milestones for Progression to the Next Phase

- May return to sport is the following criteria are met
  - Less than 10% quad difference with isokinetic testing
  - Less than 10% difference limb symmetry index with SL hopping tests
  - No pain during or after bounding or sports-specific exercise

Criteria for Return to Sport

General

- Less than 10% quad difference with isokinetic testing
- Less than 10% difference limb symmetry index with SL hopping tests
- Greater than 70 score on VISA-P questionnaire
- No pain during or after bounding or sports-specific exercise

Sport-Specific

- Volleyball
  - Complete aquatic or partial weight bearing jumping program without pain before full weight-bearing exercise.



FIGURE 29-25. Reverse leg press.

Table 29-3 Basic Walk to Jog Program

	Run	Walk	Reps	Days
Phase I	1 minutes	1–5 minutes	2	2
Phase II	2 minutes	1–4 minutes	2	2
Phase III	3 minutes	1–3 minutes	2	2
Phase IV	4 minutes	1–2 minutes	2	2
Phase V	5 minutes	1 minutes	2	2

Take at least one rest day in between each workout, non-impact cross training during off days. Take at least one complete rest day a week.
If pain develops or other symptoms return, or if the phase cannot be completed, the athlete should not progress until able to complete it without symptoms.
Complete only one phase per day.

  - Implement approach, jump, and landing techniques beginning at 50% week 1, 75% week 2, 100% week 3 after criteria to sport have been met.
  - Being sport specific activity on sand volleyball court.
  - Correct restoration of preinjury jump high and landing kinematics before unrestricted return to sport.
  - Include dynamic warmup before activity.
  - No more than Phase I on Blazina scale with sport
- Basketball
  - Complete aquatic or partial weight bearing jumping program without pain before full weight bearing exercise.
  - Implement dribbling, jumpstop, and landing techniques beginning at 50% week 1, 75% week 2, 100% week 3 after criteria to sport has been met
  - Correct restoration of pre-injury jump high and landing kinematics before unrestricted return to sport
  - Include dynamic warmup before activity
  - No more than Phase I on Blazina scale with sport

After Return to Sport

Continuing Fitness or Rehabilitation Exercises

- Implement dynamic warmup and continue LE mobility exercise before and after exercise.
- Avoid exercise/jogging on concrete.
- Continue quad strength, hip stability, and landing balance exercises 3 days/week.
- Avoid resisted leg extension and excessive anterior lunge with activity.

Exercises and Other Techniques for Prevention of Recurrent Injury

- Normalize quad strength and power.
- Avoid jogging or conditioning on concrete surface.
- Use cross training to limit excessive stress through the patellar tendon (aquatics/nonbounding exercise).
- Implement dynamic warmup with focus on quad and ankle DF mobility.
- Assess anthropometric data (i.e., hip to waist ratio) to address need for interventional program.

Evidence

Backman LJ, Danielson P: Low range of ankle dorsiflexion predisposes for patellar tendinopathy in junior elite basketball players. *Amer Jour Sports Med* 39(12):2626–2633, 2011.

Prospective cohort design study of 90 junior elite basketball players to analyze if low ankle dorsiflexion increase risk of patellar tendinopathy over a 12 month time period. Players with less than 35.6° ankle dorsiflexion were at a significant risk for patellar tendinopathy. (Level II evidence)

Cucurulo T, Louis ML, Thaunat M, et al: Surgical Treatment of patellar tendinopathy in athletes. A retrospective multicentric study. *Orthop Trauma* 935:578–584, 2009.

Multicenter study evaluating 64 patients with patellar tendinopathy, 10 undergoing surgical intervention because of the failure of conservative treatment. At 24 months f/u 87% had improved Blazina score and 63% returned to preinjury sport level. Surgical intervention had an 80% success rate. (Level IV evidence)

Kraemer R, Knobloch K: A soccer-specific balance training program for hamstring muscle and patellar and Achilles tendon injuries: An interventional study in premier league female soccer. *Am J Sports Med* 37(7):1384–1393, 2009.

This cohort study evaluated the effectiveness of a proprioceptive training program to decrease LE injuries. At the end of the 3-year training period, noncontact hamstring injuries, patellar, and Achilles tendinopathies were significantly reduced. (Level III evidence)

Lian OB, Engebretsen L, Bahr R: Prevalence of jumper's knee among elite athletes from different sports. *Am J Sports Med* 33(4):561–567, 2005.

Cross-sectional study of 50 Norwegian male and female athletes at the national level following nine sports. Volley and basketball had the highest incidence of patellar tendinopathy. (Level IV evidence)

Lorbach O, Diamantopoulous A, Paessler HH: Arthroscopic resection of the lower patellar pole in patients with chronic patellar tendinosis. *J Arthro Rel Surg* 24(2):167–172, 2008.

Prospective study evaluating the clinical results of arthroscopic resection of lower patellar post in patient with patellar tendinosis. Satisfactory results were found at 24-month follow up with subjective questionnaires and all patients returned to previous sporting activity. (Level IV evidence)

Pascarella A, Alam M, Pascarella F, et al: Arthroscopic management of chronic patellar tensinopathy. *Am J Sports Med* 38(9):1975–1983, 2011.

Case series design of 64 patients (27 who were professional) with patellar tendinopathy undergoing arthroscopic surgery. Significant improvement in symptoms and function were achieved following surgical intervention for up to 3 years. Results indicate that some patients may not be able to achieve pre-symptoms sporting level and with a 9.6% failure rate. (Level IV evidence)

Multiple Choice Questions

QUESTION 1. Initial precautions following tendinopathy debridement include

A. 50% WB with brace locked in extension.
B. 50% WB with brace open 0° to 90°.
C. WBAT with brace locked in extension.
D. WBAT with brace open 0° to 90°.

QUESTION 2. Early neuromuscular activation techniques are focused on which of the following muscles?

A. Gluteals
B. Hamstrings
C. Gastrocs
D. Adductors

QUESTION 3. Which of the following sports has the highest incidence of patellar tendinopathy?

A. Basketball
B. Soccer
C. Volleyball
D. Football

QUESTION 4. To reduce stress on the patellar tendon, which of the following exercises should be avoided?

A. OKC leg extensions
B. Single leg squat 0° to 90°
C. Lunges with good mechanics
D. Stepups

QUESTION 5. Which of the following would require additional precautions and time to facilitate healing of the patellar tendon?

A. Debridement of patella spurring
B. Utilization of platelet rich plasma
C. Excision of abnormal tissue
D. Tendon compromised greater than 30%

Answer Key

QUESTION 1. Correct answer: **C** (see weeks 0 to 2)

QUESTION 2. Correct answer: **A** (see weeks 2 to 4)

QUESTION 3. Correct answer: **C** (see Criteria for Return to Sport)

QUESTION 4. Correct answer: **A** (see Guiding Principles of Postoperative Rehabilitation)

QUESTION 5. Correct answer: **D** (see Details and Choices That May Affect Details of Rehabilitation)

BEYOND BASIC REHABILITATION: RETURN TO BASKETBALL AFTER OPERATIVE TREATMENT FOR PATELLAR TENDINOPATHY

John DeWitt, PT, DPT, SCS, ATC, and Christopher C. Kaeding, MD

Introduction

- According to current research, basketball and volleyball players have the highest incidence, 32% and 45%, respectively, of patellar tendinopathy compared with other athletes at an elite level.
- External factors, including jumping frequency, change of direction, and intensity specific to basketball can lead to overload of tissue, contributing to patellar tendinopathy morphology.

Aspects of Basketball That Require Special Attention in Rehabilitation

- Include dynamic warm-up before activity/sport.
- Restore quadriceps strength and power.
- Restore quadriceps/hip flexor muscle length.
- Normalize lumbopelvic-hip stability.
- Continue with sport if no greater than Blazina Phase I.
- Correct landing mechanics.

Literature

- There is limited evidence to guide return to sport decisions after surgical treatment of patellar tendinopathy.
- It is important to understand the need to normalize patellar tendinopathy risk factors to prevent reinjury.
- Both intrinsic and extrinsic risk factors should be considered and a graduated integration to allow tissue to adapt to higher levels of stress is crucial.
  - Intrinsic factors
    - Quadriceps weakness
    - Quadriceps hypomobility
    - Ankle DF hypomobility
    - Higher waist to hip ratio
    - Altered landing mechanics
    - Patellar tendon abnormality
  - Extrinsic factors
    - Sex (male)
    - Competition level (elite)
    - Sport (volleyball and basketball)
    - Hard surface
    - Lifting weights
    - Playing at least 12 hours/week and/or lifting weight 5 hours/week
    - Higher jumping performance

Phase I: Off Season

Periodization

- Periodization is dependent on the philosophy, time, and resources of the coaching and strength/conditioning staff.

TIMELINE 29-3: **Return to Basketball After Surgical Treatment for Patellar Tendinopathy**

PHASE I (off season)	PHASE II (preseason)	PHASE III (in season)
• Restore movement patterns • Identify dysfunctional pattern (shoulder mobility, straight leg raise, deep squat, rotatory stability, pushup, etc.) • Strength program • Days 1 and 3 • Teach triple extension • Deadlift • Stepups/downs (small plyo box) • Hip hikes/lateral stepping with resistance • Day 2 • Core/balance training • Pushup with row • Plyometric training (1–3×/week) • Cardiorespiratory training • Nonbounding aerobics (2–3 times/week) • Cycling/swimming/elliptical • Hip hike	• Restore movement patterns • Use corrective strategies dependent on dysfunction (daily) • Strength program • Day 1 • Deadlift • Increase depth of squat if good form (0° to 90°) • Cleans • Step ups/downs (large plyo box) • Day 2 • Core/balance training • Pushup with row • Medicine ball drills • Cardiorespiratory training • Focus on sport specific conditioning • Suicide lines, stationary bike, interval training • 1 : 3 work/rest cycle • Plyometric training • Agility • Day 1 • Dot drills • Ladder drills	• Restore movement patterns • Use corrective strategies dependent on dysfunction (daily) • Strength program • Day 1 • Teach triple extension • Deadlift • Cleans • Day 2 • Medicine ball drills • Cardiorespiratory training • None • Plyometric training • None

- Linear periodization has historically been the most commonly utilized mode and will be used as a general template.
- More importantly, correcting movement patterns and teaching proper technique are paramount to avoid reinjury and improve performance.

Program Design/Performance Training Program

- Focus on correcting associated risk factors of patellar tendinopathy, nonbounding aerobic and high duration/low intensity strength training. Avoid drop down plyometrics.

Neuromuscular Training

- Lumbopelvic-hip neuromuscular activation
  - Transversus abdominis, multifidi, and gluteal maximus activation with feedback
- Correct movement patterns (e.g., double and single leg squat)
  - Use assistance (UE support, resistance band, cueing, etc.) to correct abnormal sagittal and frontal plane mechanics (i.e., excessive anterior weight shift, dynamic knee valgus, hip adduction)

Restoration of Mobility

- Thoracic spine (e.g., extension over roll: two sets × 10 repetitions)
- Ankle DF (e.g., anterior half lunge: two sets × 10 repetitions)
- Quad/hip flexor (prone static and dynamic stretching: three sets × 30 seconds)

Strength Program

- Three times per week
- Days 1 and 3
  - Teach triple extension
  - Deadlift
    - Assisted (if needed) to prevent excessive anterior weight shift
    - Double leg
    - Single leg
    - Increase depth of squat if good form (0° to 90°)
    - Use straight and knee leg movements
  - Step ups/downs (small plyometrics [plyo] box)
  - Hip hikes/lateral stepping with resistance
  - Three sets × 12 to 15 repetitions
  - 90 seconds between reps
- Day 2
  - Core/balance training
    - Chops/lifts
    - Three sets × 12 to 15 reps
    - Planks
    - Two sets × 45 to 60 seconds
  - Pushup with row
  - Three sets × 12 to 15 repetitions

Plyometric Training (one to three times per week)

- Knee tuck jumps two sets × 10 repetitions
- Lateral cone hops two sets × 10 repetitions
- Box jump up two sets × 5 repetitions
- 50 to 90 seconds between sets

Cardiorespiratory Training

- Nonbounding aerobics (two to three times per week)
  - Cycling/swimming/elliptical

Phase II: Preseason

Program Design/Performance Training Program

- Maintain power and strength gained in the off season.
- Focus on higher intensity sports-specific conditioning and speed/agility work.
- Circuit training at basketball intensity.

Neuromuscular Training

- Lumbopelvic-hip neuromuscular activation
  - Transversus abdominis, multifidi, and gluteal maximus activation with feedback
- Correct movement patterns (e.g., double and single leg squat)
  - Use assistance (UE support, resistance band, cueing, etc.) to correct abnormal sagittal and frontal plane mechanics (i.e., excessive anterior weight shift, dynamic knee valgus, hip adduction)

Restoration of Mobility

- Thoracic spine (e.g., extension over roll: two sets × 10 repetitions)
- Ankle DF (e.g., anterior half-lunge: two sets × 10 repetitions)
- Quad/hip flexor (prone static and dynamic stretching: three sets × 30 seconds)

Strength Program

- Two times per week
- Day 1
  - Teach triple extension
  - Deadlift
    - Assisted (if needed) to prevent excessive anterior weight shift
    - Double leg
    - Single leg
    - Increase depth of squat if good form (0° to 90°)
  - Cleans
  - Step ups/downs (large plyo box)
  - Three sets × 10 repetitions
  - 30 to 50 seconds between sets
- Day 2
  - Core/balance training
    - Chops/lifts
    - Three sets × 12 to 15 repetitions
    - Planks
    - Two sets × 45 to 60 seconds
  - Single leg balance training program
  - Pushup with row
  - Three sets × 10 repetitions
  - Medicine ball drills (three sets × 8 repetitions each)

- Basketball plyo pushups: Athlete is in a pushup position, straddling the basketball with both hands. Lower down halfway to the ground. Explode off the floor and catch and stabilize on the basketball and hold for a one count. Toss off and land softly on the floor.
- Medicine ball rotation throws: Face a wall with a medicine ball in the hands around chest height. Quickly throw the medicine ball at a predetermined target at the wall. Have hands out in front and ready to absorb the rebound of the ball off the wall. Catch the ball and throw back.
- Slam downs: Stand with feet parallel and knees slightly bent. Pull medicine ball back behind head and forcefully throw ball down on the ground as hard as possible. Catch the ball on the bounce from the ground and repeat according to prescribed repetitions.
- Squat throws: Start with ball positioned at waist level with knees slightly bent. Quickly squat lowering ball to calf level and explode up throwing the ball as high as possible directly overhead. Let the ball bounce once, reposition, and repeat drill. This exercise is important to develop posterior chain strength.

Cardiorespiratory Training

- Focus on sport-specific conditioning
  - Suicide lines, stationary bike, interval training
  - 1:3 work/rest cycle
  - One to three times per week

Plyometric Training

- Lateral cone hops 2 sets × 10 repetitions
- Single leg jump 2 sets × 5 repetitions
- Combine jumps and agility/ladder drills
- Avoid pain and consider using pool if needed
- 50 to 90 seconds between sets
- One to two times per week

Agility Drills

- Emphasis always should be placed on good form and landing mechanics.
- Day 1
  - Cone drills
    - T-drill: 5 to 10 sets
    - Two cones are set up 5 yards apart and two cones 6 yards apart to make a T
    - Run to the top of the T, shuffle to the right top cone, then left, return to the center cone, pivot, and sprint back to the start.
    - Z-drill: 5 to 10 sets
    - Place three sets of Cones 5 yards apart and 5 yards wide. Side shuffle from cone 1 to cone 2, Start at cone 1, shuffle slide to cone 2, use a drop step to change direction and slide to cone 3, and so on through the series of cones.
    - U drill: 5 to 10 sets
  - Players run in a U pattern from baseline under basket on one side, to the foul line, then to the block on other side of basket, and receive a short pass. They do a jump stop, square up, and shoot the ball off the glass.
  - Ladder drills
    - Ickey shuffles: 5 to 10 sets
      - Step into the box with the left foot and immediately follow with the right foot. Step outside the box with the left foot. Step forward with the right foot into the next box. Step into the second box with the left foot and step outside of the box with the right foot. Continue in a side-to-side fashion for the entire ladder.
    - Ollie shuffle: 5 to 10 sets
      - Stand to the side facing the ladder. Quickly jump in a scissor-like motion alternating each foot to shuffle laterally through the ladder.
    - Single leg diagonals: 5 to 10 sets
      - Start on one foot to the right of the ladder. Jump into the first square, then jump left outside between squares 1 and 2, back into the second square, jump right between squares 2 and 3, back into the third square. Repeat this diagonal pattern throughout.

Phase III: In Season

Program Design/Performance Training Program

- Maintain strength/balance, prevent overload.
- Use multidirectional activities with emphasis on correct movement patterns.
- Use dynamic warmup to maintain lower extremity mobility (quadriceps, ankle dorsiflexion, spinal mobility, etc.)

Neuromuscular Training

- Lumbopelvic-hip neuromuscular activation
  - Transversus abdominis, multifidi, and gluteal maximus activation with feedback
- Correct movement patterns (e.g., double and single leg squat)
  - Use assistance (UE support, resistance band, cueing, etc.) to correct abnormal sagittal and frontal plane mechanics (i.e., excessive anterior weight shift, dynamic knee valgus, hip adduction)

Restoration of Mobility

- Thoracic spine (e.g., extension over roll: two sets × 10 repetitions)
- Ankle DF (e.g., anterior half lunge: two sets × 10 repetitions)
- Quad/hip flexor (prone static and dynamic stretching: three sets × 30 seconds)

Strength Program

- Two times per week
- Day 1
  - Teach triple extension
  - Deadlift
    - Assisted (if needed) to prevent excessive anterior weight shift
    - Double leg
    - Single leg
    - Increase depth of squat if good form (0° to 90°)

- Cleans
- Three sets × eight repetitions
- 30 to 50 seconds between sets
- Day 2
  - Medicine ball drills (three sets × eight repetitions each)
    - Basketball plyo pushups
    - Medicine ball wall throws
    - Medicine ball rotation throws
    - Slam down
    - Squat throws

Sports Performance Testing

General Information

- General history
- Subjective questionnaires
- Medical history
- Sports injury history
- Surgical history
- Chronic conditions/medication

Objective Tests

- Body composition tests (hip to waist ratio)
- Functional movement screen[1]
- Lower extremity functional test (Figure 29-26)
- Symmetrical vertical jump

Specific Criteria for Progression to the Next Stage to Determine Readiness for Basketball

- No compensatory movement patterns (No gross asymmetry or abnormal landing/squatting mechanics)
- No more than Blazina Phase I with activity (pain after activity only).

Recommended Ongoing Exercises

- A dynamic warmup designed to improve mobility neuromuscular activation can be implemented prior to rehabilitation or sport program.
- Quadriceps and ankle DF mobility/muscle-tendon flexibility should be continued both before and after activity.
- Strength training should be continued both before and after activity.

Evidence

Chaouach A, Brughelli M, Chamari K, et al: Lower limb maximal dynamic strength and agility determinants in elite basketball players. *J Strength Cond Res* 23(50):1570–1577, 2009.

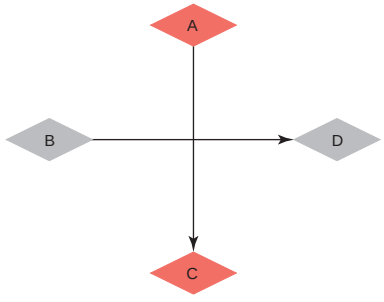
Cohort study to examine relationship between 1RM squat and basketball-specific tests in fourteen elite basketball players. Squat 1Rm was significantly related to 5-, 10-, and 30-m sprint time and recommended for inclusion in conditioning program. (Level II evidence)

Khlifa R, Aouadi R, Hermassi S, et al: Effects of plyometric training program with and without added load on jumping ability in basketball players. *J Strength Cond Res* 24(11):2955–2961, 2010.

Twenty-seven players randomly assigned to three groups: a control group (no plyometric [plyo] training), plyo group, and loaded plyo group to compare jumping performance. Following at 10-week plyo program, the loaded plyo group significantly improved jumping performance than the control or plyo group. The plyo group demonstrated significantly better jumping performance than control. (Level I evidence)

Santos EJ, Janeira MA: Effects of complex training on explosive strength in adolescent male basketball players. *J Strength Cond Res* 22(3):903–909, 2008.

A control group of 10 and experimental group of 15 young male athletes, aged 14 to 15 years old were assessed using functional performance tests after a 10-week in-season training program using weight training and plyometrics. The



30ft long by 10ft wide

1. Forward run
2. Retro run
3. Side shuffle right and left
4. Cariocas right and left
5. Figure-8 run right and left
6. 45-degree cuts right and left
7. 90-degree cuts outside leg right and left
8. 90-degree cuts inside leg (crossover cut) right and left
9. Forward run
10. Retro run

NORMS	
Males	***Females***
90 sec – good	120 sec – good
100 sec – average	135 sec – average
125 sec – below average	150 sec – below average

FIGURE 29-26. Lower extremity functional scale.

experimental group demonstrated significantly better values on power and agility tests compared with their control counterparts. (Level II evidence)

Tabor MA, Davies GJ, Kernozek TW, et al: A multicenter study of the test-retest reliability of the Lower Extremity Functional Test. *Sport Rehabil* 11:190–220, 2002.

Multicenter reliability study of the lower extremity functional test using 57 collegiate male and female athletes at two institutions without pathology, ICC values of .95 and .97 were established at separate locations indicating good test-retest reliability. (Level III evidence)

Zemkova E, Hamar D: The effect of 6-week combined agility-balance training on neuromuscular performance in basketball players. *Jour Sport Med Phys Fitness* (3):262–267, 2010.

This randomized controlled study of 34 elite female basketball compared functional outcome following a 6-week agility training on either stable or unstable surface. The experimental group using an unstable surface demonstrated significantly better neuromuscular performance. There was no difference in jumping performance. (Level I evidence)

REFERENCE

1. Parchmann CJ, et al: Relationship between FMS and athletic performance. *J Strength Cond Res* 25(12):3378–3384, 2011.

Multiple Choice Questions

QUESTION 1. A dynamic warmup should focus on which of the following impairments in an athlete with a history of patellar tendinopathy?

A. Thigh/quadriceps weakness
B. Gluteal weakness
C. SL balance deficits
D. Hamstring weakness

QUESTION 2. Which of the following strengthening exercise is best to improve posterior chain strength?

A. Basketball plyo pushup
B. Medicine ball slam downs
C. Medicine ball rotation throw
D. Medicine ball squat throws

QUESTION 3. To maximize quadriceps strength which of the following squats should be used?

A. SL squat 0° to 20°
B. SL squat 0° to 60°
C. SL squat 0° to 90°
D. SL straight leg deadlift

QUESTION 4. Which of the following times is considered "average" when testing a male collegiate athlete using the Lower Extremity Functional Test?

A. Less than 90 seconds
B. Less than 100 seconds
C. Less than 110 seconds
D. Greater than 110 seconds

QUESTION 5. The purpose of the off-season conditioning program is to

A. focus on nonbounding aerobic and high duration/low intensity strength training.
B. focus on higher intensity sports-specific conditioning and speed/agility work.
C. focus on high intensity/low duration strength training.
D. focus on sport-specific plyometric training.

Answer Key

QUESTION 1. Correct answer: **A** (see Phase I)

QUESTION 2. Correct answer: **D** (see Phase II)

QUESTION 3. Correct answer: **C** (see Phase III)

QUESTION 4. Correct answer: **B** (see Figure 29-26)

QUESTION 5. Correct answer: **A** (see Phase I)

POSTOPERATIVE REHABILITATION AFTER REPAIR OF PATELLAR AND QUADRICEPS TENDON

J. Martin Leland, MD, and Philip J. Malloy, MS PT, SCS

Indications for Surgical Treatment

- A complete rupture of the quadriceps or patellar tendon
- A partial rupture of greater than 50% of the quadriceps or patellar tendon with an inability to perform a straight leg raise or hold the knee extended against gravity
- A partial rupture of the quadriceps or patellar tendon which fails extensive conservative therapy and continues to cause pain and an inability to return to activity

Brief Summary of Surgical Treatment

Major Surgical Steps

- Identify the ruptured tendon and debride the end of the tendon to healthy tissue.

- Prepare the patella using a burr or rongeur to create a cancellous bony trough to accept the tendon.
- Use two high strength sutures for the repair, weaving them through the medial and lateral halves of the tendon with a Krackow stitching technique.
- Drill three small vertical holes in the patella to pass the sutures through, with the two central strands passing through the central hole.
- Tie the two sutures on the far side of the patella with the knee in full extension, pulling the tendon into the trough created in the patella.
- Reinforce the repair with high strength suture or Mersilene tape woven through the tendon, through the medial and lateral retinaculum, around the far pole of the patella and tied (a "relaxing suture" taking tension off of the repair).[1]
- Repair retinacular tears with interrupted stitches and close the wound in layers.

Factors That May Affect Rehabilitation

Anesthetic

- Regional nerve blocks may be used to aide in comfort in the immediate postoperative period.

Surgical

- Before closure, the surgeon should begin to flex the knee and assess the arc of motion that can be achieved without putting stress across the repair. The patient should be limited to no motion beyond this stress-free arc for the first 6 weeks postoperatively. Complexity of the tear and quality of the repair must be appreciated when determining the rate of advancement through the rehabilitation phases.[1]

Other Surgical Techniques and Options

- Mid tendon ruptures can be repaired using an end-to-end repair as is frequently performed in Achilles tendon ruptures. A "relaxing suture" would also be recommended in these situations.[1]
- Complex tears or poor tissue quality should be advanced slowly through the rehabilitation phases, giving the tissues additional time for healing before significant strain is applied.

Guiding Principles of Postoperative Rehabilitation

- Appreciate the severity of the injury and the quality of the surgical repair.
- Open communication between surgeon and therapist regarding range of motion that can be achieved without putting stress across the repair.
- Understand tendon healing time frames.
- Respect ROM guidelines during phases of healing.
- Once full range of motion is obtained, focus on restoring symmetrical strength in the lower extremities before return to play to prevent reinjury.

*Phase I (days 0 to 14): Immediate Postoperative Period**

Clinical Pearl

> Quadriceps tendon rupture is a rare event in athletes less than 40 years old. Communication between surgeon and therapist regarding range of motion and weight-bearing restrictions is critical to promote compliance in the athletic population. The patient must demonstrate proper technique with passive range of motion and home exercises before he or she is released to perform them independently to ensure appropriate protection is given to healing tissue.

Goals

- Control postoperative pain.
- Manage postoperative swelling and effusion.
- Educate patient on protection of the repair.
- Initiate early controlled passive range of motion beginning at 1 week postoperatively to prevent stiffness (0° to 45°).
- Educate patient on weight-bearing restrictions and appropriate use of crutches.

Protection

- Weight bearing is restricted to PWB 25% body weight for the first 2 weeks using bilateral axillary crutches.
- The patient is placed in a hinged knee brace that is locked at 0° extension at all times including for sleep. The patient may unlock for exercise beginning at 1 week postoperatively.
- The patient is instructed to avoid active quadriceps contraction to protect the repair.

Management of Pain and Swelling

- Treatment for pain/analgesia
  - Oral pain medication
  - Avoid the use of NSAIDs for the first 2 weeks postoperatively because of inhibition of the inflammatory cascade.
  - Modalities such as TENS, Hi Volt, and interferential current electrical stimulation can be used to modulate pain.
  - Cryotherapy is emphasized to assist with controlling postoperative pain.
- To decrease swelling
  - Vasopneumatic compression with elevation is emphasized postoperatively to manage swelling and edema.
  - Modify activities such as minimizing time spent with lower extremity in a dependent position.[2]
  - Initiate ankle pumps to promote lower extremity blood flow and prevent calf musculature atrophy.

**Prehabilitation, if appropriate, is described in the Nonoperative Rehabilitation section of this chapter.*

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Patellar mobilizations in the medial and lateral direction can be used to prevent postoperative arthrofibrosis.[3,4]

Soft Tissue Techniques

- Gentle lymphatic massage can be used to assist with postoperative swelling.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Initiate gastrocnemius stretching with a strap to promote calf flexibility
- Ankle circles to promote ankle ROM

Other Therapeutic Exercises

- Avoid any total body or upper extremity strengthening that puts the operative extremity in a dependent position because of the increase in swelling that would result.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- A submaximal quadriceps setting can be initiated under the guidance of a rehabilitation professional.[4,5–7]
- Neuromuscular electrical stimulation (NMES) may be useful in assisting with quadriceps activation.[5]

Milestones for Progression to the Next Phase

- Pain and swelling control
- Wound healing of incision site
- Passive knee flexion to 45°
- Independent ambulation in brace locked in full extension with assistive device

Phase II (weeks 2 to 6 postoperatively)

Clinical Pearl

Patellar mobilizations in all directions are important in preventing arthrofibrosis during this phase.[3,4] Restoring passive range of motion is important to prevent postoperative knee stiffness, but care always must be taken to not stress the healing repair.[3] Modalities such as NMES may be useful in facilitating quadriceps activation to promote control and assist with eliminating extensor lag during a straight leg raise.[5] This will also assist the patient to transition to weight bearing as tolerated without stress across the repair.

Goals

- Restore 0° to 90° of passive knee motion by 6 weeks (0° to 60° by 4 weeks and 90° by 6 weeks): This should be limited to the stress-free arc that was determined by the surgeon intraoperatively.
- Initiate straight leg raise in brace locked at 0° of extension.
- Initiate weight bearing as tolerated with brace locked in extension.
- Initiate multi plane straight leg raise using the hip stabilizers to promote proximal stability (hip abduction, adduction, extension).

Protection

- Progress to weight bearing as tolerated in brace locked in extension beginning at 2 weeks postoperatively based on patent's pain and swelling.
- Continue use of brace at all times locked in extension except during structured physical therapy sessions.

TIMELINE 29-4: **Postsurgical Rehabilitation After Repair of Patellar or Quadriceps Tendon**

PHASE I (weeks 1 to 2)	PHASE II (weeks 3 to 6)	PHASE III (weeks 6 to 10)
• Partial weight bearing 25% foot flat gait pattern • Hinged brace locked at 0° extension • Pain control through use of oral analgesics • Cryotherapy with vasopneumatic for swelling control • No NMES week 1 • NO PROM week 1 • Begin seated PROM 0° to 45° (week 2) • Begin sub maximal quadriceps setting week 2 • Activity modification to manage swelling	• Progress to weight bearing as tolerated in brace locked at 0° extension • Cryotherapy and vasopneumatic for swelling control • Begin patellar mobilizations and scar massage when incision is healed • Soft tissue mobilization to quadriceps and hamstrings • Upper body ergometer for cardiovascular • Upper body strengthening and core stabilization avoiding quadriceps activation • Seated flexion PROM to 0° to 60° 2 to 4 weeks • Seated flexion PROM 0° to 90° 4 to 6 weeks • NMES to quadriceps • Initiate straight leg raises in brace and progress to out of brace • Begin multiplane hip musculature strengthening and progress as tolerated	• D/C brace and restore normal symmetrical gait weeks 6 to 7 • Cryotherapy as needed for swelling • Begin active assisted and active knee ROM 0° to 120° • Joint and soft tissue mobilization as tolerated • Core stability and total arm strengthening as tolerated • Stationary bike once 110° active flexion is achieved • Begin short arc quadriceps exercise 30° to 0° • Initiate and progress single leg balance and proprioceptive exercises • Double leg closed chain lower extremity strength progression to 30° flexion

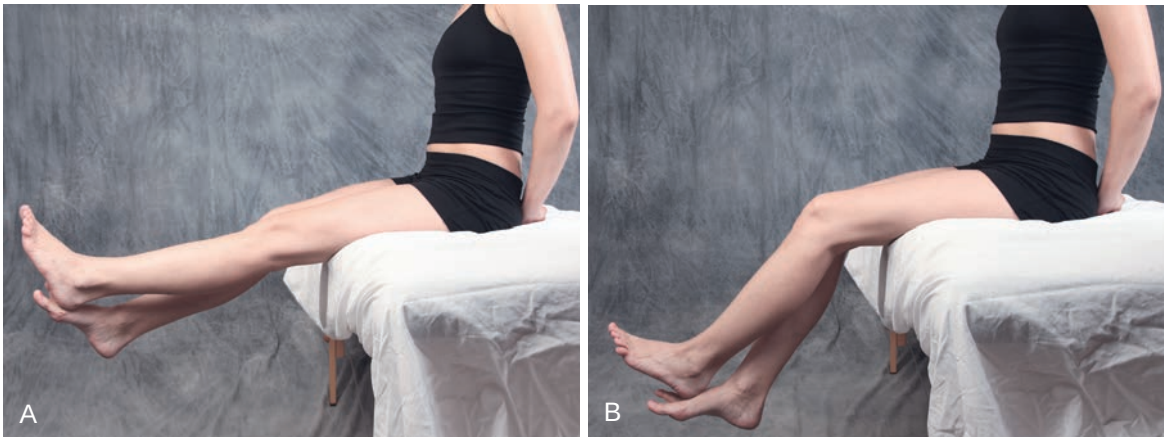


FIGURE 29-27. Seated passive knee flexion using uninvolved leg.

- The patient may doff the brace for showering beginning at 2 weeks. It is recommended that the patient use a shower seat with the knee maintained in extension at all times.

Management of Pain and Swelling

- Treatment for pain/analgesia
  - Oral analgesics as needed weaning to non-narcotic medication for residual pain. (NSAIDs may be initiated at 2 weeks postoperatively.)
  - Cryotherapy should be continued to manage pain and swelling.
  - Be aware of increased pain as weight bearing is increased and modify or limit activities as necessary.
- To decrease swelling:
  - Use of nonsteroidal antiinflammatory medication as indicated for continued postoperative swelling.
  - Continue with lymphatic massage, ankle pumps, and cryotherapy to reduce residual swelling.
  - Ankle pumps are initiated to promote lower extremity blood flow and prevent calf musculature atrophy.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Patellar mobilizations in all directions should begin at week 2 based on the quality of wound healing to prevent postoperative scarring and adhesion of the anterior knee.[4]
- If lacking full extension, begin tibiofemoral joint mobilizations to restore terminal extension.[4]
- Continue passive knee flexion exercises progressing to 90° as tolerated (0° to 60° by 4 weeks and 0° to 90° by 6 weeks). Limit to the stress-free arc determined intraoperatively (Figures 29-27 to 29-29).

Soft Tissue Techniques

- Initiate soft tissue mobilization to the quadriceps and hamstrings to assist with passive knee flexion and extension.
- Initiate scar mobilization based on quality of wound healing.

TIMELINE 29-4: **Postsurgical Rehabilitation After Repair of Patellar or Quadriceps Tendon** (Continued)

PHASE IV (weeks 10 to 14)	PHASE V (weeks 14 to 24)	PHASE VI (weeks 24 to 52)
• PT modalities as needed • Restore full active and passive knee ROM (<5° uninvolved) • Advance stretching to restore flexion symmetry • Mobilizations as needed for flexion and extension • Begin and progress cardiovascular endurance with elliptical trainer and treadmill uphill walking • Begin long arc quads without resistance • Progress double leg strengthening squat depth • Initiate short arc single leg squats • Progress balance and proprioceptive training • Initiate mid-range lunge progression	• PROM: maintain full motion • Mobilizations as needed • TBS/TAS/TLS activities as recommended and tolerated • Cardiovascular training as tolerated • Advance single leg strengthening (weeks 14 to 18) • Advance balance and proprioceptive exercises (weeks 14 to 18) • Initiate agility drills (week 18) • Begin return to running progression (week 20) • Begin plyometrics (week 24)	• PROM: maintain full motion • Mobilizations as needed • Lower extremity flexibility exercises • TBS/TAS/TLS activities as recommended and tolerated • Advanced plyometric and jump training (week 24 to 26) • Initiate and complete a return to sport progression (week 26 to 30) • Closed chain lower extremity strength maintenance program • Balance and proprioceptive training as needed

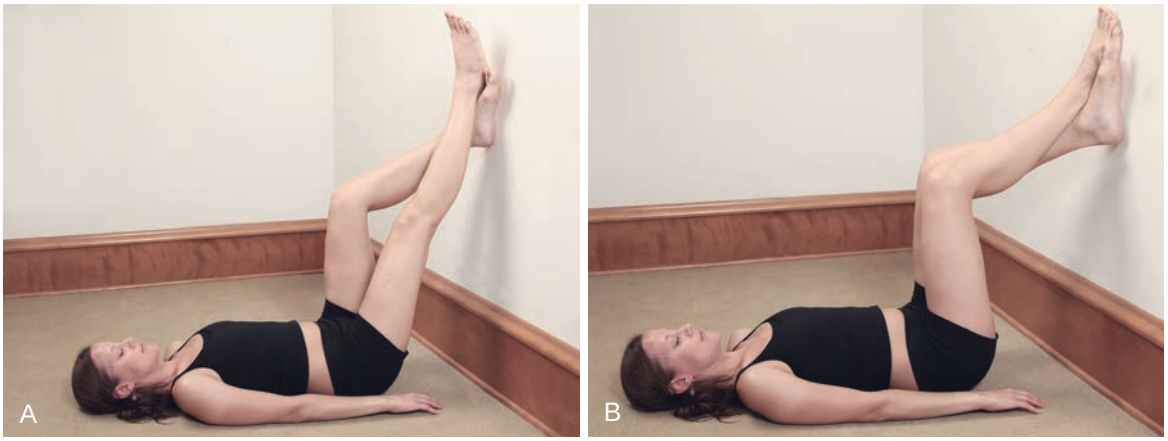


FIGURE 29-28. Supine wall slides.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Initiate supine passive hamstring, ITB, and adductor stretching with knee in full extension.

Other Therapeutic Exercises

- Upper body ergometer for cardiovascular endurance
- May initiate upper body and core stabilization with knee locked in brace. Avoid quadriceps activation with any strengthening exercise.
  - Abdominal crunches
  - Seated trunk rotations with resistance band
- Isometric contraction of all lower extremity musculature can begin during this phase to prevent atrophy.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Elevate the heel on a bolster during quadriceps sets if the patient is lacking terminal extension.
- Straight leg raises can be initiated in a locked brace (Figure 29-30).
- Utilization of NMES to the quadriceps may assist in facilitating activation.[5]

Sensorimotor Exercises

- Begin weight shifting exercises to promote appropriate weight transfer during gait.
- Initiate single leg balance in brace locked in extension to facilitate single limb support during stance phase of gait cycle (Figure 29-31).

Open and Closed Kinetic Chain Exercises

- Emphasize proximal stability through the initiation of multiplane hip stabilization such as hip abduction, adduction, and extension in the supported position[8] (Figures 29-32 and 29-33).
- Begin clam progression (Figures 29-34 and 29-35).

Milestones for Progression to the Next Phase

- Passive knee range of motion 0° to 90° or as limited by the intraoperative stress-free arc
- Normal patellar mobility in all planes
- Elimination of extensor lag with straight leg raises
- Minimal swelling
- Initiate weight-bearing exercise and restore weight-bearing status as tolerated in brace.

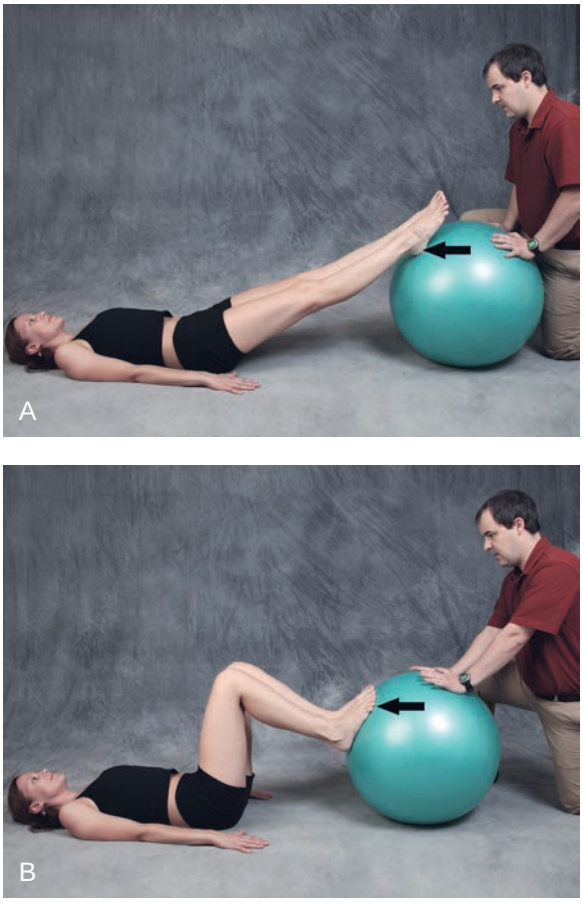


FIGURE 29-29. Supine passive flexion with exercise ball.

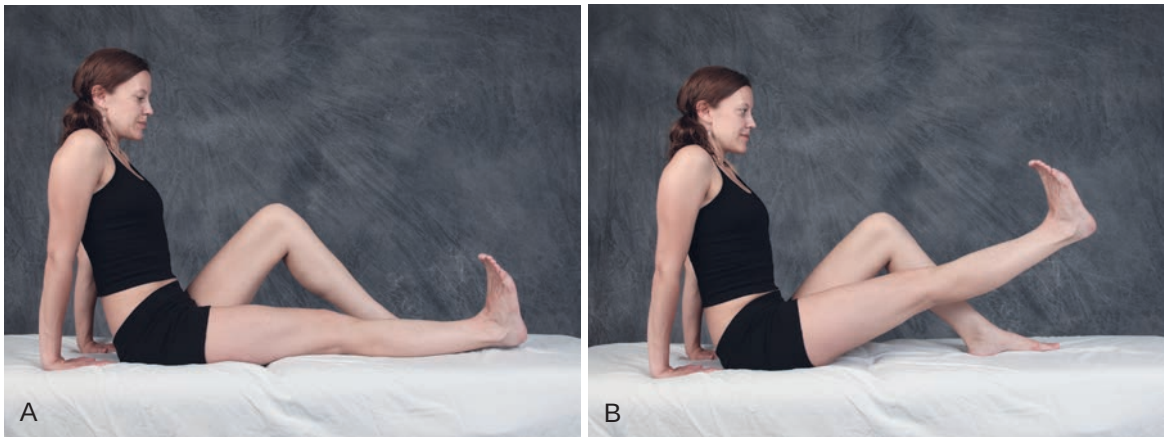


FIGURE 29-30. Straight leg raise.



FIGURE 29-31. Single leg balance on level surface.



FIGURE 29-33. Prone leg raises.



FIGURE 29-34. Side-lying clam exercise.



FIGURE 29-32. Side leg raises.



FIGURE 29-35. Side-lying clam exercise with resistance band.

Phase III (weeks 6 to 10 postoperatively)

Clinical Pearl

The brace may be removed for ambulation once the patient exhibits good strength with straight leg raise testing. Appropriate quadriceps control must be emphasized when returning to brace-free ambulation. Avoid increasing postoperative effusion and emphasize proper motor control when initiating closed chain exercises to prevent anterior knee pain.

Goals

- Restore knee range of motion 0° to 120°.
- Minimize postoperative swelling and muscle inhibition.
- Eliminate extensor lag with straight leg raises (three sets × 15 reps without brace) to discontinue brace use for ambulation and initiate closed chain strengthening.
- Restore symmetrical gait pattern without assistive device and brace.
- Initiate double leg closed chain strengthening in limited range of motion 0° to 30°.

Protection

- Unlock brace 0° to 90° for initial ambulation until the athlete is able to achieve straight leg criteria mentioned in the preceding.
- Gradually wean out of brace over a 1- to 2-week period depending on quad control during walking.[2]

Management of Pain and Swelling

- Treatment for pain/analgesia: NSAIDs as needed
- To manage swelling:
  - Initiate cryotherapy as needed after exercise.
  - Modify activity as needed if swelling persists.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Advance to 0° to 120° of active knee range of motion using manual techniques as needed.
- Tibiofemoral joint mobilizations to restore arthrokinematics during open chain active knee flexion and extension.
- Tibial rotation mobilizations are useful in restoring end ranges of knee flexion and extension assisting the screw home mechanism.
- Femoral and tibial anterior and posterior glides can also be initiated during this phase to promote joint mobility and range of motion.

Soft Tissue Techniques

- Utilize soft tissue mobilizations as needed to promote tissue extensibility, especially at the repair site.



FIGURE 29-36. Avoid aggressive passive flexion stretching.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Continue lower extremity stretching and begin Thomas hip flexor stretching.
- Avoid aggressive prone quadriceps stretching to avoid stress across the repair[6] (Figure 29-36).

Other Therapeutic Exercises

- Upper body ergometer for cardiovascular endurance
- Begin zero resistance stationary biking when 110° of flexion is achieved.
- Advance core stabilization initiating a plank progression (Figures 29-37 and 29-38).
- Initiate deep water aqua jogging.[4]

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Progress quadriceps activation to include open chain short arc quadriceps and standing terminal knee extension with resistance band[9,10] (Figures 29-39 and 29-40).
- Progress straight leg raises to include light ankle weights once good quadriceps control is established.
- Initiate exercise ball double leg assisted squats (Figure 29-41).



FIGURE 29-37. Prone planks.



FIGURE 29-38. Prone planks with opposite hip extension.

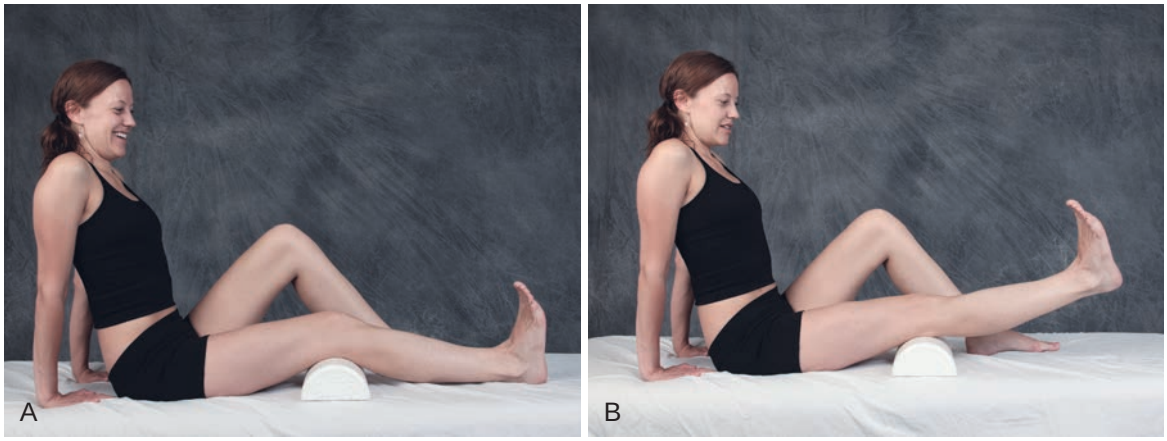


FIGURE 29-39. Short arc quadriceps exercise.

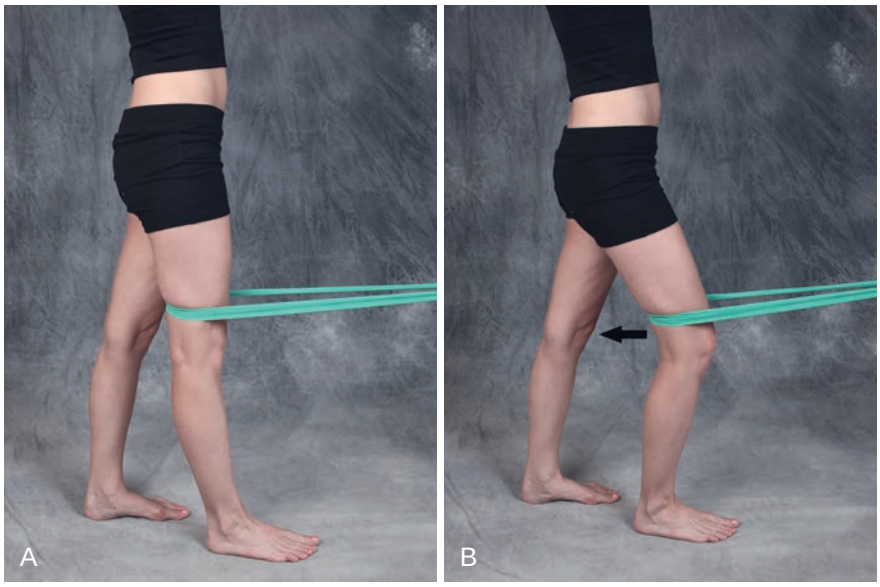


FIGURE 29-40. Standing terminal knee extension with resistance.

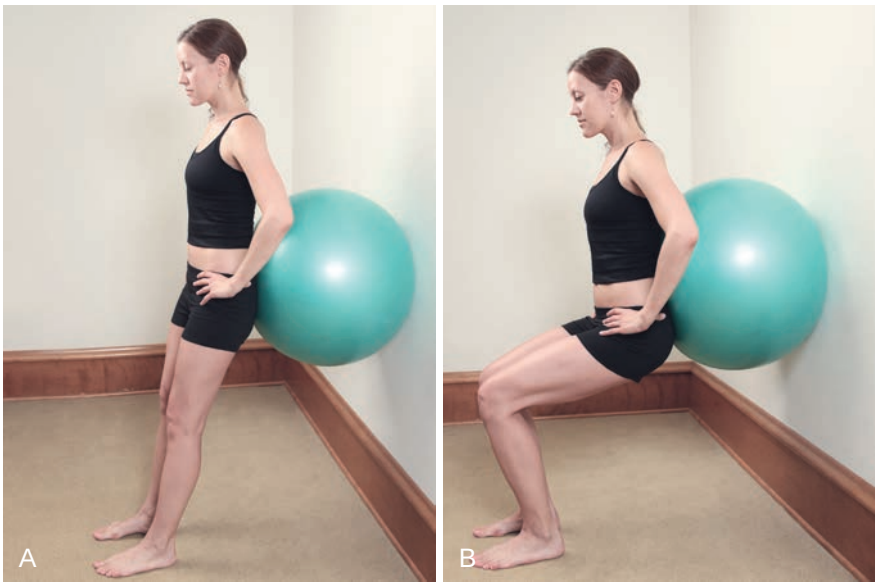


FIGURE 29-41. Assisted wall squats with exercise ball.

Sensorimotor Exercises

- Single leg balance progressing from with brace to without brace on level surface.
- Progress to single leg balance on unstable surface such as a foam pad, Dyna-disc, or BOSU (Figure 29-42).

Open and Closed Kinetic Chain Exercises

- Progress OKC multiplane straight leg raises with ankle weights.
- Begin manual resisted diagonal patterns to promote motor control.
- Initiate concentric-eccentric quadriceps in sitting between 0° and 45° (avoid resistance).
- Initiate closed chain standing one-third knee bends (0° to 30°) in brace progressing to out of brace[4,10] (Figure 29-43).



FIGURE 29-42. Single leg balance on BOSU.

Neuromuscular Dynamic Stability Exercises

- Initiate seated exercise ball core stability exercise to promote trunk control.

Milestones for Progression to the Next Phase

- Symmetrical gait pattern with good quadriceps control
- Knee AROM to 0° to 120°
- Ability to perform double leg knee squat to 30° without anterior knee pain and good control
- Minimal swelling after activity

Phase IV (weeks 10 to 14 postoperatively)

Clinical Pearl

Emphasize prolonged holds with double leg strengthening to promote muscular endurance. Educate the athlete on lower extremity position and proper alignment during exercise to avoid undue stress on anterior knee that can cause patellofemoral pain.

Goals

- Restore symmetrical knee active range of motion (less than 5° loss).
- Progress closed chain double leg strengthening 0° to 60°.
- Initiate step training promoting restoration of eccentric quadriceps control.
- Eliminate swelling and joint effusion.

Management of Pain and Swelling

- Continue the use of NSAIDs for any residual pain or inflammation.

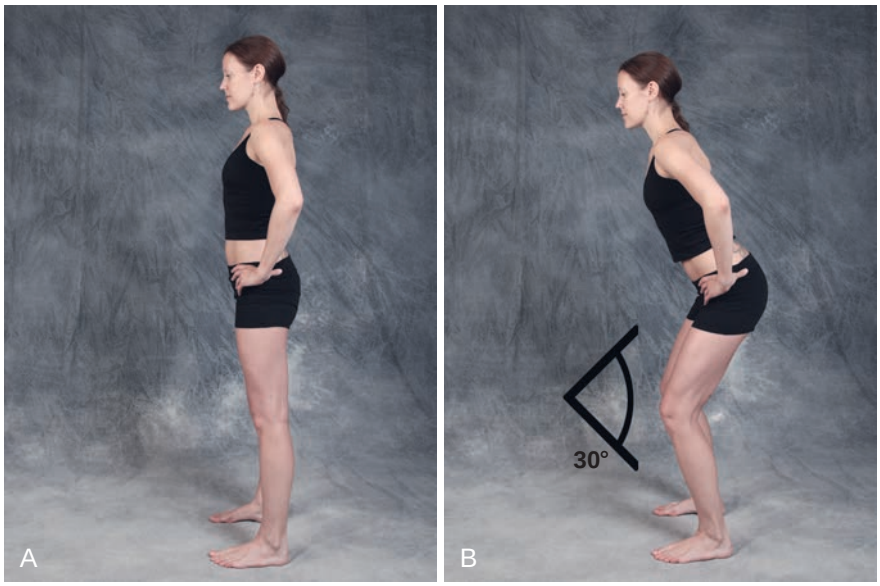


FIGURE 29-43. One-third knee bends.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Tibiofemoral joint mobilization should continue to promote normal arthrokinematics and symmetrical joint motion during open and closed chain exercise.

Soft Tissue Techniques

- Initiate PNF contract-relax stretching for quadriceps.
- Advanced soft tissue mobilization can now include deep tissue mobilizations to improve flexion range of motion.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Prone manual knee flexion stretching can be initiated to restore symmetrical knee flexion.
- Dynamic quadriceps stretching can also be initiated during this phase.
- Continue lower extremity stretching of all muscle groups focusing on two joint muscles (i.e., hip flexor, hamstrings, quadriceps, gastrocnemius).

Other Therapeutic Exercises

- Advance stationary biking to include resistance (maintain 80 to 120 rpm).
- Initiate elliptical trainer.
- Initiate treadmill uphill walking (7% to 12% grade).[3]
- Progress core stability as tolerated in all positions.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Progress quadriceps activation to include step progression (4- to 6-inch step)[10] (Figure 29-44).
- Long arc quadriceps extensions 90° to 0° without resistance.[10]

Sensorimotor Exercises

- Continue to progress single leg balance on altered surface to promote endurance.
- Incorporate upper extremity and trunk patterns and movements into single leg balance exercises.[9]

Open and Closed Kinetic Chain Exercises

- Gradually advance knee range of motion during double leg closed chain strengthening.
- Begin double leg squats with side to side weight shifts to promote single limb stability.
- Progress step training promoting eccentric control of the knee and hip.



FIGURE 29-44. Lateral step-down.

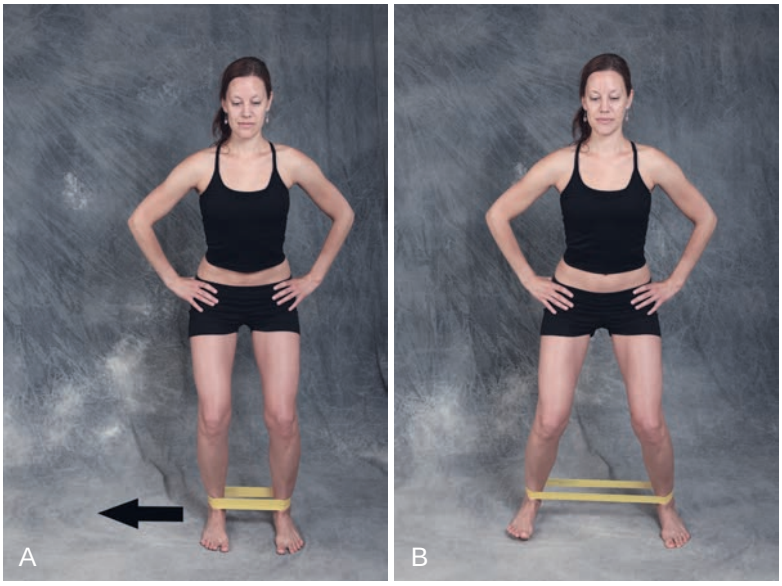


FIGURE 29-45. Side-step with resistance band.

- Begin single leg static holds at 20° of knee flexion to promote endurance for single leg strengthening.
- Begin resisted side stepping (Figure 29-45).

Techniques to Increase Muscle Strength, Power, and Endurance

- Begin double leg stance chopping exercises.
- Incorporate resisted upper extremity motions into single leg static holds to promote core stability and motor control.

Neuromuscular Dynamic Stability Exercises

- Continue to advance lower extremity diagonal patterns to include trunk and upper extremity in all positions.[9]

Milestones for Progression to the Next Phase

- Restoration of symmetrical knee range of motion
- Pain free with activities of daily living
- Ability to ascend and descend an 8-inch step with good control of lower extremity
- No anterior knee pain during or after strengthening exercises

Phase V (weeks 14 to 24 postoperatively)

Clinical Pearl

Avoid anterior knee pain with advancing single leg strengthening. Emphasize motor control with advanced strengthening exercises. Sport-specific positions should be used when developing strengthening programs for athletes during this phase.

Goals

- Shift focus to strengthening by beginning agility and sport-specific training.
- Initiate plyometric and functional training.
- Restore cardiovascular fitness and endurance.
- Complete a lateral step down test with appropriate form and control.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- If range of motion is less than uninjured side, advanced to aggressive joint mobilizations (grade 4 to 5) to restore full mobility.
- If range of motion is still limited at 4 months postoperatively, manipulation under anesthesia in the operating room should be considered.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Continue quadriceps stretching as needed to restore symmetrical flexibility in Thomas Test position

Other Therapeutic Exercises

- Initiate advance cardiovascular training using treadmill, elliptical trainer, stationary biking, and aquatic workouts.
  - Jogging progression can be initiated on a treadmill.
- Continue performing core stability exercises as part of home and gym workout routine.
- Advance upper body weight training as tolerated without restrictions.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Add resistance to open chain quadriceps strengthening between 60° and 0° once full range of motion is achieved.

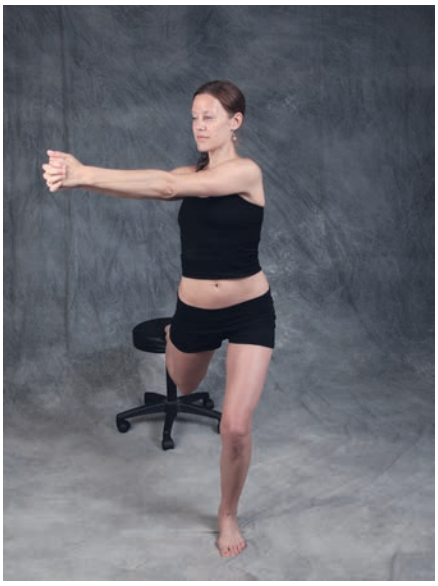


FIGURE 29-46. Balance squat with trunk rotations.

Sensorimotor Exercises

- Advance balance and proprioceptive training as tolerated (Figure 29-46)

Open and Closed Kinetic Chain Exercises

- Initiate single leg supported squatting[4,11] (Figure 29-47).
- Progress single knee bends to 60° flexion (Figure 29-48).

Techniques to Increase Muscle Strength, Power, and Endurance

- Advance lower extremity weight training for quadriceps, hamstrings, proximal hip stabilizers (external rotators and gluteals), and gastrocnemius.
- The athlete may gradually return to a modified weight training program with strength and conditioning coach or trainer (avoid Olympic lifts until next phase).

Neuromuscular Dynamic Stability Exercises

- Begin lunge progression advancing from split lunge to single plane to multiplane.[11]
- Diagonal trunk patterns with single leg squatting to promote single limb and trunk control.

Plyometrics

- Initiate double leg plyometric training at 4 months postoperatively.[12]
- Progress plyometric training from single plane hopping to multiplane.[12,13]

Functional Exercises

- Begin initial agility consisting of lateral shuffle and carioca.
- Advanced agility such as W cuts, Z cuts, and chop downs can begin at 5 months postoperatively.[3]

Sport-Specific Exercises

- Initiate a return to running progression.
- Sport specific activities that do not involve eccentric loading or explosive movements can begin toward the middle of this phase such as shooting baskets, volleying during tennis, setting or bumping in volleyball, or walk through movements.

Milestones for Progression to the Next Phase

- Completion of a lateral step down test with appropriate form and control compared with uninvolved[14] (see Figure 29-44).



FIGURE 29-47. Balance squats.

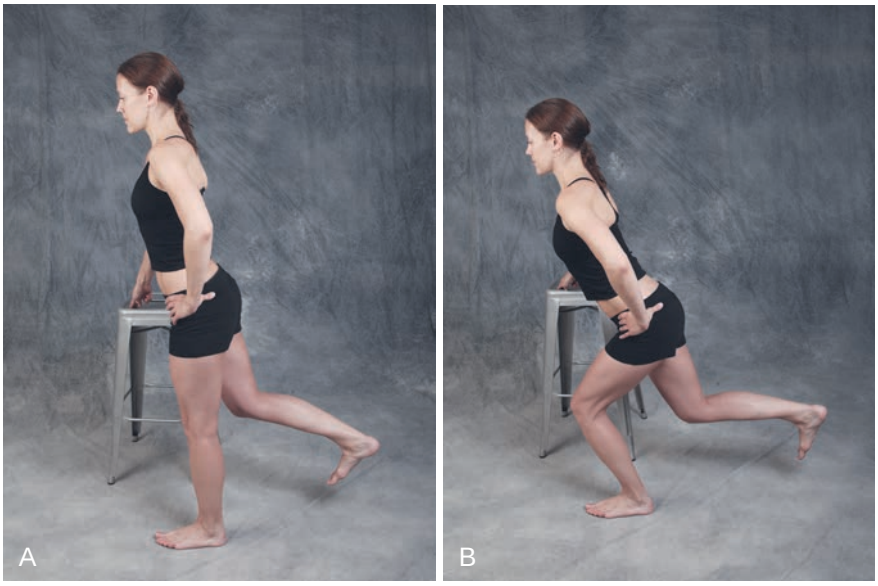


FIGURE 29-48. Single knee bends.

- Pain free with initial and advanced agility exercises.
- Proper form and control with double leg plyometric exercises.

Phase VI (weeks 24 to 52 postoperatively)

Clinical Pearl

> The complete clinical picture of the athlete should be taken into account before return to competition, which will include strength assessment and return to sport testing. A gradual re-introduction to competition is recommended to ensure that appropriate endurance is attained to prevent reinjury caused by fatigue.

Goals

- Restoration of 90% strength compared with uninvolved lower extremity with isokinetic testing of the quadriceps.
- Completion of single limb hop testing or functional return-to-sport testing.[4,13]
- Return to competition.

Techniques to Increase Muscle Strength, Power, and Endurance

- May begin Olympic lifting techniques that can be useful to focus on strength and power.
- Focus on building endurance of quadriceps, hamstrings, gluteals/hip abductors, gastrocnemius, and hip adductors.

Neuromuscular Dynamic Stability Exercises

- Advance upper and lower extremity integrated movement patterns focusing on coordination, speed, and control.

Plyometrics

- Initiate single leg plyometric training.
- Advance plyometric and sport-specific jump training emphasizing eccentric control with landing.

Functional Exercises

- Advance agility drills emphasizing speed during this phase.

Sport-Specific Exercises

- Begin noncontact practicing and sport-specific drills.
- Gradually add contact drills to practice routines.

Milestones for Progression to the Next Phase

- Restoration of 90% strength compared with uninvolved lower extremity with isokinetic testing.[6,11,14]
- Successful completion of single limb functional hop testing or return to sport testing.

Criteria for Return to Sport

General

- Pain free and no apprehension with sport-specific activities
- Symmetrical active knee range of motion (<5° difference for flexion)
- 90% quadriceps strength of uninvolved leg with isokinetic testing at 180° and 360° per second
- Successful completion of single limb functional hop testing or return to sport testing

Sport-Specific

- Football: acceleration, multidirectional cutting and muscular endurance equivalent to preinjury levels. The

athlete must demonstrate these while playing his or her position in a scrimmage situation without deficiency.
- Competitive weight lifting: symmetrical lower extremity strength and endurance with a focus on power. This must be performed through the entire range of movement of all required lifts.

After Return to Sport

Continuing Fitness or Rehabilitation Exercises

- Advanced core stability training as part of normal workout routine
- Plyometric training

Exercises and Other Techniques for Prevention of Recurrent Injury

- Consider screening athletes for use of steroids, which can lead to unusual tendon ruptures.
- Evaluate and instruct in proper lower extremity landing mechanics that may prevent injury.
- Lower extremity stretching and flexibility exercises
- Core stabilization and motor control
- Maintain eccentric knee and hip control with advanced strengthening.
- Maintain sport-specific cardiovascular endurance.

Evidence

Enad JG, Loomis LL: Patellar tendon repair post-operative treatment. *Arch Phys Med Rehabil* 81:786–788, 2000.

This is a prospective analysis of 10 patients consecutively undergoing patellar tendon repair over a 1-year period. Five patients were treated with immobilization in a cast and isometric exercise and the five patients were treated with early mobilization and isometrics. There was no significant difference between the groups over a mean 16-week period.

Feil S, Newell J, Minogue C, et al: The effectiveness of supplementing a standard rehabilitation program with superimposed neuromuscular electrical stimulation after anterior cruciate ligament reconstruction: A prospective single blind, randomized study. *Am J Sports Med* 39:1238–1247, 2011.

This single-blind randomized control trial examined the use of superimposed neuromuscular stimulation as an adjunct to a standard rehabilitation program following ACL reconstruction. They found that the use of neuromuscular electrical stimulation in addition to standard rehabilitation was effective at improving quadriceps torque, single leg hop testing, and Lysholm knee scores compared to a control. (Level I evidence)

Fives G: Patellar and quadriceps tendon repair. In Cioppa-Mosca J, Cahill JB, Cavanaugh JT, et al, editors: *Post surgical rehabilitation guidelines for the orthopedic clinician*, St. Louis, MO, Mosby, pp 393–406, 2006.

This chapter is a review of a rehabilitation protocol following a quadriceps or patellar tendon rupture. It offers review of literature on a functional approach to rehabilitation.

McGinty G, Irrang JJ, Pezzullo D: Biomechanical considerations for rehabilitation of the knee. *Biomechanics* 15:160–166, 2000.

This article provides a review of the arthrokinematics and osteokinetics of the knee during open and closed chain motion. This understanding is crucial for clinicians when developing rehabilitation programs for patients following knee injury or surgery. (Level IV evidence)

Millett PJ, Johnson B, Carlson J, et al: Rehabilitation of the arthrofibrotic knee. *Am J Orthop* 32:531–538, 2003.

This review article provides a framework for a rehabilitation following surgical intervention for arthrofibrosis. The rehabilitation progression for these patients is similar to athletes with patellar or quadriceps tendon rupture.

Millett PJ, Wickiewicz TL, Warren RF: Motion loss of ligament injuries to the knee. Part 1. Causes. *Am J Sports Med* 29:664–675, 2001.

This article is a review of the causes of motion loss following knee ligament injury or surgery to the knee. It discusses the factors that can influence motion loss, which may assist clinicians in developing an approach to the management of this condition.

Myer GD, Paterno MV, Ford KR, et al: Rehabilitation after anterior cruciate ligament reconstruction: Criteria based progression through return to sport. *JOSPT* 36:385–402, 2006.

This review article demonstrates a progression for an athlete following ACL reconstruction through return to sport. It provides clinical outcome measures that are useful for measuring return to sport function following knee surgery.

West JL, Keene JS, Kaplan LD: Early motion after quadriceps and patellar tendon repairs: Outcomes with single-suture augmentation. *Am J Sports Med* 36(2):316–323, 2008.

This retrospective case series examined 50 patients with quadriceps or patellar tendon ruptures repaired primarily and augmented with a "relaxing suture." One week postoperatively patients began full weight bearing in an extension brace and range of motion 0° to 55°. By 6 months, all patients reached their preinjury levels of activity and no patients lacked more than 10° of active extension. All were classified as good or excellent results by the Lysholm score. (Level IV evidence)

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Multiple Choice Questions

QUESTION 1. To prevent injury to the healing tendon in the first 6 weeks postoperatively, range of motion should be

A. prevented for 4 to 6 weeks before starting gentle motion.
B. limited to 0° to 60° by 4 weeks and 0° to 90° by 6 weeks.
C. limited to the stress-free arc determined intraoperatively.
D. unrestricted but limited by the pain threshold of the patient.

QUESTION 2. In the immediate postoperative period (first 14 days), pain and swelling may be treated with

A. NSAIDs, TENS, cryotherapy, and elevation of the extremity.
B. narcotics, interferential current electrical stimulation, cryotherapy, and activity modification.
C. Elevation, Hi Volt, soaking the knee in cool baths, and narcotics.
D. TENS, cryotherapy, NSAIDs, and patellar mobilizations in the superior-inferior directions.

QUESTION 3. During which time frame should the athlete restore knee active range of motion equal to the uninjured side?

A. 2 to 6 weeks
B. 6 to 10 weeks
C. 10 to 14 weeks
D. 14 to 18 weeks

QUESTION 4. Which of the following exercises should NOT be used to increase strength during the 14- to 24-week postoperative period?

A. Plyometric training
B. Lunge progression
C. Olympic lifting techniques
D. Single leg supported squatting

QUESTION 5. After return to sport, techniques that can be used to prevent recurrent injury include all of the following EXCEPT

A. screening athletes for use of steroids.
B. lower extremity stretching and flexibility exercises.
C. evaluation of and instruction in proper lower extremity landing techniques.
D. strength training using primarily high weights with few repetitions.

Answer Key

QUESTION 1. Correct answer: **C** (see Brief Summary of Surgical Technique)

QUESTION 2. Correct answer: **B** (see Phase I)

QUESTION 3. Correct answer: **C** (see Phase IV)

QUESTION 4. Correct answer: **C** (see Phase V)

QUESTION 5. Correct answer: **D** (see After Return to Sport)

Chapter 30



Meniscus Injuries

INTRODUCTION

Frank R. Noyes, MD

Epidemiology

- Meniscus tears are among the most common injuries treated by orthopaedic surgeons.
- Approximately 1 million meniscal surgeries are performed each year,[1] with more than 50% done in patients 45 years of age or older.
- It has been estimated that the incidence of meniscus tears in athletes is 61 in 100,000.[2]
- Although early studies reported a male-female ratio of this injury of 3:1,[3] more recent data suggest a fairly even distribution according to gender.[4]
- Approximately 60% of meniscus tears occur in patients aged 20 to 49.[4]
- Meniscus tears usually occur in two demographic populations: young, active patients who sustain a specific knee injury (usually during sports) and patients who are greater than 50 years of age who never had an injury, but develop degenerative tears
- Asymptomatic degenerative tears are common in middle-aged and older adult patients.[5]
- Common sports associated with meniscus tears are soccer, skiing, handball, basketball, wrestling, football, gymnastics, and tennis.[4]

Pathophysiology

Intrinsic Factors

- Acute ACL rupture: associated meniscus tears in approximately 60%[6]
- Chronic ACL deficiency: increased shear forces, risk of giving-way
- Varus (medial meniscus) or valgus (lateral meniscus) malalignment

Traumatic Factors

- Common mechanisms include a sudden twist, change in direction, jumping, pivoting, or deep knee flexion.
- Commonly occurs with other knee injuries such as an ACL rupture.

Classic Pathological Findings

- Tibiofemoral joint line pain
- Locking or clicking medial or lateral tibiofemoral compartment
- Posterior knee pain with flexion greater than 90°
- Knee effusion
- Lack of pain-free extension

Clinical Presentation

History

- Knee injury involving sudden twist, change in direction, jumping, pivoting, or deep knee flexion
- Frequently encountered in knees with ACL ruptures
- Tibiofemoral joint line pain, swelling, locking, catching

Physical Examination

Abnormal Findings

- Tibiofemoral joint line pain on palpation
- Pain with full flexion
- Lack of pain-free full knee extension
- Positive McMurray test: internal or external rotation knee flexion produces pain, clicking, crepitus

- Meniscal displacement during joint compression indicated by popping, clicking, catching
- Tenderness on palpation at the posterolateral aspect of the joint at the anatomic site of the popliteomeniscal attachments

Pertinent Normal Findings

- Symptoms: lack of pain with activities, rotational knee movements
- No joint line tenderness
- Negative provocative meniscus tests (McMurray)
- Full knee motion without pain

Imaging

- Radiographs: lateral 30° of flexion, patellofemoral axial, weight bearing posteroanterior 45° of flexion
- Knees with varus or valgus malalignment: full standing hip-knee-ankle weight-bearing radiographs to measure weight-bearing line, mechanical axis
- MRI using a proton-density weighted, high-resolution, fast-spin echo sequence or similar techniques for enhanced articular cartilage resolution

Differential Diagnosis

- Medial or lateral ligament acute tear producing tibiofemoral joint pain
- Saphenous neuritis, complex regional pain syndrome producing medial pain, tenderness to palpation
- Lateral patellofemoral subluxation syndrome producing pain in medial retinacular structures, medial patellar-meniscal ligament attachments (pain anterior to superficial medial collateral ligament)
- Medial tibial stress fracture, pes tendonitis with pain along anteromedial tibial region just distal to joint line
- Lateral iliotibial band friction syndrome with pain, tenderness just proximal to lateral tibiofemoral joint

Treatment

Nonoperative Management

- Rest, activity modification
- Oral nonsteroidal antiinflammatory medications
- Physical therapy

Guidelines for Choosing Among Nonoperative Treatments

- Degenerative meniscus tears with positive MRI, often asymptomatic; do not require surgery (Figure 30-1)
- Degenerative meniscus tears with episodic pain, clicking in sedentary patient
- Patient willing to modify activities
- Patient unwilling to undergo arthroscopy
- Patient unwilling or unable to follow postoperative rehabilitation program
- Severe loss tibiofemoral joint space, majority of symptoms related to arthritis

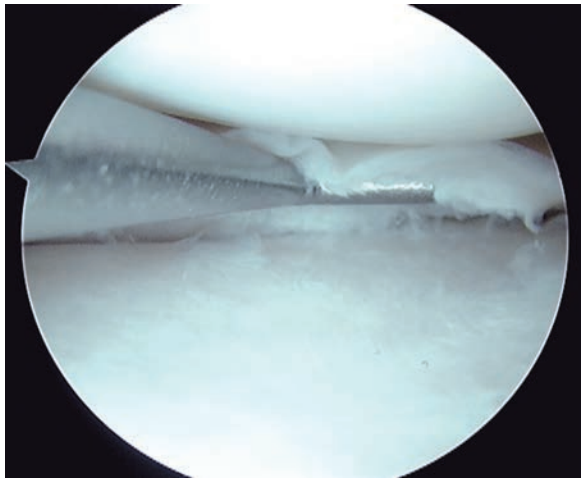

FIGURE 30-1. A degenerative longitudinal medial meniscus tear in a 55 year-old woman. *(Reprinted with permission from Noyes FR, Barber-Westin SD: Meniscus tears: Diagnosis, repair techniques, and clinical outcomes. In Noyes' knee disorders: surgery, rehabilitation, clinical outcomes, Philadelphia, 2009, Saunders, pp. 733–771. Fig. 28-3-G.)*

Surgical Indications

- Unstable meniscus tear (locking, pain, giving way), particularly in younger or active patient who will usually require meniscectomy if intervention not performed using meniscus repair[7]
- Unresolved tibiofemoral joint pain
- Giving way, recurrent joint effusion
- Associated painful meniscus cyst

Aspects of History, Demographics, or Exam Findings that Affect Choice of Treatment

- Patient requires functional, pain-free knee as soon as possible for occupation or sports activities.
- Failed conservative treatment, unresolved tibiofemoral joint pain more than 2 months
- Patient willing to comply with postoperative rehabilitation, activity restrictions
- Degenerative tears, delay surgery if symptoms are episodic, livable

Aspects of Clinical Decision Making When Surgery Is Indicated

- Tear must be classified according to type, location, quality of tissue, damage to meniscus tissue and remaining meniscus bed in order to decide on repair versus excision (Figure 30-2).[8]
- Peripheral single longitudinal tears: repairable in all cases, high success rate (Figure 30-3)
- Middle third region, complex tears (horizontal, flap, radial, double and triple longitudinal) often repairable, evaluate individual basis (Figures 30-4, 30-5, 30-6)[9,10]
- Special cases considered for repair include lateral meniscus tear with a meniscal cyst (Figure 30-7), posterior horn popliteomeniscal attachment tear (Figure 30-8), and posterior meniscus root attachment tear (Figure 30-9).
- Small longitudinal tears (less than 10 mm in length) left in situ

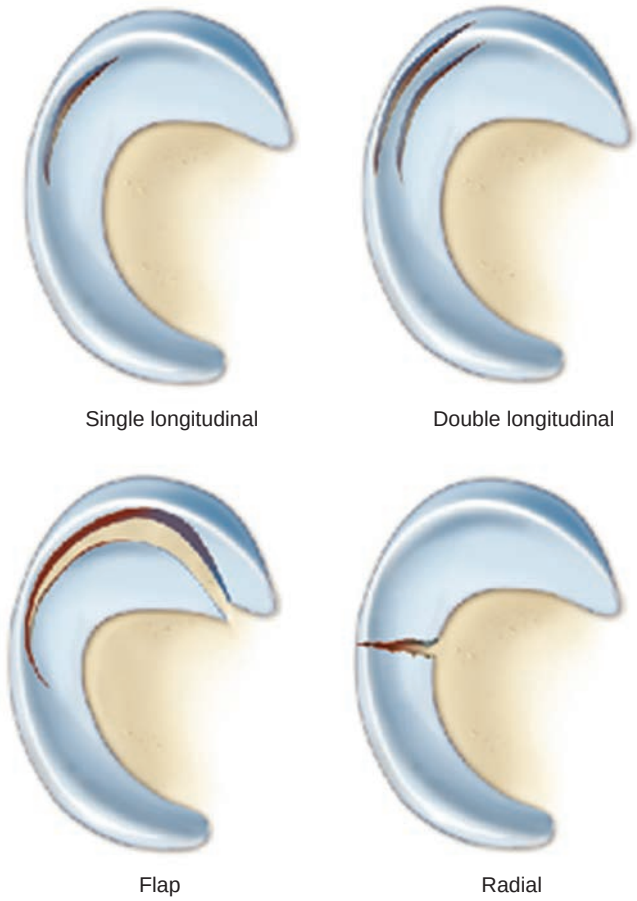

FIGURE 30-2. Illustrations of the common complex and avascular meniscus tear patterns. Note the single-plane configuration of the single longitudinal and radial tears and the multiplane (complex) configuration of the double longitudinal and flap tears. *(Redrawn with permission from Noyes FR, Barber-Westin SD. Meniscus tears: Diagnosis, repair techniques, and clinical outcomes. In Noyes' knee disorders: surgery, rehabilitation, clinical outcomes, Philadelphia, 2009, Saunders, pp. 733–771. Fig. 28-1.)*

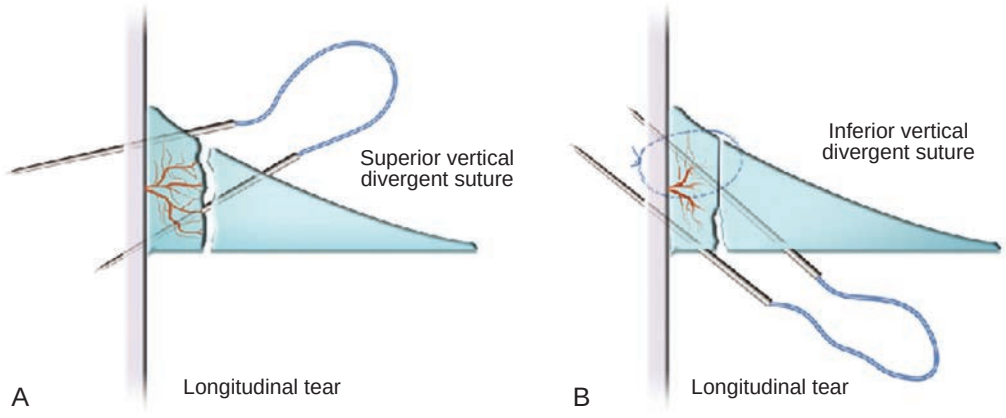

FIGURE 30-3. Double-stacked vertical suture pattern used in the repair of longitudinal meniscus tears. **A,** The superior sutures are placed first to close the superior gap and to reduce the meniscus to its bed. **B,** Then, the inferior suture is placed through the tear to close the inferior gap. *(Redrawn with permission from Noyes FR, Barber-Westin SD. Meniscus tears: Diagnosis, repair techniques, and clinical outcomes. In Noyes' knee disorders: surgery, rehabilitation, clinical outcomes, Philadelphia, 2009, Saunders, pp. 733–771. Fig. 28-10.)*

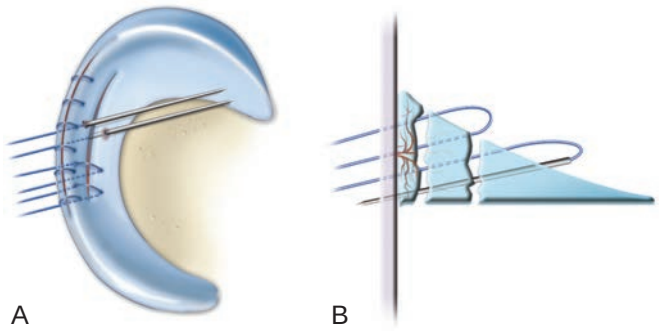

FIGURE 30-4. Double-stacked repair technique for double longitudinal tears. The peripheral tear is repaired first with superior and inferior vertical divergent sutures (**A**), followed by repair of the inner tear in the same fashion (**B**). *(Redrawn with permission from Noyes FR, Barber-Westin SD. Meniscus tears: Diagnosis, repair techniques, and clinical outcomes. In Noyes' knee disorders: surgery, rehabilitation, clinical outcomes, Philadelphia, 2009, Saunders, pp. 733–771. Fig. 28-12.)*

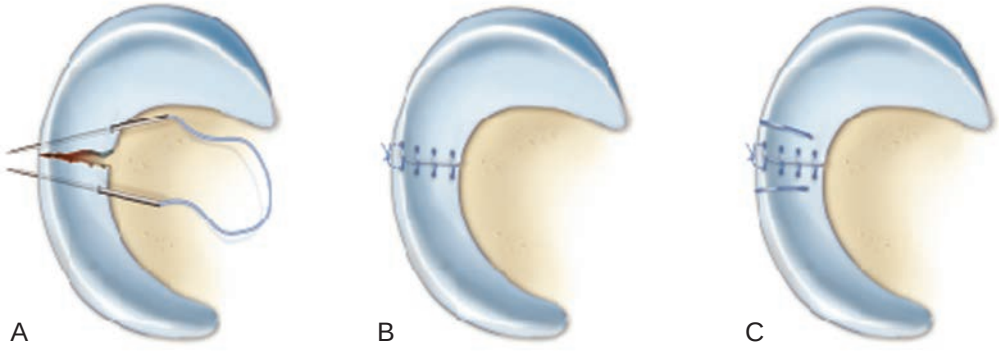

FIGURE 30-5. Repair technique for radial meniscus tears. The inner sutures (**A**) are placed first, followed by the peripheral sutures (**B**). The first suture needle is placed midway through the meniscus body, then used to apply a circumferential tension to reduce the tear gap, and then advanced through the posterior meniscus bed. The second suture needle is placed in a similar manner. This reduces the radial gap, allowing subsequent sutures to be placed. Usually 3 to 4 sutures are placed superiorly and two sutures, inferiorly. **C,** Occasionally superior vertical divergent sutures are placed along the tear site to help stabilize the repair. *(Redrawn with permission from Noyes FR, Barber-Westin SD. Meniscus tears: Diagnosis, repair techniques, and clinical outcomes. In Noyes' knee disorders: surgery, rehabilitation, clinical outcomes, Philadelphia, 2009, Saunders, pp. 733–771. Fig. 28-14.)*

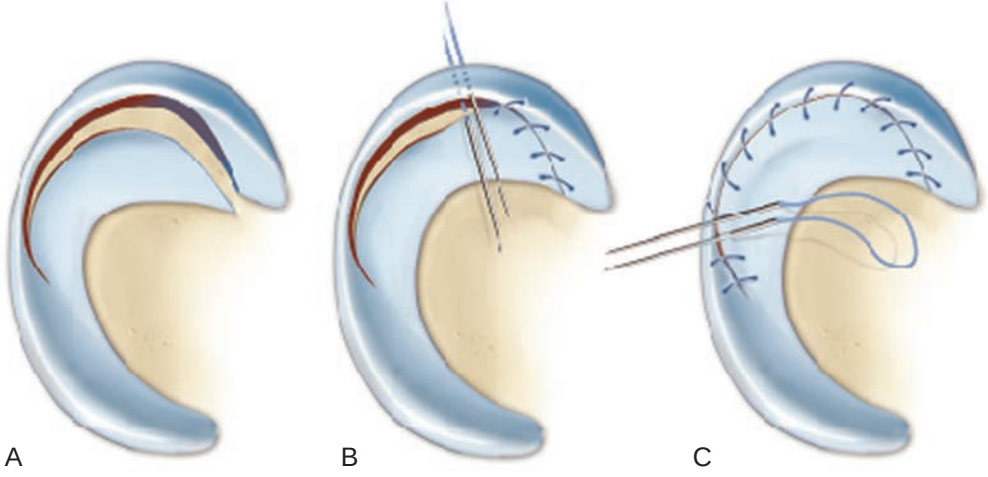

FIGURE 30-6. Repair technique for flap tears. **A,** the tear is identified and reduced. **B,** Horizontal tension sutures are placed to anchor the radial component of the tear. **C,** The longitudinal component is sutured using the double-stacked suture technique. *(Redrawn with permission from Noyes FR, Barber-Westin SD. Meniscus tears: Diagnosis, repair techniques, and clinical outcomes. In Noyes' Knee Disorders: Surgery, Rehabilitation, Clinical Outcomes, Saunders, Philadelphia, 2009, pp. 733–771. Fig. 28-17.)*

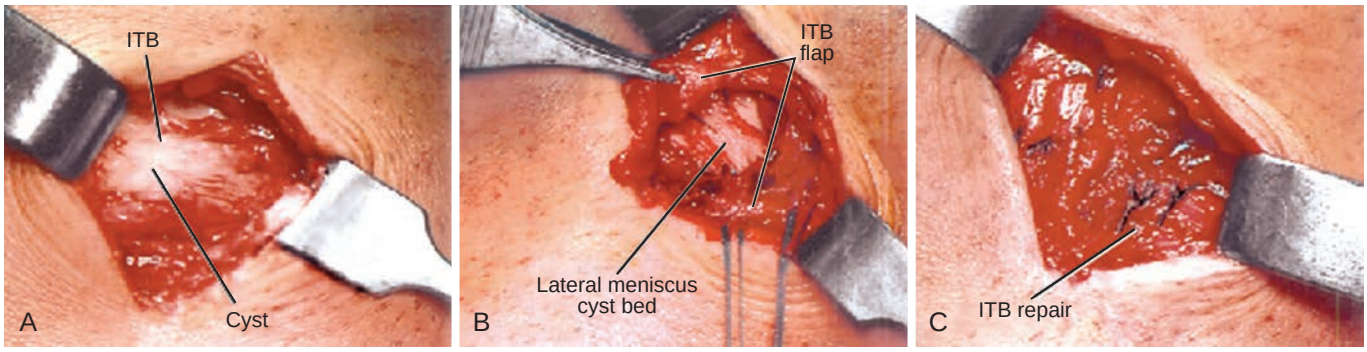

FIGURE 30-7. Demonstration of repair of lateral meniscus horizontal tear with a meniscal cyst. **A,** A 3-cm lateral joint incision placed directly over cyst shows the iliotibial band and an obvious protruding cyst. **B,** Iliotibial band is split in a line of fibers over the cyst and retracted, the cyst is removed, and repair is performed of the remaining meniscus to the attachments. **C,** Closure of the iliotibial band over the meniscus. Vertical sutures placed through the peripheral meniscus and iliotibial band help stabilize the repair. Then the arthroscopic inside-out repair of the meniscus body tear is performed. *(Reprinted with permission from Noyes FR, Barber-Westin SD. Meniscus tears: Diagnosis, repair techniques, and clinical outcomes. In Noyes' knee disorders: surgery, rehabilitation, clinical outcomes, Philadelphia, 2009, Saunders, pp. 733–771. Fig. 28-15.)*

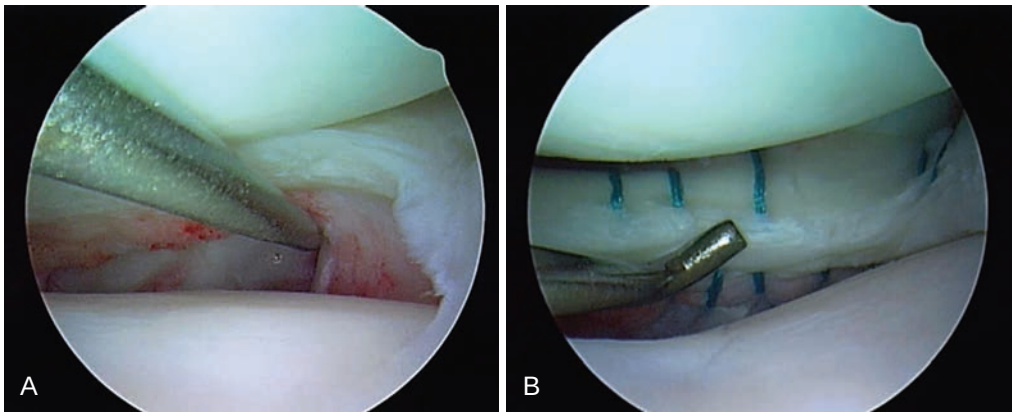

FIGURE 30-8. An athlete who had a prior negative arthroscopic examination and MRI and continued posterolateral joint pain shows a posterior horn popliteomeniscal attachment tear that required suture repair. **A,** Enlarged popliteal hiatus and laxity of the meniscotibial attachments is shown. **B,** Multiple vertical divergent superior and inferior inside-out sutures. *(Reprinted with permission from Noyes FR, Barber-Westin SD. Meniscus tears: Diagnosis, repair techniques, and clinical outcomes. In Noyes' knee disorders: surgery, rehabilitation, clinical outcomes, Philadelphia, 2009, Saunders, pp. 733–771. Fig. 28-4.)*

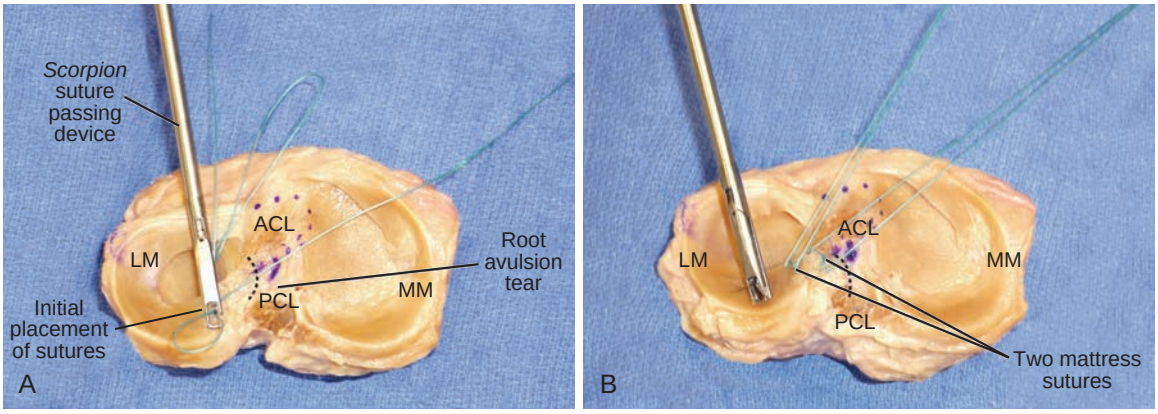

FIGURE 30-9. Posterior meniscus root attachment tear. **A,** Placement of two mattress sutures; the meniscus suture-passing device (Arthrex, Naples, FL) may be passed in and out of the portal to place higher-holding strength mattress sutures over a single suture. **B,** Final placement of sutures brought out through a 4-mm transtibial tunnel and tied over a post to restore the meniscus attachment. *(Reprinted with permission from Noyes FR, Barber-Westin SD. Meniscus tears: Diagnosis, repair techniques, and clinical outcomes. In Noyes' knee disorders: surgery, rehabilitation, clinical outcomes, Philadelphia, 2009, Saunders, pp. 733–771. Fig. 28-16.)*

- Inner third region and chronic degenerative tears resected
- Use vertical divergent sutures to anatomically appose the tear site. This suture technique has superior tensile strength compared with horizontal sutures and meniscus fixators.
  - Complex tears are usually repaired with the vertical divergent suture technique. The other option, all-inside suture devices, is not preferred because only 2 to 4 sutures are placed, which does not provide an adequate repair for sufficient healing, especially with immediate range of motion programs.

Evidence

Crawford R, Walley G, Bridgman S, et al: Magnetic resonance imaging versus arthroscopy in the diagnosis of knee pathology, concentrating on meniscal lesions and ACL tears: a systematic review. *Br Med Bull* 84:5–23, 2007.

This systematic review studies differences between MRI and arthroscopy in the diagnosis of knee pathology. A total of 59 articles met the study criteria. Ages of the patients ranged from 3 to 87 years. MRI had accuracy rates in detecting medial and lateral meniscus tears of 86.3% and 88.8%, respectively. The study concluded that MRI was an appropriate screening tool before arthroscopy. (Level II evidence)

Fithian DC, Paxton EW, Stone ML, Luetzoq WF, et al: Prospective trial of a treatment algorithm for the management of the anterior cruciate ligament-injured knee. *Am J Sports Med* 33:335–346, 2005.

A prospective study was performed on 108 female and 101 male patients to determine if certain risk factors could be used to indicate whether ACL reconstruction or conservative management should be used for managing this injury. Patients were classified as high, moderate, or low-risk using preinjury sports participation and knee laxity measurements. Early ACL reconstruction was recommended for high-risk patients, conservative management for low-risk patients, and either treatment method for moderate-risk patients. Patients were followed a mean of 6.6 years after their injury. The results found that early phase conservative management resulted in more late phase meniscus surgery than did early phase ACL reconstruction at all risk levels. Early reconstruction reduced late phase knee laxity, risk of symptomatic instability, and late meniscus tear and surgery. (Level II evidence)

Levy IM, Torzilli PA, Warren RF: The effect of medial meniscectomy on anterior-posterior motion of the knee. *J Bone Joint Surg* 64:883–888, 1982.

An in vitro knee testing apparatus was used to measure anterior displacement of the tibia on the femur and tibial rotations in response to an applied AP force in nine intact knees, five medial-meniscectomized knees, three ACL-resected knees, and eight medial-meniscectomized and ACL-resected knees. Excision of the medial meniscus in knees with sectioned ACLs resulted in significantly greater increases in anterior tibial displacement compared to those with ACL section only. The significant differences were observed at all knee flexion angles, with the greatest increase (58%) at 60° of knee flexion and the smallest increase (18%) at 0°. The authors concluded that it seemed likely that the posterior horn of the medial meniscus served as a secondary restraint to anterior tibial translation. Removal of the medial meniscus after ACL rupture could further compromise these knees. (Controlled laboratory study)

Majewski M, Susanne H, Klaus S: Epidemiology of athletic knee injuries: a 10-year study. *Knee* 13:184–188, 2006.

This prospective study analyzed the type and frequency of knee injuries that presented in a clinic in Switzerland over a 10-year period. There were 17,397 patients with 19,530 sports injuries analyzed. The ACL was injured the most frequently in knees that underwent surgery, followed by the MCL, medial meniscus, and lateral meniscus. Data on meniscus injuries (284 lateral and 836 medial) showed no difference in incidence rates between gender, and approximately 60% occurred in patients aged 20 to 39. (Level IV evidence)

Mohan BR, Gosal HS: Reliability of clinical diagnosis in meniscal tears. *Int Orthop* 31:57–60, 2008.

This retrospective study determined the clinical diagnostic test characteristics of 130 patients diagnosed with a meniscus tear. The clinical examination findings were compared to those documented at arthroscopy. The tibiofemoral joint line test and McMurray test had accuracy rates of 88% for medial meniscus tears and 92% for lateral meniscus tears. (Level III Evidence)

Musahl V, Jordan SS, Colvin AC, et al: Practice patterns for combined anterior cruciate ligament and meniscal surgery in the United States. *Am J Sports Med* 38:918–923, 2010.

The frequency of meniscal repair to meniscectomy in patients undergoing ACL reconstruction using the American Board of Orthopaedic Surgeons database was performed form 2003–2007. There were 8,342 patients identified, 4.088 of whom underwent concomitant meniscus surgery with an ACL reconstruction. Of these, 34% underwent partial meniscectomy and 15% underwent meniscal repair. Meniscal repair was significantly more likely to be performed when the ACL surgery was done by a sports medicine fellowship-trained surgeon (16.6%) compared with a general orthopaedic surgeon (11.7%) or other fellowship-trained surgeon (12%). Concomitant partial meniscectomy was performed twice as frequently as meniscal repair by sports medicine fellowship-trained surgeons and three times as frequently by other surgeons. The authors concluded that concomitant meniscal repair was performed by fellowship-trained surgeons in only 18% of the reported cases, approximately half that of meniscectomy, warranting further investigation. (Level III Evidence)

Noyes FR, Chen RC, Barber-Westin SD, et al: Greater than 10-year results of red-white longitudinal meniscal repairs in patients 20 years of age or younger. *Am J Sports Med* 39:1008–1017, 2011.

A prospective longitudinal study was performed in 33 meniscus repairs performed for single longitudinal tears that extended into the central avascular region. Twenty-nine repairs were done in patients aged 20 years or younger who were followed a mean of 16.8 years (range, 10.1 to 21.9 years) postoperatively. The results were ascertained from two validated knee rating systems, MRI with 3T scanner and T2 mapping, and weightbearing posteroanterior radiographs. The data showed that 62% had normal or nearly normal characteristics, 21% required partial arthroscopic resection, 10% failed according to MRI criteria, and 7% had loss of tibiofemoral joint space on radiographs. A chondroprotective effect was demonstrated in the healed repairs, warranting the procedure in select patients. (Level IV Evidence)

Rubman MH, Noyes FR, Barber-Westin SD: Arthroscopic repair of meniscal tears that extend into the avascular zone. A review of 198 single and complex tears. *Am J Sports Med* 26:87–95, 1998.

The results of 198 meniscus repairs for complex tears that extended into the central third region were evaluated by clinical examination (mean, 42 months postoperative) or follow-up arthroscopy (mean, 18 months postoperative). The data showed that 80% of the repairs were asymptomatic for tibiofemoral joint symptoms. Patients who had joint symptoms underwent repeat arthroscopic surgery. The findings allowed recommendation of repair of these types of meniscus tears, especially for patients under the age of 30 and highly competitive athletes. The authors recommended inside-out repair techniques with vertical divergent sutures in contrast to all-inside repair. (Level IV Evidence)

Tandogan RN, Taser O, Kayaalp A, et al: Analysis of meniscal and chondral lesions accompanying anterior cruciate ligament tears: Relationship with age, time from injury, and level of sport. *Knee Surg Sports Traumatol Arthrosc* 12:262–270, 2004.

The cases of 764 patients with ACL tears were analyzed to determine the relationships between meniscus tears and chondral lesions and patient age, time from injury, and sports level. The patients were assessed a mean of 20 + 33 months (range, 0.2 to 360 months) after their injury. A total of 73% of the patients had one or more meniscus tears. The odds of the patient sustaining a medial meniscus tear were 2.2 times higher at 2 to 5 years postinjury compared with the first year, and 5.9 times higher after 5 years compared with the first year. A total of 86% of patients who were greater than 5 years postinjury had a medial meniscus tear and 48% had a lateral meniscus tear. (Level IV Evidence)

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Multiple-Choice Questions

QUESTION 1. Meniscus tears frequently accompany which other knee injury?

A. Patellar subluxation
B. Saphenous neuritis
C. Anterior cruciate ligament rupture
D. Tibial stress fracture

QUESTION 2. Which of the following findings may be misdiagnosed as a meniscus tear?

A. Pain with full flexion
B. Pain anterior to superficial medial collateral ligament
C. Lack of pain-free full extension
D. Tibiofemoral compartment clicking

QUESTION 3. Full standing radiographs should be performed under which circumstances?

A. Positive Lachman test
B. Patient walks with severe limp
C. Older patient with potential for arthritis
D. Knee with varus or valgus malalignment

QUESTION 4. Which type of meniscus tear should always be treated by resection and not by repair?

A. Longitudinal tears less than 10 mm in length
B. Posterior root attachment
C. Flap
D. Triple longitudinal

QUESTION 5. One of the factors that significantly increases healing rates and the ability to repair complex meniscus tears is:

A. Horizontal suture technique
B. All-inside suture technique
C. Vertical divergent suture technique
D. Meniscus fixators

Answer Key

QUESTION 1. Correct answer: **C** (see Clinical Presentation)

QUESTION 2. Correct answer: **B** (see Differential Diagnosis)

QUESTION 3. Correct answer: **D** (see Imaging Studies)

QUESTION 4. Correct answer: **A** (see Aspects of Clinical Decision Making When Surgery Is Indicated)

QUESTION 5. Correct answer: **C** (see Aspects of Clinical Decision Making When Surgery Is Indicated)

NONOPERATIVE REHABILITATION OF MENISCUS INJURIES

K. Donald Shelbourne, MD, and Heather E. Freeman, PT, DHS

GUIDING PRINCIPLES OF NONOPERATIVE REHABILITATION

- When any type of degenerative meniscus tear is accompanied by an effusion and/or any loss of range of motion or strength compared with the opposite knee, rehabilitation to address these impairments is usually effective for reducing or eliminating the patient's symptoms.
- Steroid injections, oral steroids, or nonsteroidal antiinflammatory medications may be used as an adjunct to rehabilitation by decreasing the effusion and pain.
- Rehabilitation should be structured into phases based on the following goals:
  - Reduce the effusion and restore normal knee extension (symmetric to the noninvolved knee).
  - Restore normal, symmetric knee flexion.
  - Restore symmetric lower extremity strength.
  - Gradually re-introduce impact activities/athletics.
  - Progression of rehabilitation to the next phase is determined by meeting the goals of each phase rather than based on a timeline.

Introduction

- Selecting an appropriate course of treatment for meniscus tears needs to be based on an understanding of the type and location of the meniscus tear as well as an assessment of concomitant impairments such as loss of range of motion (ROM), strength, and the presence of an effusion.
- It is important for clinicians to recognize that meniscal pathology seen on a magnetic resonance imaging (MRI) scan of a middle-aged patient is frequently an incidental finding.[1–3]
- Clinical correlation of symptoms, physical examination findings, and diagnostic imaging studies is needed to determine whether the patient's symptoms are related to the meniscal pathology, early osteoarthritis, or other associated impairments.[3,4]
- Even in the presence of a degenerative meniscus tear, a patient with a loss of ROM and/or a knee joint effusion may improve with a well-directed rehabilitation program designed to resolve these deficits.
- The knee pain may be a new occurrence, but it is important to consider that the degenerative meniscus tear may have been present for quite some time without causing pain.[1–3] If the tear is not new, then the pain may be related to stiffness, deconditioning, or a joint effusion.
- The overall goal of treatment is to regain symmetry. By restoring full, symmetric knee extension first, then knee flexion, and finally strength, the patient often experiences a significant improvement or resolution of symptoms.
- The progression of this rehabilitation process should be based on meeting specific goals, rather than based on a timeline.
- Patients with tibiofemoral joint space narrowing typically have meniscal abnormalities that are amenable to rehabilitation rather than surgical treatment.[1,4]
- One common type of meniscus tear in the osteoarthritic patient is a posterior horn radial tear that extrudes beyond the tibiofemoral articulation. This occurs when narrowing of the joint space places a compressive force on the meniscus, creating "hoop stress" that eventually causes the meniscus to tear and the peripheral part of the meniscus gets extruded.
- The patient often gives a history of feeling a painful "pop," followed by a joint effusion and decreased ROM. Although this type of tear is very painful initially, a combined treatment approach of medication and rehabilitation is often very effective.
- An initial course of nonoperative treatment is most appropriate for degenerative meniscus tears because many patients will improve to a functional level without surgery.[5]
- Meniscus tears that are degenerative in nature are not amenable to repair owing to the characteristic

TIMELINE 30-1: **Nonoperative Rehabilitation of Meniscus Injuries**

PHASE I	PHASE II

• Cold-compression device and elevation to decrease effusion
• Gait training
• Knee extension ROM- regain symmetry
  • Heel prop
  • Towel stretch
  • Passive knee extension device
• Active heel lifts for quadriceps muscle neuromuscular control
	• Maintain full knee extension
	• Knee flexion ROM—regain symmetry
	  • Wall slide
	  • Heel slide
	• Low impact exercise progression (bike, elliptical, stair climber)
	• Cold-compression and elevation as needed

horizontal cleavage seen with a degenerative tear, the poor blood supply, and the frayed, degenerative quality of the meniscus at the tear location.[6] These tears often occur in patients who are middle aged or older and are most common in the medial meniscus.[7]
- Most meniscus tears in young, competitive athletes are not degenerative in nature and therefore, would not respond as well to nonsurgical intervention.
- Hence, the focus on this chapter is on nonsurgical treatment of degenerative meniscus tears in the older, recreational athlete.

Phase I[1]

Goal

- To eliminate effusion and restore normal, symmetric knee extension

Protection

- No protection required. Encourage the patient to fully weight bear on the affected leg and use the knee normally as soon as possible.
- Provide gait training to restore normal gait pattern. By teaching the patient to stop favoring the leg, there will be less strength and range of motion loss owing to disuse.

Management of Pain and Swelling

- Over-the-counter nonsteroidal antiinflammatory medications and acetaminophen may be used as needed to help with swelling control and pain.
- If additional pain control is needed to allow the patient to tolerate rehabilitation during the early phase, injected or oral steroids may be used.
- If a moderate or severe effusion is present, significant relief may also be achieved by draining the knee.

Techniques for Progressive Increase in Range of Motion

- First determine what amount of ROM is normal for the patient.

[1]The timeframes of each phase of the rehabilitation will vary widely between patients. Progression to the next phase of rehabilitation is criteria based rather than time based.



FIGURE 30-10. Patient positioning for measurement of knee extension. Patient is lying supine with both heels propped up on a bolster high enough to allow the knees to fall into hyperextension.

- If the opposite knee is normal, use the ROM of that knee as a baseline for determining how much knee extension and flexion is normal for that patient.
- Most people have some degree of knee hyperextension,[6] so the goal is not to achieve 0° of extension; rather, the goal is to restore normal knee extension, which may include hyperextension.
- In some instances the opposite knee may not be normal and may also have limited ROM, which makes determining the goals for ROM more difficult. When both knees have limited ROM attempts should be made to achieve knee hyperextension, and although the end goal may not be as clearly defined, maximize ROM of both knees until the patient reaches a plateau and do not stop simply because 0° of extension is achieved.
- Measure knee extension by having the patient lie supine and prop both heels up on a bolster high enough to allow the knees to fall into hyperextension (Figure 30-10).
- Perform a low-load, long duration stretch for knee extension/hyperextension three to five times per day.
  - Instruct the patient to perform a 10-minute heel prop with an ankle weight placed above and below the knee joint, AND/OR
  - Use a passive knee extension device for 10 to 15 minutes (Figure 30-11).
- Perform towel stretches into maximal extension. Stabilize the thigh with one hand while using a towel to pull the heel upwards (Figure 30-12). Hold for 5 seconds and perform ten repetitions.

TIMELINE 30-1: Nonoperative Rehabilitation of Meniscus Injuries (Continued)

PHASE III	PHASE IV

• Maintain full knee extension and flexion
• Regain symmetric lower extremity strength
  • Single leg press
  • Single knee extension
  • Step downs
• Continue low impact exercise progression
• Return to low impact sports-related activities (nonrunning/jumping)
	• Return to sport progression
	• Functional progression
	• Sport-specific drills
	• Scrimmage
	• Competition
	• Monitor ROM and swelling, adjust activity level as needed



FIGURE 30-11. A passive knee extension device is used for a low-load, long duration stretch. The patient controls the intensity of the stretch through a hand-held crank.

Activation of Primary Muscles Involved

- Ensure that good neuromuscular control of the quadriceps is achieved.
  - Perform active heel lifts. Have the patient sit with the leg extended, contract the quadriceps muscle group, and actively lift the heel up off of the table (Figure 30-13).
  - If the patient cannot achieve an active heel lift, add a short-arc quad exercise to help facilitate activation of the quadriceps muscle group.

Techniques to Reduce Effusion

- Instruct patient in use of a cold-compression device.
- Advise patient to elevate the knee above the level of the heart while using the cold-compression device and whenever possible.
- Advise patient to avoid high impact activities such as running, jumping, and prolonged walking.

Functional Exercises

- Teach the patient standing and sitting extension habits.



FIGURE 30-12. The towel stretch exercise is used to stretch the knee into maximal extension, including hyperextension.

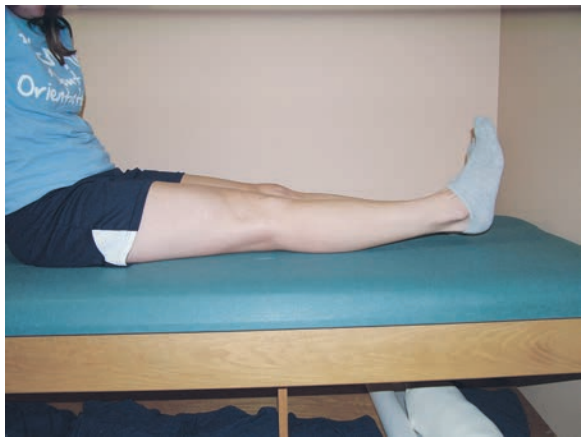

FIGURE 30-13. The active heel lift is performed in a long-sitting position. The patient contracts the quadriceps and dorsiflexes the ankle, elevating the heel above the supporting surface.

  - Stand with body weight shifted onto the involved leg and lock the knee out straight.
  - Sit with the heel propped and knee straight, allowing the knee to fall into hyperextension.

Milestones for Progression to the Next Phase

- Little to no effusion present in the knee
- Full, symmetric knee extension equal to the opposite normal knee

Phase II

Goals

- To restore normal, symmetric knee flexion and maintain symmetric knee extension

Management of Pain and Swelling

- Over-the-counter nonsteroidal antiinflammatory medications and acetaminophen may be used as needed to help with swelling control and pain.

Techniques for Progressive Increase in Range of Motion

- First determine what amount of knee flexion is normal for the patient.
- If the opposite knee is normal, use the range of motion of that knee as a baseline for determining how much knee flexion is normal for that patient.
- Measure knee flexion by having the patient perform a heel slide. Ask the patient to slide the heel toward the buttocks, pulling the knee into as much flexion as possible while in a long-sitting position (Figure 30-14). Compare the involved knee to the non-involved knee.
- Perform a heel slide exercise. Hold the stretch for 5 seconds, then pull the knee into slightly more flexion and hold for an additional 5 seconds.
- If knee flexion is more severely limited, begin with a wall slide exercise (Figure 30-15)



FIGURE 30-14. A heel slide is performed by having the patient use the hands or a towel to slide the heel toward the buttocks as far as possible.

Other Therapeutic Exercises

- Perform towel stretches to monitor knee extension (see Figure 30-12).
- If any loss of knee extension is detected, back off from flexion exercises and return to focusing on knee extension.
- Begin a low impact exercise program using a bike, elliptical, or stair climber. Begin with light resistance and gradually increase time from 5 minutes to 30 minutes. Then slowly increase the resistance.

Functional Exercises

- Continue with standing and sitting extension habits to encourage full knee extension and normal use of the involved leg.



FIGURE 30-15. In cases of more severe knee flexion loss, the wall slide is an effective exercise to improve knee flexion. The patient uses the foot of the noninvolved leg to apply gentle, downward pressure on the foot of the involved leg, increasing the knee flexion of the involved leg.

Milestones for Progression to the Next Phase

- Full, symmetric knee range of motion compared to the opposite, normal knee
- No effusion
- Good neuromuscular control of the quadriceps muscle group

Phase III

Goals

- To restore symmetric lower extremity strength

Management of Pain and Swelling

- Although some activity-related soreness and swelling may occur, pain and swelling should mostly be under control during this phase.
- Patients are advised to use a cold-compression device as needed for swelling and pain control.
- Over-the-counter nonsteroidal antiinflammatory medications and acetaminophen may also be used as needed.

Techniques for Progressive Increase in Range of Motion

- Range of motion should be maximized prior to the beginning of Phase III. Monitor range of motion by performing towel stretch and heel slide and comparing with the opposite, normal knee.
- If any loss of range of motion occurs as the strengthening program is underway, discontinue strengthening exercises and focus on Phase I and II exercises until symmetric range of motion is restored.

Other Therapeutic Exercises

- Objectively measure strength of the quadriceps and hamstring muscle groups for both the involved and noninvolved legs (Cybex, Biodex, etc.)
- If a side-to-side deficit is detected (greater than or equal to 10%), begin single-leg strengthening program 5 to 7 times per week. Reevaluate strength testing on a regular basis and transition to bilateral strengthening exercises once full strength symmetry has been restored.
  - Single leg press
  - Single knee extension
  - Step-down
- Continue to progress the low impact exercise program (bike, elliptical, or stair climber) by increasing resistance and/or increasing workout time.

Sport-Specific Exercises

- Patients involved in low impact sports (nonrunning or jumping) activities may gradually return to these activities at this time.
- Participation in sports requiring running or jumping should be delayed until full strength and range of motion symmetry has been regained.

Milestones for Progression to the Next Phase

- Quadriceps and hamstring muscle group strength at least 90% (involved knee/non-involved knee)
- Full, symmetric knee range of motion compared to the opposite, normal knee.
- No effusion

Phase IV

Goal

- Return to sports

Management of Pain and Swelling

- Some soreness and swelling may occur during this phase as the patient's activity level is increased and should be treated with use of a cold-compression device as needed.

Techniques for Progressive Increase in Range of Motion

- Range of motion should be maximized prior to the beginning of Phase IV. Monitor range of motion by performing towel stretch and heel slide and comparing with the opposite, normal knee.
- If any loss of range of motion occurs during the return to sport phase, discontinue impact activities and focus on Phase I and II exercises until symmetric range of motion is restored.

Other Therapeutic Exercises

- Continue with the low impact exercise program for cardiovascular conditioning and as a form of cross-training.
- Once symmetric strength has been achieved, begin doing lower extremity strengthening program for both legs.

Functional Exercises

- For patients returning to sports requiring change of direction, gradually progress through a functional progression to introduce jumping, planting, and pivoting.
- Add increased speed and multidirectional components to the movement patterns throughout the progression.

Sport-Specific Exercises

- When introducing impact activities (running, jumping, etc.) begin with an every-other-day schedule to allow the knee to adjust to the new level of activity without increasing amounts of soreness or swelling.
- Begin with structured drills to allow the patient to work through each component skill of the sport individually.
- Progress into "scrimmage" situations where skills are combined together in a non-competitive situation.
- Finally, progress to full competition.

Milestones for Progression to Advanced Sport-Specific Training and Conditioning

- Symmetric ROM, symmetric strength, no effusion
- Completion of functional progression

Criteria for Abandoning Nonoperative Treatment and Proceeding to Surgery or More Intensive Intervention

- Continued pain that is isolated to the medial or lateral joint line and limits activity despite attempts to regain symmetry
- Patient is unable to tolerate rehabilitation because of pain that is not controlled with the pain control measures described previously.

Specific Criteria for Return to Sports Participation: Tests and Measurements

- Full, symmetric knee range of motion compared with the opposite, normal knee
- No effusion
- Quadriceps and hamstring muscle group strength at least 90% (involved knee/noninvolved knee)
- Completion of functional progression

Evidence

DeCarlo MS, Sell KE: Normative data for range of motion and single-leg hop in high school athletes. *J Sport Rehab* 6:246–255, 1997.

The authors performed a study to determine normative values of range of motion and single-leg hop tests in high school athletes. This study shows that in normal, healthy subjects, hyperextension of the knee is a normal finding. The mean amount of hyperextension was 5° for males and 6° for females. Furthermore, some degree of hyperextension was found in 95% of the males and 96% of the females. The authors discuss that in light of these findings, the goal for rehabilitation programs should not just be to achieve 0° of extension, rather some degree of hyperextension is normal for most people. (Level III evidence)

Englund M, Guermazi A, Lohmander SL: The role of the meniscus in knee osteoarthritis: A cause or consequence? *Radiol Clin N Am* 47:703–712, 2009.

The authors provide a clinical review of the role of the meniscus and meniscus pathology in osteoarthritis. The difference between acute, traumatic meniscus tears and degenerative meniscus tears is clearly explained and the authors discuss the prevalence of incidental findings of degenerative changes

in the meniscus on MRI, particularly in the middle-aged or older adult age groups. The authors acknowledge that meniscus tears can lead to osteoarthritis, but osteoarthritis can also lead to meniscus tears. They conclude that arthroscopic resection of nonobstructive degenerative lesions may be unnecessary. (Level V evidence)

Fukuta S, Kuge A, Korai F: Clinical significance of meniscal abnormalities on magnetic resonance imaging in an older population. *The Knee* 16:187–190, 2009.

Using MRI, this study evaluated 85 knees of asymptomatic subjects over the age of 40 for meniscal abnormalities. The subjects were divided into two groups based on whether or not they had radiographic evidence of osteoarthritis. The posterior segment of the medial meniscus was the most common location of meniscal abnormalities in both groups. Meniscal abnormalities were found in 63.4% of subjects without osteoarthritis and 80.4% of subjects with osteoarthritis. The authors concluded that there is a high prevalence of asymptomatic meniscus tears in this age group and MRI alone should not be used to evaluate meniscus tears in this age group. (Level III evidence)

Kornick J, Trefelner E, McCarthy S, et al: Meniscal abnormalities in the asymptomatic population at MR imaging. *Radiology* 177:463–465, 1990.

This study evaluated the prevalence of meniscal abnormalities of 70 knees in 64 symptomatic subjects (33 males and 31 females) using MRI. Subjects ranged in age from the second to eighth decade of life. The prevalence of meniscal abnormalities was at least 25% as early as the second decade. The prevalence increased with age, with a prevalence of nearly 60% in the sixth and seventh decades. The most common location for signal abnormalities was in the posterior horn of the medial meniscus. (Level III evidence)

LaPrade RF, Burnett QM, Veenstra MA, et al: The prevalence of abnormal magnetic resonance imaging findings in asymptomatic knees. With correlation of magnetic resonance imaging to arthroscopic findings in symptomatic knees. *Am J Sports Med* 22:739–745, 1994.

This prospective study was done to evaluate the prevalence of abnormal MRI scans of the knee in 54 asymptomatic subjects, ranging in age from 19 to 39 years. A comparison of MRI findings to arthroscopic findings was also done in a separate group of 72 symptomatic subjects to determine the specificity and sensitivity of MRI of the knee joint. The prevalence of meniscal tears in asymptomatic knees was 5.6%, although 24.1% had grade II changes (linear signal not extending to the meniscal surface) in the medial meniscus. The authors caution against using MRI without correlating physical examination findings to determine if surgery is necessary. (Level II and III evidence)

Rimington T, Mallik K, Evans D, et al: A prospective study of the nonoperative treatment of degenerative meniscus tears. *Orthopedics* 32(8):pii, 2009.

The authors performed a prospective study of 26 subjects who were clinically diagnosed with a degenerative meniscus tear. The subjects were followed for 37 months and completed both subjective and objective follow-up testing. All subjects were initially treated with non-steroidal anti-inflammatory drugs for 4 weeks, then they were offered arthroscopic partial meniscectomy or continued nonoperative treatment. Forty-six percent of patients declined surgical treatment and improved to a functional level. The operative group demonstrated significantly higher Modified Lysholm Knee Scores ($p = .04$); however, all other measures showed no difference. The authors concluded that an initial course of nonoperative treatment should be recommended for all patients with degenerative medial meniscus tears. (Level II evidence)

Shelbourne KD, Gray T: Meniscus tears to leave in situ, with or without trephination or synovial abrasion to stimulate healing. *Sports Med Arthros Rev* 20:62–67, 2012.

The authors provide a review of the treatment options based on the type of tear, location of the tear, and whether the tear is in a stable (ACL-intact) or unstable knee. The difference between degenerative and nondegenerative tears is described and their respective treatment options are outlined. Much of the article is based on the decision making for meniscus tears encountered at the time of ACL surgery. (Level V evidence)

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7. Shelbourne KD, Gray T: Meniscus tears to leave in situ, with or without trephination or synovial abrasion to stimulate healing. *Sports Med Arthros Rev* 20:62–67, 2012.

Multiple-Choice Questions

QUESTION 1. The first phase of rehabilitation should focus on swelling control and regaining symmetric _____.

A. strength
B. knee extension
C. thigh girth
D. knee flexion

QUESTION 2. Nonoperative treatment of meniscus tears is most appropriate for which type of tear?

A. Medial meniscus
B. Nondisplaced bucket handle
C. Degenerative
D. Meniscus tears associated with ACL tears

QUESTION 3. Normal knee range of motion is defined as:

A. whatever the range of motion of the opposite, normal knee is.
B. 0° of extension to 135° of flexion.
C. 0° of extension to 145° of flexion.
D. 5° of hyperextension to 145° of flexion.

QUESTION 4. When measured objectively, symmetric strength is defined as being within ___% of the opposite knee.

A. 5
B. 10
C. 15
D. 20

QUESTION 5. Forms of lower impact exercise are:

A. Bike
B. Stair climber
C. Elliptical
D. All of the above

Answer Key

QUESTION 1. Correct answer: **B** (see Phase I)

QUESTION 2. Correct answer: **C** (see Introduction)

QUESTION 3. Correct answer: **A** (see Phase I)

QUESTION 4. Correct answer: **B** (see phase III)

QUESTION 5. Correct answer: **D** (see Phase III)

POSTOPERATIVE REHABILITATION AFTER MENISCUS REPAIR

Frank R. Noyes, MD, Timothy P. Heckmann, PT, ATC, and Sue D. Barber-Westin, BS

Indications for Surgical Treatment

- Meniscus tear with unresolved tibiofemoral joint pain
- Patient less than 50 years of age or in 50s and physically active
- Meniscus tear reducible with good tissue integrity affirmed at surgery
- Meniscus tear classified at surgery according to location, type, size, integrity of tissue, and remaining meniscus bed
- Peripheral single longitudinal tears (red-red, one plane)—repairable in all cases, high success rates
- Middle third region (red-white or white-white—often repairable with reasonable success rates
- Outer-third and middle-third regions (red-white, one plane) longitudinal, radial horizontal tears—decision on repair versus excision made at surgery
- Patients willing to comply with postoperative rehabilitation program

Brief Summary of Surgical Treatment

Major Surgical Steps[1]

- Diagnostic arthroscopy
- Meniscus tissue and synovial junction rasped, loose unstable meniscus fragments removed
- Preferred procedure uses multiple vertical divergent sutures
- Neurovascular structures protected throughout procedure with posterolateral or posteromedial exposure and Henning retractor (Figure 30-16)
- Placement of sutures depends on tear pattern.
- Single longitudinal tears: vertical divergent sutures placed 3- to 4-mm intervals along the length of the tear

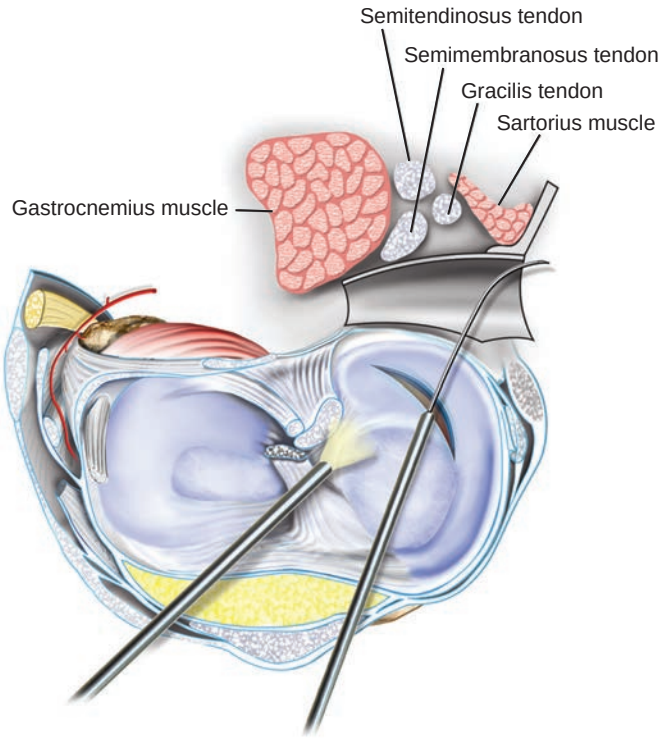

FIGURE 30-16. Cross-section showing popliteal retractor between the posterior capsule and the medial gastrocnemius for a medial meniscus repair. The suture cannula is placed through the lateral or medial portal with care taken to angle the needle away from the neurovascular structures. *(Reprinted with permission from Noyes FR, Barber-Westin SD: Meniscus tears: Diagnosis, repair techniques, and clinical outcomes. In Noyes FR, Barber-Westin SD, editors: Noyes' knee disorders: surgery, rehabilitation, clinical outcomes, Philadelphia, 2009, Saunders, pp. 733–771. Fig. 28-7.)*

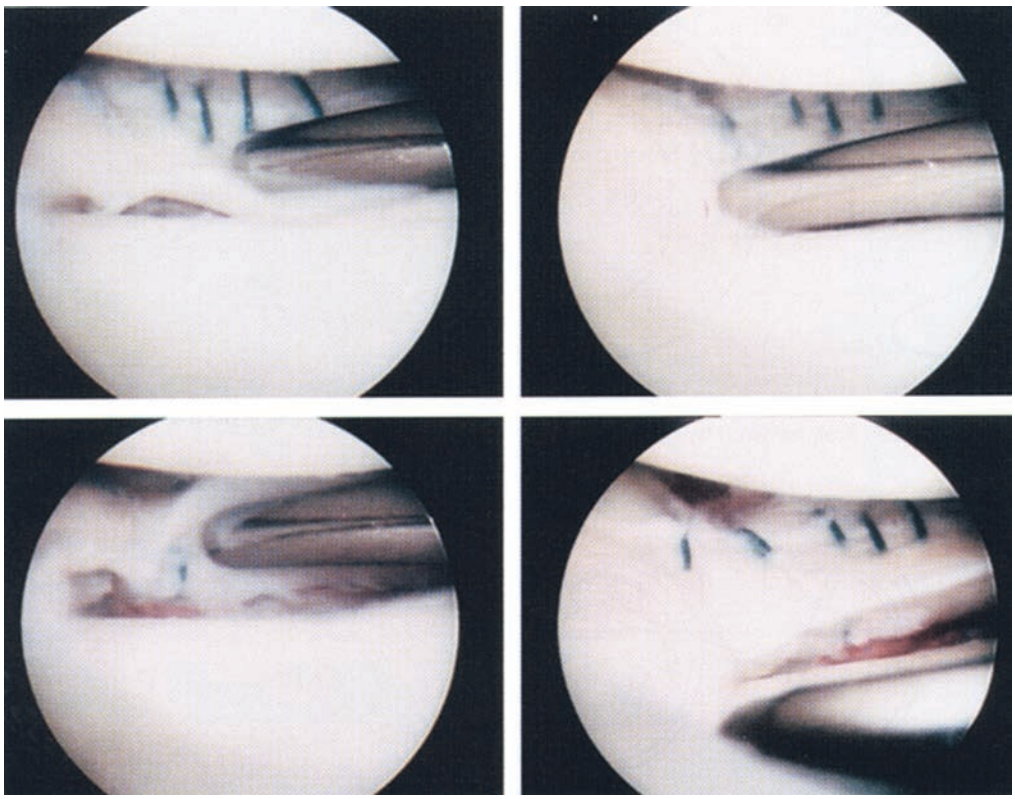

FIGURE 30-17. A longitudinal meniscal tear site demonstrating some fragmentation inferiorly. This tear required multiple superior and inferior vertical divergent sutures to achieve an anatomic reduction. *(Reprinted with permission from Noyes FR, Barber-Westin SD: Arthroscopic repair of meniscal tears extending into the avascular zone in patients younger than twenty years of age. Am J Sports Med 30:589–600, 2002.)*

in alternating fashion; first on the superior surface to reduce the meniscus and then on the inferior surface to close the inferior tear (see Figure 30-3)
- Sutures are brought out through posterolateral or posteromedial accessory incision and tied directly over the posterior meniscal attachment and capsule.
- Tension in each suture is confirmed arthroscopically after the knot is tied
- Double-longitudinal meniscus tears require an additional set of sutures (Figure 30-17; see also Figure 30-4)
- Radial tears are repaired with horizontal sutures placed at 2- to 4-mm intervals along the tear site (see Figure 30-5).
- Flap tears require two sets of sutures (see Figure 30-6).

Factors That May Affect Rehabilitation

- Classification of meniscus tear according to location, type and size of tear, and integrity of meniscal tissue[2]
- Meniscus repairs located in the periphery (outer one-third region) heal rapidly, complex multiplanar repairs that extend into central one-third region require greater caution with rehabilitation
- Type of repair: inside-out multiple vertical sutures versus all-inside
- All-inside repairs use only a few sutures, require delay in full weight bearing and added protection
- Presence of articular cartilage damage, 2-B or 3-A, B (Cincinnati Knee Rating classification)
- Concurrent procedures such as knee ligament reconstruction, high tibial osteotomy, articular cartilage restorative procedures

GUIDING PRINCIPLES OF POSTOPERATIVE REHABILITATION

- Understand type and location of meniscus tear and repair technique.
- Knowledge of concurrent operative procedures and condition of articular cartilage throughout knee joint
- Early return (within 4 to 6 months) to strenuous activities, high impact loading, deep knee flexion, sudden pivoting or twisting carries definite risk of repeat meniscus tear.
- Supervised rehabilitation program is supplemented with home exercises performed daily.
- Be aware of potential complications, signs, symptoms requiring prompt treatment
  - Continued pain in involved tibiofemoral compartment
  - Failure to achieve knee extension and flexion goals according to protocol
  - Decreased patellar mobility (early arthrofibrosis)
  - Decreased voluntary quadriceps contraction and muscle tone
  - Persistent joint effusion, inflammation

Phase I (days 0–14):[2] Immediate Postoperative Period

Clinical Pearls

Important early postoperative signs for the therapist to monitor are effusion, pain, gait, knee flexion and extension, patellar mobility, strength and control of the lower extremity, lower extremity flexibility, and tibiofemoral compartment symptoms. Use modalities such as electrical muscle stimulation, biofeedback, and cryotherapy as required. The patient's response to surgery and progression during the first 14 days sets the tone for the initial phases of rehabilitation. Monitor for posteromedial or infrapatellar burning, posteromedial tenderness along the distal pes anserine tendons, tenderness of Hunter's canal along the medial thigh, hypersensitivity to light pressure or temperature change, abnormal pain response, quadriceps shutdown, and inability to achieve knee motion goals as designated by protocol.

Goals

- Range of motion (ROM) minimum: 0° to 90° first 2 weeks postop
- Weight bearing: toe-touch to half body weight (BW) for peripheral repairs; toe-touch to quarter BW for complex or all-inside repairs; none to toe-touch for radial repairs
- Pain, hemarthrosis controlled
- Good patellar mobility
- Adequate quadriceps contraction

Protection

- Long-leg postoperative brace for complex or all-inside meniscus repairs. Brace is opened from 0° to 90°, but is locked at 0° at night. Brace not routinely used for peripheral repairs.
- Crutches. Toe-touch to half BW for peripheral repairs. Toe-touch to quarter BW for complex and all-inside repairs. None to toe-touch weight bearing for radial repairs. "Sponge (very light) pressure" allowed during toe-touch weight bearing.

Management of Pain and Swelling

- Oral medications as required
- Therapeutic modalities: electrical muscle stimulation, cryotherapy
- Elevate lower limb as frequently as possible.

Techniques for Progressive Increase in Range of Motion

- Begin first day postoperative
  - Passive knee flexion and passive and active/active-assisted knee extension exercises
  - Seated position, 0° to 90°, three to four times a day in 10-minute sessions
  - Active knee flexion is limited to avoid hamstring strain to the posteromedial joint.
  - Hyperextension avoided in anterior horn meniscus repairs.
- Patellar mobilization in superior, inferior, medial, and lateral directions
- Hamstring and gastrocnemius-soleus flexibility

TIMELINE 30-2: **Postoperative Rehabilitation After Meniscus Repair**

PHASE I (weeks 1 to 2)	PHASE II (weeks 3 to 6)
• Brace • Toe-touch to ½ BW for peripheral repairs • Toe-touch to ¼ BW for complex and all-inside repairs • None to toe-touch weight bearing for radial repairs • ROM 0°–90°, begin first day postoperative • Patellar mobilization • Flexibility: hamstrings, gastrocnemius-soleus • Weight shifting side-side, forward-backward • Cup walking • Quadriceps isometrics • Straight leg raises, flexion only • Active-assisted knee extension 90°-30°	• Brace • Full weight bearing peripheral repairs weeks 3–4 • Weight bearing ½ to ¾ BW complex, all-inside repairs (increase by approximately 25% per week) • ROM 0°–135° by week 6 • Patellar mobilization • Flexibility: hamstrings, gastrocnemius-soleus • Double-leg balance exercises • Balance board • Minitrampoline for balance exercises • Multi-angle quadriceps isometrics • Straight leg raises flexion, extension, abduction, adduction • Knee extension, active-assisted, 90°–0° • Toe raises, heel raises • Wall sits (above 60°) • Minisquats (0°–40°) • Hamstring curls, peripheral repairs (0°–90°) • Leg press, peripheral repairs (70°–10°) • Knee extension (90°–30°) • Multihip • Upper body ergometer



FIGURE 30-18. Extension overpressure hanging-weight exercise. *(Reprinted with permission from Heckmann TP, Noyes FR, Barber-Westin SD: Rehabilitation of meniscus repair and transplantation procedures. In Noyes FR, Barber-Westin SD, editors: Noyes' knee disorders: surgery, rehabilitation, clinical outcomes, Philadelphia, 2009, Saunders, pp. 806–817, Figure 30-3.)*

- If 0° to 90° not achieved by seventh day postoperative, begin overpressure exercises.
  - Hanging weights for extension (Figure 30-18)
  - Rolling stool, wall-sliding for flexion (Figures 30-19, 30-20)
  - Commercially available ROM devices

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Activation of the quadriceps, hamstrings, gastrocnemius-soleus, and hip musculature is accomplished immediately postoperatively with the exercises described in this time frame.

Electrical muscle stimulation and/or biofeedback may be used to enhance quadriceps contraction.



FIGURE 30-19. Rolling stool overpressure exercise for knee flexion. *(Reprinted with permission from Heckmann TP, Noyes FR, Barber-Westin SD: Rehabilitation of primary and revision anterior cruciate ligament reconstructions. In Noyes FR, Barber-Westin SD, editors: Noyes' knee disorders: surgery, rehabilitation, clinical outcomes, Philadelphia, 2009, Saunders, pp. 306–336, Figure 13-7A.)*

Sensorimotor Exercises

- Begin first week postoperative during partial weight-bearing period.
  - Weight shifting side-to-side and front-to-back with crutch support
  - Cup walking to develop symmetry between limbs, hip and knee flexion, quadriceps control during

TIMELINE 30-2: Postoperative Rehabilitation After Meniscus Repair (Continued)

PHASE III (weeks 7 to 12)	PHASE IV (weeks 13 to 26)	PHASE V (weeks 27+)
• DC brace, crutches • Full weight bearing • Flexibility: hamstrings, gastrocnemius-soleus, quadriceps, iliotibial band • Balance board • Lateral step-ups (5–10 cm) • Stationary bicycling (high seat/ low resistance) • Swimming, straight leg kicking (light, from hip) • Walking (level) • Stair climbing machine (short stroke/ decreased resistance) • Ski machine (decreased resistance) • Elliptical cross-trainer (decreased resistance) • Straight leg raises: flexion, extension, abduction, adduction (up to 10% BW) • Knee extension, active-assisted, 90°-0° • Toe raises, heel raises • Wall sits (above 60°) • Minisquats, rubber tubing (0°–40°) • Hamstring curls (0°–90°) • Leg press, start weeks 9–12 for complex repairs • Knee extension • Multihip	• Stationary bicycling • Swimming, straight leg kicking • Water walking • Stair climbing machine • Ski machine • Elliptical cross-trainer • Balance board • Single-leg stance, unstable platform • Perturbation training • Ball toss on plyoback, single-leg stance • Straight leg raises, rubber tubing • Minisquats, rubber tubing • Hamstring curls • Leg press, start weeks 9–12 for complex repairs • Knee extension • Multihip • Running program week 16–20 peripheral repairs, based on criteria provided • Running program week 24 complex repairs, based on criteria provided • Cutting, carioca, agility drills week 24 peripheral repairs • Plyometrics week 24 peripheral repairs, based on criteria provided • Sport-specific exercises week 20–24 peripheral repairs • Return to sports, peripheral repairs: based on criteria provided	• Stationary bicycling • Swimming, straight leg kicking • Water walking • Stair climbing machine • Ski machine • Elliptical cross-trainer • Balance board • Single-leg stance, unstable platform • Perturbation training • Ball toss on plyoback, single-leg stance • Straight leg raises, rubber tubing • Minisquats, rubber tubing • Hamstring curls • Leg press • Knee extension • Multi-hip • Cutting, carioca, agility drills week 30 complex repairs • Plyometrics week 30 peripheral repairs, based on criteria provided • Sport-specific exercises week 30 peripheral repairs • Return to sports, complex repairs: based on criteria provided



FIGURE 30-20. Wall slide overpressure exercise for knee flexion. *(Reprinted with permission from Heckmann TP, Noyes FR, Barber-Westin SD: Rehabilitation of primary and revision anterior cruciate ligament reconstructions. In Noyes FR, Barber-Westin SD, editors: Noyes' knee disorders: surgery, rehabilitation, clinical outcomes, Philadelphia, 2009, Saunders, pp. 306–336, Fig. 13-7C.)*

midstance, hip and pelvic control during midstance, and gastrocnemius-soleus control during pushoff (Figure 30-21).

Open and Closed Kinetic Chain Exercises

- Begin first day postoperative.
  - Quadriceps isometrics: one set × 10 repetitions every hour patient is awake
  - Straight leg raises, flexion plane only initially: three sets × 10 repetitions
    - Add leg raises in extension, abduction, adduction planes when patient has sufficient quadriceps control to prevent an extensor lag during flexion plane leg raises.



FIGURE 30-21. Cup walking. *(Reprinted with permission from Heckmann TP, Noyes FR, Barber-Westin SD: Rehabilitation of meniscus repair and transplantation procedures. In Noyes FR, Barber-Westin SD, editors: Noyes' knee disorders: surgery, rehabilitation, clinical outcomes, Philadelphia, 2009, Saunders, pp. 806–817, Figure 30-6A.)*

  - Active-assisted knee extension 90° to 0°: three sets × 10 repetitions. Limit to 90° to 30° for anterior horn repairs.

Milestones for Progression to the Next Phase

- ROM 0° to 90°
- Adequate quadriceps contraction, exhibited by no extensor lag on supine straight leg raise
- Pain, inflammation controlled
- Good patellar mobility: patient or therapist is able to move the patella medial-lateral and inferior-superior directions without problems.

Phase II (weeks 3 to 6)

Clinical Pearl

By 6 weeks postoperative, the patient should have at least 0° to 135° of knee motion and a normal gait pattern.

Goals

- ROM 0° to 135°
- Gradually resume full weight bearing with a normal gait pattern.
- Begin closed-chain exercises.
- Progress balance, proprioceptive training.
- Progress lower extremity strength exercises.

Protection

- Brace discontinued week 6 for complex and all-inside meniscus repairs; 6 to 8 weeks for radial repairs.
- Crutches discontinued week 4 for peripheral repairs.
- Half to full weight bearing for complex and all-inside repairs

Management of Pain and Swelling

- Continue cryotherapy following all exercise sessions.
- Oral medications if required

Techniques for Progressive Increase in Range of Motion

- ROM is increased to 120° by weeks 3 to 4 and 135° by weeks 5 to 6.
  - Patients who fail to achieve these goals are placed into the overpressure program and should be evaluated by the surgeon.
  - Gentle manipulation under anesthesia may be indicated for noteworthy limitations of knee motion by week 6.

Other Therapeutic Exercises

- Upper body ergometer at 3 to 4 weeks if available

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Activation of the quadriceps, hamstrings, gastrocnemius-soleus, and hip musculature is accomplished with the exercises described in this time frame.

Sensorimotor Exercises

- Double-leg balance exercises: The patient should point the feet straight ahead in tandem (heel/toe), flex the knee 20° to 30°, extend the arms outward to horizontal, and position the torso upright with the shoulders above the hips and the hips above the ankles. Stand in this position until balance is disturbed.
  - Balance exercises may be done on a minitrampoline for greater challenge.
- Walk on Styrofoam half rolls and whole rolls
- Balance board

Open and Closed Kinetic Chain Exercises

- Multiangle quadriceps isometrics (active), 0°, 30°, 60°, 90°: 1 set × 10 repetitions each
- Straight leg raises in flexion, extension, abduction, and adduction: 3 sets × 10 repetitions. Add ankle weights at 5 to 6 weeks of less than 10% of body weight.
- Knee extension (active/ active-assisted) 90 to 0°: three sets × 10 repetitions. Limit to 90° to 30° for anterior horn repairs
- Toe raises: three sets × 20 repetitions
- Heel raises begin at 5 to 6 weeks: three sets × 10 repetitions
- Wall sits (above 60°) to fatigue: three sets
- Minisquats: 3 sets
- At 5 to 6 weeks, peripheral meniscus repairs, hamstring curls, 0° to 90°: three sets × 10 repetitions
- At 5 to 6 weeks, peripheral meniscus repairs, leg press, 70 to 10°: three sets × 10 repetitions
- At 5 to 6 weeks, all repairs, multi-hip machine (flexion, extension, abduction, adduction): three sets × 10 repetitions
- 5 to 6 weeks, all repairs, knee extension (resisted), 90° to 30°: three sets × 10 repetitions

Milestones for Progression to the Next Phase

- ROM 0° to 135°
- Normal gait
- Normal patellar mobility: patient or therapist able to move the patella in all directions without resistance
- Pain, effusion controlled
- Muscle control throughout ROM as observed by therapist as patient performs exercises

Phase III (weeks 7 to 12)

Clinical Pearl

Full return to activities of daily living by 8 to 12 weeks postoperative. Precautions include no impact loading, no pivoting or twisting, no deep squatting.

Goals

- Progress lower extremity strength
- Progress balance, proprioception
- Increase endurance

Protection

- Crutches discontinued weeks 8 to 12 for complex, all-inside, and radial repairs
- Weight bearing advanced per gait pattern and change in knee symptoms

Management of Pain and Swelling

- Cryotherapy as required

Techniques for Progressive Increase in Range of Motion

- If knee motion is still limited during this time period, a gentle manipulation under anesthesia may be indicated. Severe limitations may be treated with arthroscopic debridement. The program for treatment of knee motion problems has been described in detail.[3]
- Flexibility: hamstring, gastrocnemius-soleus, quadriceps, iliotibial band

Other Therapeutic Exercises

- Weeks 7 to 8: stationary bicycling, 15 minutes, one to two times a day
- Weeks 9 to 12 (select one activity a day for 15 minutes)
  - Stationary bicycling
  - Water walking
  - Swimming with straight leg kicking
  - Walking
  - Stair climbing machine, low resistance, low stroke
  - Ski machine, short stride, level, low resistance
  - Elliptical cross-trainer

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Activation of the quadriceps, hamstrings, gastrocnemius-soleus, and hip musculature is accomplished with the exercises described in this time frame.

Sensorimotor Exercises

- Balance board: two-legged, three times per day for 5 minutes
- Lateral step-ups: 5- to 10-cm block, three times per day, three sets × 10 repetitions
- Resisted gait training: resisted band marching and elastic band resistance to terminal single leg standing balance

Open and Closed Kinetic Chain Exercises

- Straight leg raises flexion, extension, adduction, abduction: three sets × 10 repetitions
  - Add rubber tubing, three sets × 30 repetitions

- Toe and heel raises: three sets × 10 repetitions
- Wall sits, to fatigue: three sets
- Minisquats: three sets
  - Weeks 9 to 12: add rubber tubing, 0° to 40°: three sets × 20 repetitions
- Hamstring curls all meniscus repairs, active: three sets × 10 repetitions
- Knee extension, active, 90° to 30°: three sets × 10 repetitions
- Multihip: three sets × 10 repetitions
- Leg press, 70° to 10°: three sets × 10 repetitions
  - Start weeks 9 to 12 for complex repairs.

Techniques to Increase Muscle Strength, Power, and Endurance

- See Open and Closed Kinetic Chain Exercises described above.

Neuromuscular Dynamic Stability Exercises

- See Sensorimotor Exercises described above.

Milestones for Progression to the Next Phase

- No effusion, painless ROM
- Performs daily activities without problems
- Can walk 20 minutes without pain
- Normal range of motion

Phase IV (weeks 13 to 26)

Clinical Pearl

Primary focus during this phase is developing lower extremity muscle strength and cross-training for cardiovascular endurance.

Goals

- Increase strength and endurance.
- Peripheral repairs may begin running program 20 weeks postoperative if tolerated (Box 30-1)

Management of Pain and Swelling

- Cryotherapy as required

Therapeutic Exercises

- Patients encouraged to perform upper body and core strengthening according to future desired activity level.
- Aerobic conditioning, three times a week for 20 minutes; select one activity per session
  - Stationary bicycle
  - Water walking
  - Swimming, straight-leg kicking
  - Walking
  - Stair climbing machine
  - Ski machine
  - Elliptical cross-trainer

BOX 30-1 Running Program for Rehabilitation of Meniscus Injuries

A running program is begun at approximately 20 weeks postoperative in patients who had peripheral meniscus repairs and who have no more than a 30% deficit in average peak torque for the quadriceps and hamstrings on isometric testing performed on a Biodex dynamometer (Biodex Corp., Shirley, NY). This program is delayed until approximately 30 weeks postoperative in patients who had complex meniscus repairs and until at least 1 year postoperative in patients who had a meniscus transplant.

Isometric muscle testing is initially performed at an angle of 60° of knee flexion, which places the knee in a protected position for both the meniscus and the patella. Progression to isokinetic testing at high speeds is important, but the initial goal is to test the integrity of the quadriceps and hamstring musculatures. Other testing parameters worth evaluating include peak torque to bodyweight ratios, agonist-to-antagonist ratios, and time to peak torque values.

Patients begin with a walk/run combination program, using running distances of 18, 37, 55, and 91 meters. Initially, patients run at 25% to 50% of their normal speed. Once patients can run straight ahead at full speed, lateral and crossover maneuvers are added. Short distances (such as 18 m) are used to work on speed and agility. Side-to-side running over cups may be used to facilitate agility and proprioception. Figure-eight and carioca running drills are also useful.

Running, Begin

- 20 wk postoperative peripheral meniscus repairs
- 30 wk postoperative complex meniscus repairs
- Minimum 1 yr postoperative meniscus transplants

Patient must demonstrate no more than 30% deficit in quadriceps and hamstrings peak torque on isometric testing.

Use Walk/Run Program Initially

- 18, 37, 55, 91 m
- 25%–50% normal running speed, straight
- Progress to 100% speed

Add lateral, crossover, side-to-side, figure eights, carioca drills for agility

(From Heckmann TP, Noyes FR, Barber-Westin SD: Rehabilitation of meniscus repair and transplantation procedures. In Noyes FR, Barber-Westin SD, editors: *Noyes' knee disorders: surgery, rehabilitation, clinical outcomes*, Philadelphia, 2009, Saunders, *pp. 806–817*.)

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Activation of the quadriceps, hamstrings, gastrocnemius-soleus, and hip musculature is accomplished with the exercises described in this time frame.

Sensorimotor Exercises

- Balance board, two-legged, three times a day for 5 minutes

- Single-leg stance, unstable platform, three times a day for 5 minutes
- Perturbation training
- Ball toss on plyoback, single-leg stance

Open and Closed Kinetic Chain Exercises

- Straight leg raises with rubber tubing, high speed: three sets × 30 repetitions
- Minisquats, rubber tubing, 0° to 40°: three sets × 20 repetitions
- Hamstring curls, with resistance, 0° to 90°: three sets × 10 repetitions
- Knee extension, active with resistance, 90° to 30°: three sets × 10 repetitions
- Multi-hip: three sets × 10 repetitions
- Leg press, 70° to 10°: three sets × 10 repetitions

Techniques to Increase Muscle Strength, Power, and Endurance

- See Open and Closed Kinetic Chain Exercises.

Neuromuscular Dynamic Stability Exercises

- See Sensorimotor Exercises.

Plyometrics

- Week 24 for peripheral meniscus repairs only. Must have completed running program.
- Level surface box hops on 4-square grid. Double-legged hops, land in knee flexion. 4 levels.
- Single-leg hops
- Vertical box hops

Functional Exercises

- Week 16 to 20: peripheral meniscus repairs allowed to begin running program if tolerated. Patient must have less than 30% deficit in quadriceps and hamstrings peak torque on isometric and/or isokinetic testing to begin running.
- Week 24: peripheral meniscus repairs allowed to begin cutting, carioca, figure 8 agility, plyometrics (box hops, level, double-leg) if tolerated. Must have less than 20% deficit for quadriceps/hamstrings peak torque on isometric and/or isokinetic testing to begin plyometrics.

Sport-Specific Exercises

- Begin week 20 to 24 for peripheral meniscus repairs.

Milestones for Progression to the Next Phase

- No pain, effusion
- Can perform ADL, walk for 20 minutes without pain

Phase V (weeks 27 and beyond)

Clinical Pearls

Return to activity at 6 to 9 months for peripheral repairs, 9 to 12 months for complex, all-inside and radial repairs.

Condition of the articular cartilage may also be a determining factor for functional progressions.

Goals

- Increase strength, endurance, lower extremity function.
- Return to previous or desired activity level.

Management of Pain and Swelling

- Cryotherapy as required

Therapeutic Exercises

- Patients encouraged to perform upper body and core strengthening according to future desired activity level.
- Aerobic conditioning, three times a week for 20 to 30 minutes; select one activity per session
  - Stationary bicycle
  - Water walking
  - Swimming, straight-leg kicking
  - Walking
  - Stair climbing machine
  - Ski machine
  - Elliptical cross-trainer

Sensorimotor Exercises

- Balance board, two-legged, three times a day for 5 minutes
- Single-leg stance, unstable platform, three times a day for 5 minutes. Progress from 2-legged to 1-legged activity.
- Perturbation training
- Ball toss on plyoback, single-leg stance

Open and Closed Kinetic Chain Exercises

- Straight-leg raises with rubber tubing, high speed: 3 sets × 30 repetitions
- Minisquats, rubber tubing, 0° to 40°: three sets × 20 repetitions
- Knee extension, active with resistance, 90° to 30°: three sets × 10 repetitions
- Hamstring curls, with resistance, 0° to 90°: three sets × 10 repetitions
- Multihip: three sets × 10 repetitions
- Leg press, 70° to 10°: three sets × 10 repetitions

Techniques to Increase Muscle Strength, Power, and Endurance

- See Open and Closed Kinetic Chain Exercises.

Neuromuscular Dynamic Stability Exercises

- See Sensorimotor Exercises.

Plyometrics

- Week 30 for complex meniscus repairs. Must have completed running program.
- Level surface box hops on 4-square grid. Double-legged hops, land in knee flexion. 4 levels.
- Single-leg hops
- Vertical box hops

Functional Exercises

- Week 24: complex meniscus repairs allowed to begin running program if tolerated. Patient must have less than 30% deficit in quadriceps and hamstrings peak torque on isometric and/or isokinetic testing to begin running.
- Week 30: complex meniscus repairs allowed to begin cutting, carioca, figure 8 agility, plyometrics (box hops, level, double-leg) if tolerated. Patient must have less than 20% deficit in quadriceps and hamstrings peak torque on isometric and/or isokinetic testing to advance to cutting.

Sport-Specific Exercises

- Begin week 30 for complex meniscus repairs.

Criteria for Return to Sport

- No knee joint pain or swelling
- Full range of knee motion
- Less than or equal to 10% deficit quadriceps and hamstrings strength isokinetic testing
- Less than or equal to 15% deficit lower limb symmetry single-leg hop testing
- Successful completion running and functional training
- Complete trial of function by returning to sport, monitor for overuse symptoms
- Patient education for re-evaluation if any future knee problems occur

After Return to Sport

Continuing Fitness or Rehabilitation Exercises

- Aerobic conditioning recommended according to patient activity levels.
- Lower extremity strengthening to be advanced or maintained as required.

Evidence

The authors' postoperative rehabilitation program following meniscus repairs (performed with inside-out multiple vertical divergent suture techniques) in both the peripheral and central avascular regions has been used in the following clinical studies.

Buseck MS, Noyes FR: Arthroscopic evaluation of meniscal repairs after anterior cruciate ligament reconstruction and immediate motion. *Am J Sports Med* 19:489–494, 1991.

The healing rate of 79 meniscus tears that underwent follow-up arthroscopy an average of 12 months postoperative was determined in 66 patients. Fifty-one repairs were done for tears located in the periphery or outer third region and 28 for tears that extended into the central avascular region. The healing rates for tears in the periphery or outer third region were 94% complete, 4% partial, and 2% failed. The healing rates for tears in the central avascular region were 54% healed, 32% partially healed, and 14% failed. The results allowed recommendation for routine repair of meniscus tears located in the periphery as well as those that extend into the central region, including flap and double longitudinal tears. (Level IV evidence)

Noyes FR, Barber-Westin SD: Arthroscopic repair of meniscus tears extending into the avascular zone with or without anterior cruciate ligament reconstruction in patients 40 years of age and older. *Arthroscopy* 17:822–829, 2000.

A prospective study was performed to determine the outcome of meniscus repairs for tears that extended into the central avascular region in a case series of patients 40 years of age or older. A total of 30 meniscus repairs in 29 patients were evaluated by a clinical examination a mean of 34 months postoperative, by follow-up arthroscopy a mean of 24 months postoperative, or both. The mean age of the patients was 45 years (range, 40 to 58 years). We found that 87% of the meniscus repairs were asymptomatic for tibiofemoral symptoms and had not required subsequent surgery. Three repairs failed and required partial meniscectomy and one with tibiofemoral symptoms related to the repair had been treated conservatively. There were no infections, knee motion limitations, or other complications. In athletically active patients, the recommendation was made to preserve meniscal tissue whenever possible regardless of age. Indications should be based on current and future activity levels and the condition of the meniscal tissue determined at surgery. (Level IV evidence)

Noyes FR, Barber-Westin SD: Arthroscopic repair of meniscal tears extending into the avascular zone in patients younger than twenty years of age. *Am J Sports Med* 30:589–600, 2002.

A prospective study was conducted on 71 meniscal repairs in 64 knees for tears extending into the central third avascular region in patients less than 20 years of age. We followed 67 repairs with a clinical examination a mean of 51 months after surgery and 36 by follow-up arthroscopy a mean of 18 months postoperative. The meniscus tears included single longitudinal, double longitudinal, triple longitudinal, horizontal, radial, and flap. We found that 75% of the patients had no tibiofemoral compartment symptoms at follow-up. In 25%, patients had tibiofemoral symptoms that lead to arthroscopy or were deemed clinical failures on examination. There were no complications or limitations of knee motion. Repair of these meniscus tears was recommended in young active patients. (Level IV evidence)

Noyes FR, Chen RC, Barber-Westin SD, et al: Greater than 10-year results of red-white longitudinal meniscal repairs in patients 20 years of age or younger. *Am J Sports Med* 39:1008–1017, 2011.

A prospective longitudinal investigation was conducted to determine the long-term outcome of single longitudinal

meniscal repairs that extended into the central third avascular region in patients aged 20 years or younger. Thirty-three repairs were performed; the long-term success rate was determined in 29 repairs using 2 validated knee rating systems, advanced 3T MRI using T2 mapping, weight-bearing posteroanterior radiographs, a comprehensive knee examination, and follow-up arthroscopy when required. The mean follow-up was 16.8 years (range, 10.1–21.9 years). The data showed that 18 (62%) of the meniscus repairs had normal or nearly normal characteristics. Six required partial arthroscopic resection, two had loss of joint space on radiographs, and three failed according to MRI criteria. There were no limitations of knee motion or other complications. A chondroprotective joint effect was demonstrated in the healed meniscus repairs, warranting the procedure in young active patients. (Level IV evidence)

Rubman MH, Noyes FR, Barber-Westin SD: Arthroscopic repair of meniscal tears that extend into the avascular zone. A review of 198 single and complex tears. *Am J Sports Med* 26: 87–95, 1998.

We determined the results of 198 meniscus tears that extended into the central avascular region in 177 patients. The repairs were evaluated by clinical examination a mean of 42 months postoperative, by follow-up arthroscopy a mean of 18 months postoperative, or both. We found that 80% of the 198 tears were asymptomatic for tibiofemoral joint symptoms and had not failed clinically. The remaining 20% had tibiofemoral symptoms related to the repair that required follow-up arthroscopy. There were statistically significant differences in the rates of healing for tibiofemoral compartment of the repair, time from repair to follow-up arthroscopy, and the presence of tibiofemoral joint symptoms. There were no limitations of knee motion or complications other than one infection which resolved with treatment. The results allowed recommendation of repair of these meniscal tears in young active patients. (Level IV evidence)

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3. Noyes FR, Barber-Westin SD: Prevention and treatment of knee arthrofibrosis. In Noyes FR, Barber-Westin SD, editors: *Noyes' knee disorders: Surgery, rehabilitation, clinical outcomes*, Philadelphia, 2009, Saunders, pp 1053–1095.

Multiple-Choice Questions

QUESTION 1. Which of the following is not considered as part of the criteria for classifying meniscus tears?

A. Type of tear
B. Location of tear
C. Degree of articular cartilage damage
D. Size of tear

QUESTION 2. Which of the following meniscal repairs requires the greatest degree of protection in the postoperative recovery phase?

A. Peripheral repair
B. Radial repair
C. Complex repair
D. All inside repair

QUESTION 3. Which of the following is not considered an important precaution during the postoperative rehabilitation when attempting to minimize risk for reinjury?

A. High impact loading
B. Sudden pivoting or twisting
C. Deep weight bearing knee flexion
D. Resisted knee extension

QUESTION 4. Which of the following is not considered to be a possible early postsurgical complication of meniscus repair?

A. Delayed return to running
B. Limitation of knee motion
C. Quadriceps inhibition
D. Hypersensitivity and/or burning

QUESTION 5. Return to activity after a meniscus repair requires careful consideration of both subjective and objective measurements. Which of the following factors would not be considered acceptable in allowing the patient to return to full activity?

A. Successful completion of running/functional training
B. No knee pain and/or swelling
C. Greater than 30% deficit of quadriceps and hamstrings on an isokinetic strength test
D. Full range of motion

Answer Key

Question 1. Correct answer: **C** (see Indications for Surgery)

Question 2. Correct answer: **B** (see Immediate Postop Period):

Question 3. Correct answer: **D** (see Principles of Postop Rehab Box)

Question 4. Correct answer: **A** (see Clinical Pearls section, Phase 1)

Question 5. Correct answer: **C** (see criteria for Return to Sport, Week 27)

POSTOPERATIVE REHABILITATION AFTER MENISCUS REPAIR AND PRIMARY ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

Frank R. Noyes, MD, Timothy P. Heckmann, PT, ATC,
and Sue D. Barber-Westin, BS

Indications for Surgical Treatment

- Meniscus tear with unresolved tibiofemoral joint pain
- Complete anterior cruciate ligament (ACL) tear (grade 2 to 3 pivot shift, Lachman)
  - This chapter discusses primary ACL reconstruction only.
- Patients less than 50 years of age or in their fifties and physically active
- Meniscus tear reducible with good tissue integrity affirmed at surgery
- Meniscus tear classified at surgery according to location, type, size, integrity of tissue, and remaining meniscus bed
- Peripheral single longitudinal tears (red-red, one plane)—repairable in all cases, high success rates
- Middle third region (red-white or white-white)—often repairable with reasonable success rates
- Outer-third and middle-third regions (red-white, one plane) longitudinal, radial horizontal tears—decision repair versus excision made at surgery
- Patients willing to comply with postoperative rehabilitation program

Brief Summary of Surgical Treatment

Major Surgical Steps

- Diagnostic arthroscopy
- Description of meniscus repair provided in previous section of this chapter
- ACL reconstruction operative techniques described in detail elsewhere[1]
- Prefer bone-patellar tendon-bone (B-PT-B) autograft for athletes, semitendinosus-gracilis (STG) autograft in recreational or more sedentary patients or those with patellofemoral problems
- B-PT-B graft harvested (Figure 30-22), placed in central anatomic tibial and femoral attachment sites (Figure 30-23).
- Avoid proximal ACL femoral attachment and posterior ACL tibial attachment locations, as these result in a vertically oriented graft that does not resist rotational coupled motions (Figure 30-24).
- B-PT-B graft passed, femoral fixation secured with interference screw, graft conditioned at 44 N for 40 cycles, graft position verified arthroscopically, tibial fixation with interference screw
- Perform Lachman test, and ensure the knee is not overconstrained.
- STG graft femoral fixation: endobutton. Tibial fixation: interference screw plus suture post.

Factors That May Affect Rehabilitation

- Classification of meniscus tear according to location, type and size of tear, and integrity of meniscal tissue[2]
- Meniscus repairs located in the periphery (outer ⅓ region) heal rapidly, complex multiplanar repairs that extend into central one-third region require greater caution with rehabilitation
- Type of repair: inside-out multiple vertical sutures versus all-inside
- All-inside repairs use only a few sutures, require delay in full weight bearing and added protection
- Presence of articular cartilage damage, 2-B or 3-A, B (Cincinnati Knee Rating classification)

GUIDING PRINCIPLES OF POSTOPERATIVE REHABILITATION[2]

- Understand type and location of meniscus tear and repair technique.
- Know type of ACL graft and fixation used.
- Know concurrent operative procedures and condition of articular cartilage throughout knee joint.
- Early return (within 4 to 6 months) to strenuous activities, high impact loading, and deep knee flexion carry a definite risk of repeat meniscus tear or reinjury to the knee.
- A supervised rehabilitation program is supplemented with home exercises performed daily.[3,4]
- Be aware of potential complications, signs, and symptoms requiring prompt treatment:
  - Continued pain in involved tibiofemoral compartment
  - Failure to achieve knee extension and flexion goals according to protocol[5]
  - Decreased patellar mobility (early arthrofibrosis)
  - Decreased voluntary quadriceps contraction and muscle tone
  - Persistent joint effusion, inflammation

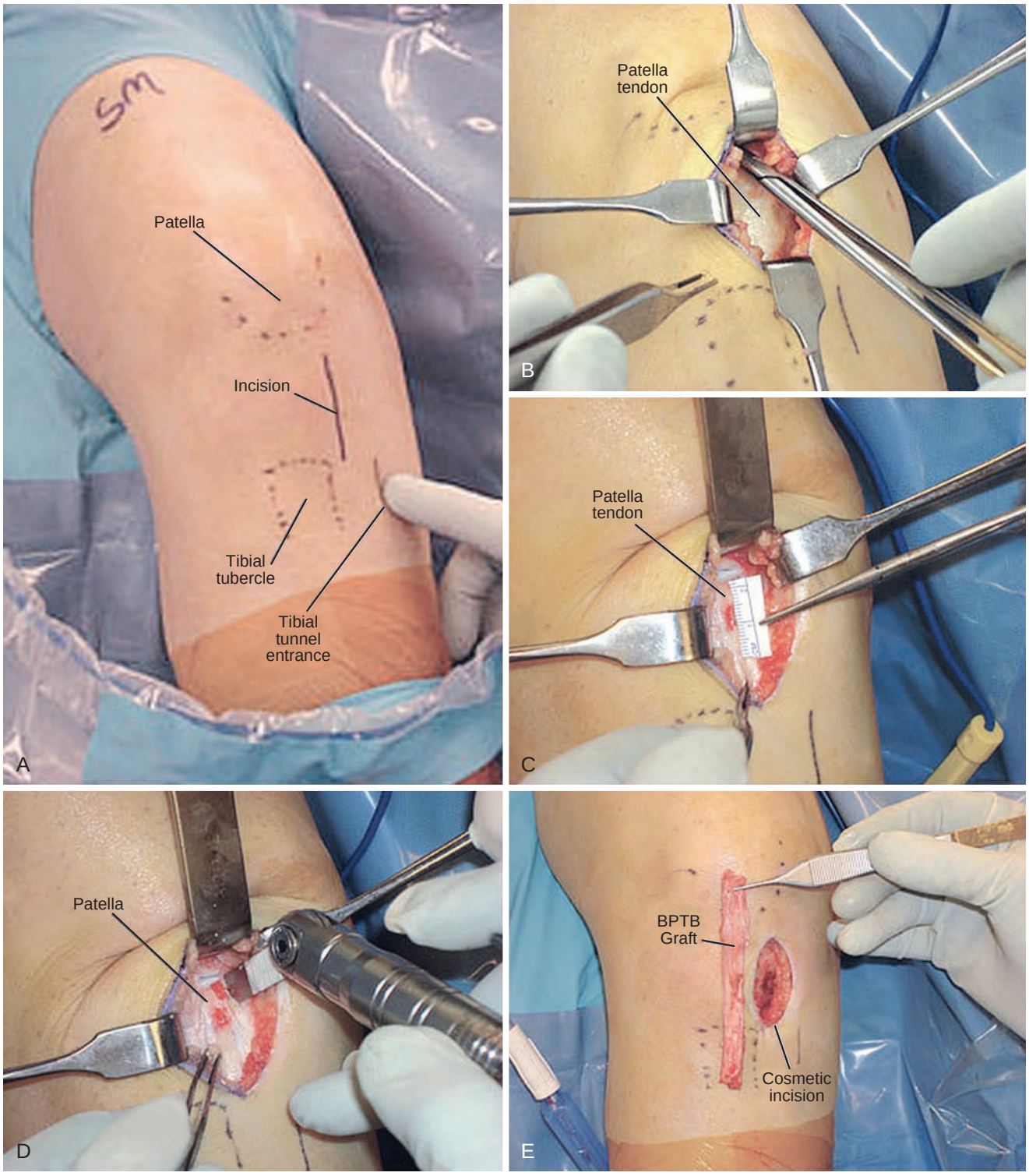

FIGURE 30-22. **A,** A 3- to 4-cm skin incision, just medial to the patellar tendon, is made to avoid the bony prominence of the patella and tibial tubercle. The index finger points to the planned tibial tunnel, which can be reached through this cosmetic incision. **B,** Mobilization of subcutaneous tissues to allow the cosmetically placed incision to be moved in a proximal-distal and medial fashion. **C,** A ruler measures the length of the patellar tendon and a 10-mm wide patellar tendon graft is marked by two to three ink dots. **D,** The patella is displaced distally and the patellar bone block removed. The saw has a tape marking a 9-mm depth to prevent from cutting too deep into the patella. The saw is angled 10° to 15° to produce a trapezoidal bone block. The saw carefully cuts the medial and lateral borders, making sure the bone beneath the tendon insertion has been cut to prevent a fracture of the graft. **E,** Appearance of the graft after harvest. *(Reprinted with permission from Noyes FR, Barber-Westin SD: Anterior cruciate ligament primary and revision reconstruction: Diagnosis, operative techniques, and clinical outcomes. In Noyes' Knee Disorders: Surgery, Rehabilitation, Clinical Outcomes. Saunders, 2009, Philadelphia, pp. 140–228.)*

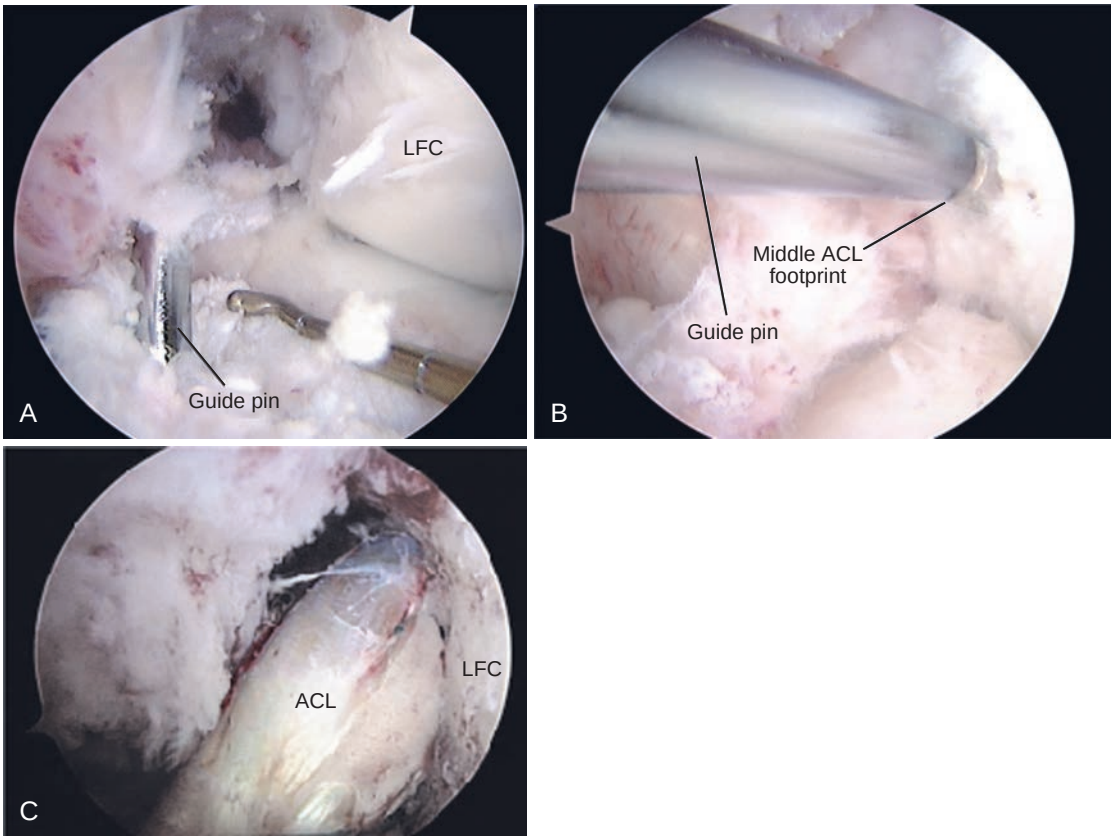

FIGURE 30-23. A, Guide pin placement is shown into the center of the ACL tibial attachment and adjacent, but not behind, the lateral meniscus attachment. **B,** ACL femoral central point is reached with knee hyperflexion and anteromedial portal or with a two-incision rear-entry technique. **C,** Final ACL graft appearance on the lateral femoral wall. *(Reprinted with permission from Noyes FR, Barber-Westin SD: Anterior cruciate ligament primary and revision reconstruction: Diagnosis, operative techniques, and clinical outcomes. In Noyes' Knee Disorders: Surgery, Rehabilitation, Clinical Outcomes. Saunders, 2009, Philadelphia, pp. 140–228.)*

TIMELINE 30-3: **Postoperative Rehabilitation After Meniscus Repair and Primary ACL Reconstruction**

PHASE I (weeks 1 to 2)

- Brace
- Toe-touch to ½ WB for peripheral meniscus repairs
- Toe-touch to ¼ WB for complex and all-inside meniscus repairs
- None-toe touch WB for radial meniscus repairs
- ROM 0° to 90°, begin first postoperative day
- Patellar mobilization
- Flexibility: hamstrings, gastrocnemius-soleus
- Weight shifting side-side, forward-backward
- Cup walking
- Quadriceps isometrics
- Straight leg raises, flexion only
- Active-assisted knee extension 90° to 30°

PHASE II (weeks 3 to 6)

- Brace
- Full WB peripheral meniscus repairs weeks 3–4
- ½ to ¾ BW complex, all-inside meniscus repairs (increase by approximately 25% per week)
- ¼ WB for radial repairs (increase by approximately 25% per week)
- ROM 0° to 135° by week 6
- Patellar mobilization
- Flexibility: hamstrings, gastrocnemius-soleus
- Double-leg balance exercises
- Balance board
- Mini-trampoline for balance exercises
- Multi-angle quadriceps isometrics
- Straight leg raises flexion, extension, abduction, adduction
- Knee extension, active-assisted ROM, 90° to 0°
- Toe raises, heel raises
- Wall sits (above 60°)
- Mini-squats (0° to 40°)
- Hamstring curls, peripheral meniscus repairs (0° to 90°)
- Leg press, peripheral meniscus repairs (70° to 10°)
- Knee extension PRE (90° to 30°)
- Multi-hip
- Upper body ergometer

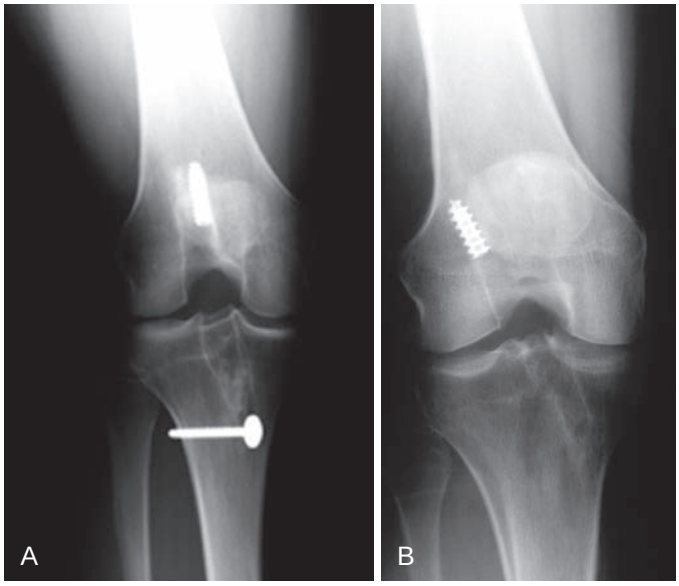

FIGURE 30-24. A, Anteroposterior radiograph shows a vertically oriented ACL graft with enlarged tibial and femoral tunnels. This graft placement should be avoided at all times, as it will not be effective in restoring normal ACL function. **B,** Correct ACL graft placement is shown. *(Reprinted with permission from Noyes FR, Barber-Westin SD: Anterior cruciate ligament primary and revision reconstruction: Diagnosis, operative techniques, and clinical outcomes. In Noyes' Knee Disorders: Surgery, Rehabilitation, Clinical Outcomes. Saunders, 2009, Philadelphia, pp. 140–228.)*

Phase I (days 0 to 14): Immediate Postoperative Period[1]

Clinical Pearl

Important early postoperative signs for the therapist to monitor are effusion, pain, gait, knee flexion and extension, patellar mobility, strength and control of the lower extremity, lower extremity flexibility, and tibiofemoral compartment symptoms. Use modalities such as electrical muscle stimulation, biofeedback, and cryotherapy as required. The patient's response to surgery and progression during the first 14 days sets the tone for the initial phases of rehabilitation. Monitor for posteromedial or infrapatellar burning, posteromedial tenderness along the distal pes anserine tendons, tenderness of Hunter's canal along the medial thigh, hypersensitivity to light pressure or temperature change, abnormal pain response, quadriceps shutdown, and inability to achieve knee motion goals as designated by protocol.

[1]*Prehabilitation, if appropriate, is described in the Nonoperative Rehabilitation section of this chapter.*

TIMELINE 30-3: **Postoperative Rehabilitation After Meniscus Repair and Primary ACL Reconstruction** (Continued)

PHASE III (weeks 7 to 12)	PHASE V (weeks 13 to 26)	PHASE VI (weeks 27+)
• DC brace, crutches • Full weight bearing • Flexibility: hamstrings, gastrocnemius-soleus, quadriceps, iliotibial band • Balance board • Lateral step-ups (5–10 cm) • Stationary bicycling (high seat/ low resistance) • Swimming, straight leg kicking (light, from hip) • Walking (level) • Stair climbing machine (short stroke/ decreased resistance) • Ski machine (decreased resistance) • Elliptical cross-trainer (decreased resistance) • Straight leg raises: flexion, extension, abduction, adduction (up to 10% BW) • Knee extension, active-assisted ROM, 90° to 0° • Toe raises, heel raises • Wall sits (>60°) • Mini-squats, rubber tubing (0° to 40°) • Hamstring curls (0° to 90°) • Leg press, start weeks 9–12 for complex meniscus repairs • Knee extension, PRE (90° to 30°) • Multi-hip	• Stationary bicycling • Swimming, straight leg kicking • Water walking • Stair climbing machine • Ski machine • Elliptical cross-trainer • Balance board • Single-leg stance, unstable platform • Perturbation training • Ball toss on plyoback, single-leg stance • Straight leg raises, rubber tubing • Mini-squats, rubber tubing • Hamstring curls • Leg press, start weeks 9–12 for complex meniscus repairs • Knee extension • Multi-hip • Running program week 16–20 peripheral meniscus repairs, based on criteria provided • Running program week 24 complex meniscus repairs, based on criteria provided • Cutting, carioca, agility drills week 24 peripheral meniscus repairs • Plyometrics week 24 peripheral meniscus repairs, based on criteria provided • Sport-specific exercises week 20–24 peripheral meniscus repairs • Return to sports, peripheral meniscus repairs: based on criteria provided	• Stationary bicycling • Swimming, straight leg kicking • Water walking • Stair climbing machine • Ski machine • Elliptical cross-trainer • Balance board • Single-leg stance, unstable platform • Perturbation training • Ball toss on plyoback, single-leg stance • Straight leg raises, rubber tubing • Mini-squats, rubber tubing • Hamstring curls • Leg press • Knee extension • Multi-hip • Cutting, carioca, agility drills week 30 complex meniscus repairs • Plyometrics week 30 peripheral meniscus repairs, based on criteria provided • Sport-specific exercises week 30 peripheral meniscus repairs Return to sports, complex meniscus repairs: based on criteria provided

Goals

- Range of motion (ROM) minimum: 0° to 90°
- Weight bearing depends on type of meniscus repair: toe touch, ½ body weight (BW) for peripheral repairs; toe touch, ¼ BW for complex or all-inside repairs; none, toe touch for radial repairs
- Pain, hemarthrosis controlled
- Good patellar mobility
- Adequate quadriceps contraction

Protection

- Long-leg postoperative brace for complex or all-inside meniscus repairs. Brace is opened from 0° to 90°, but is locked at 0° at night. Brace not routinely used for peripheral repairs, but an immobilizer may be used for patient comfort.
- Crutches. Toe-touch to ½ WB for peripheral repairs. Toe-touch to ¼ WB for complex and all-inside repairs. None to toe touch WB for radial repairs. "Sponge (very light) pressure" allowed during toe-touch WB.

Management of Pain and Swelling

- Oral medications as required.
- Therapeutic modalities: electrical muscle stimulation, cryotherapy.
- Elevate lower limb as frequently as possible.

Techniques for Progressive Increase in Range of Motion

- Begin on first postoperative day.
  - Passive knee flexion and passive and active/active-assisted knee extension exercises
  - Seated position, 0° to 90°, three to four times a day in 10-minute sessions
  - Active knee flexion is limited to avoid hamstring strain to the posteromedial joint.
  - Hyperextension avoided in anterior horn meniscus repairs
- Patellar mobilization in superior, inferior, medial, and lateral directions
- Hamstring and gastrocnemius-soleus flexibility
- If 0° to 90° not achieved by seventh postoperative day, begin overpressure exercises.
  - Hanging weights for extension
  - Rolling stool, wall-sliding for flexion
  - Commercially available ROM devices

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Activation of the quadriceps, hamstrings, gastrocnemius-soleus, and hip musculature is accomplished immediately postoperatively with the exercises described in this time frame.
- Electrical muscle stimulation and/or biofeedback may be used to enhance quadriceps contraction (Figure 30-25).

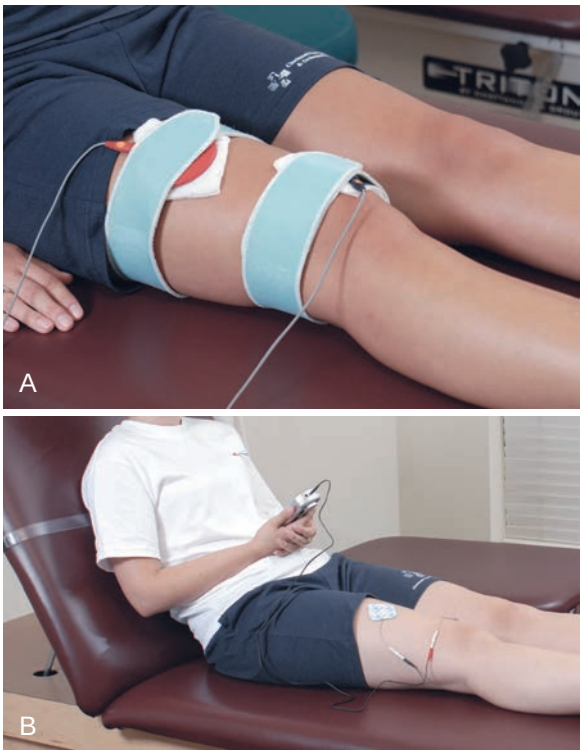

FIGURE 30-25. A, Electrical muscle stimulation. **B,** Biofeedback. *(Reprinted with permission from Noyes FR, Barber-Westin SD: Anterior cruciate ligament primary and revision reconstruction: Diagnosis, operative techniques, and clinical outcomes. In Noyes' Knee Disorders: Surgery, Rehabilitation, Clinical Outcomes. Saunders, 2009, Philadelphia, pp. 306–336.)*

Sensorimotor Exercises

- Begin first postoperative week during partial weight-bearing period.
  - Weight shifting side-to-side and front-to-back with crutch support
  - Cup walking to develop symmetry among limbs, hip and knee flexion, quadriceps control during mid-stance, hip and pelvic control during midstance, and gastrocnemius-soleus control during push-off

Open and Closed Kinetic Chain Exercises

- Begin first postoperative day
  - Quadriceps isometrics: one set × 10 repetitions every hour patient is awake
  - Straight leg raises, flexion plane only initially: three sets × 10 repetitions
    - Add leg raises in extension, abduction, adduction planes when patient has sufficient quadriceps control to prevent an extensor lag during flexion plane leg raises.
  - Active-assisted knee extension 90° to 0°: three sets × 10 repetitions. Limit to 90° to 30° for anterior horn repairs.

Milestones for Progression to the Next Phase

- ROM 0° to 90°
- Adequate quadriceps contraction, exhibited by no extensor lag on supine straight leg raise

- Pain, inflammation controlled
- Good patellar mobility

Phase II (weeks 3 to 6)

Clinical Pearl

By 6 weeks postoperative, the patient should have at least 0° to 135° of knee motion and a normal gait pattern. The KT-2000 arthrometer or Lachman test should be normal, with less than 3 mm increased anterior tibial displacement compared to the opposite knee.

Goals

- ROM 0° to 135°
- Gradually resume full WB with a normal gait pattern.
- Begin closed-chain exercises.
- Progress balance, proprioceptive training
- Progress lower extremity strength exercises

Protection

- Brace discontinued week 6 for complex and all-inside meniscus repairs; 6 to 8 weeks for radial repairs.
- Crutches discontinued week 4 for peripheral repairs.
- ½ to full WB for complex and all-inside repairs.

Management of Pain and Swelling

- Continue cryotherapy following all exercise sessions.
- Oral medications if required

Techniques for Progressive Increase in Range of Motion

- ROM is increased to 120° by weeks 3 to 4 and 135° by weeks 5 to 6.
  - Patients who fail to achieve these goals are placed into the overpressure program and should be evaluated by the surgeon.
  - Gentle manipulation under anesthesia may be indicated for noteworthy limitations of knee motion by week 6.

Other Therapeutic Exercises

- Upper body ergometer at 3 to 4 weeks if available

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Activation of the quadriceps, hamstrings, gastrocnemius-soleus, and hip musculature is accomplished with the exercises described in this time frame.

Sensorimotor Exercises

- Double-leg balance exercises. The patient should point the feet straight ahead in tandem (heel/toe), flex the knee 20° to 30°, extend the arms outward to horizontal, and position the torso upright with the shoulders above the hips and the hips above the ankles. Stand in this position until balance is disturbed.
  - Balance exercises may be done on a mini-trampoline for greater challenge.
- Walk on Styrofoam half rolls.
- Balance board

Open and Closed Kinetic Chain Exercises

- Multi-angle quadriceps isometrics (active), 0°, 30°, 60°, 90°: one set × 10 repetitions each
- Straight leg raises in flexion, extension, abduction, and adduction: three sets × 10 repetitions. Add ankle weights at 3 to 4 weeks of less than 10% of body weight.
- Knee extension (active/active-assisted) 90° to 0°: three sets × 10 repetitions. Limit to 90° to 30° for anterior horn repairs.
- Toe raises: three sets × 20 repetitions
- Heel raises begin at 5 to 6 weeks: three sets × 10 repetitions.
- Wall sits (above 60°) to fatigue: three repetitions with at least eight repetitions per day.
- Mini-squats: 3 sets × 10 repetitions 90-40)
- At 5 to 6 weeks, peripheral meniscus repairs, hamstring curls, 0° to 90°: three sets × 10 repetitions
- At 5 to 6 weeks, peripheral meniscus repairs, leg press, 70° to 10°: three sets × 10 repetitions
- At 5 to 6 weeks, all repairs, multi-hip machine (flexion, extension, abduction, adduction): three sets × 10 repetitions
- 5 to 6 weeks, all repairs, knee extension (resisted), 90° to 30°: three sets × 10 repetitions

Neuromuscular Dynamic Stability Exercises

- See Sensorimotor Exercises in the preceding

Milestones for Progression to the Next Phase

- ROM 0° to 135°
- Normal gait
- Normal patellar mobility
- Pain, effusion controlled
- Muscle control throughout ROM
- Lachman less than 3 mm increase

Phase III (weeks 7 to 12)

Clinical Pearl

Full return to activities of daily living by postoperative weeks 8 to 12.

Precautions include no impact loading, no pivoting or twisting, no deep squatting.

Goals

- Progress lower extremity strength
- Progress balance, proprioception
- Increase endurance

Protection

- Crutches discontinued weeks 8 to 12 for complex, all-inside, and radial meniscus repairs.
- Weight bearing advanced per gait pattern and change in knee symptoms.

Management of Pain and Swelling

- Cryotherapy as required

Techniques for Progressive Increase in Range of Motion

- If knee motion is still limited during this time period, gentle manipulation under anesthesia may be indicated. Severe limitations may be treated with arthroscopic debridement. The program for treatment of knee motion problems has been described in detail.[7]
- Flexibility: hamstring, gastrocnemius-soleus, quadriceps, iliotibial band

Other Therapeutic Exercises

- Weeks 7 to 8: stationary bicycling, 15 minutes, one to two times a day
- Weeks 9 to 12 (select one activity a day for 15 minutes), with a goal of increasing duration by 10% per week.
  - Stationary bicycling
  - Water walking
  - Swimming with straight leg kicking
  - Walking
  - Stair climbing machine, low resistance, low stroke
  - Ski machine, short stride, level, low resistance
  - Elliptical cross-trainer

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Activation of the quadriceps, hamstrings, gastrocnemius-soleus, and hip musculature is accomplished with the exercises described in this time frame.

Sensorimotor Exercises

- Balance board: two-legged, three times per day for 5 minutes
- Lateral step-ups: 5- to 10-cm block, three times per day, three sets × 10 repetitions (Figure 30-26)
- Resisted gait training: resistance band marching and elastic band resistance to terminal single leg standing balance.



FIGURE 30-26. Lateral step-up exercise. *(Reprinted with permission from Noyes FR, Barber-Westin SD: Anterior cruciate ligament primary and revision reconstruction: Diagnosis, operative techniques, and clinical outcomes. In Noyes' Knee Disorders: Surgery, Rehabilitation, Clinical Outcomes. Saunders, 2009, Philadelphia, pp. 306–336.)*

Open and Closed Kinetic Chain Exercises

- Straight leg raises flexion, extension, adduction, abduction: three sets × 10 repetitions
  - Add rubber tubing, three sets × 30 repetitions
- Toe and heel raises: three sets × 20 repetitions
- Wall sits, to fatigue: three repetitions
- Mini-squats: three sets × 10 repetitions
  - Weeks 9 to 12: add rubber tubing, 0° to 40°: three sets × 20 repetitions
- Hamstring curls all meniscus repairs, active: three sets × 10 repetitions
- Knee extension, active, 90° to 30°: three sets × 10 repetitions
- Multi-hip: three sets × 10 repetitions
- Leg press, 70° to 10°: three sets × 10 repetitions
  - Start weeks 9 to 12 weeks for complex repairs.

Techniques to Increase Muscle Strength, Power, and Endurance

- See the preceding

Neuromuscular Dynamic Stability Exercises

- See the preceding

Functional Exercises

- See the preceding

Milestones for Progression to the Next Phase

- No effusion, painless ROM
- Performs daily activities without problems

- Can walk 20 minutes without pain
- Normal range of motion
- Lachman less than 3 mm

Phase IV (weeks 13 to 26)

Clinical Pearl

Primary focus during this phase is developing lower extremity muscle strength and cross-training for cardiovascular endurance.

Early phases of a functional progression are implemented.

Goals

- Increase strength and endurance.
- Peripheral repairs may begin running program 20 weeks postoperative if tolerated.

Management of Pain and Swelling

- Cryotherapy as required

Therapeutic Exercises

- Patients encouraged to perform upper body and core strengthening according to future desired activity level
- Aerobic conditioning, three times per week for 20 minutes, select one activity per session
  - Stationary bicycle
  - Water walking
  - Swimming, straight leg kicking
  - Walking
  - Stair climbing machine
  - Ski machine
  - Elliptical cross-trainer

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Activation of the quadriceps, hamstrings, gastrocnemius-soleus, and hip musculature is accomplished with the exercises described in this time frame.

Sensorimotor Exercises

- Balance board, two-legged, three times per day for 5 minutes
- Single-leg stance, unstable platform, three times per day for 5 minutes
- Perturbation training
- Ball toss on plyoback, single-leg stance

Open and Closed Kinetic Chain Exercises

- Straight leg raises with rubber tubing, high speed: three sets × 30 repetitions
- Mini-squats, rubber tubing, 0° to 40°: three sets × 20 repetitions
- Hamstring curls, with resistance, 0° to 90°: three sets × 10 repetitions
- Knee extension, active with resistance, 90° to 30°: three sets × 10 repetitions
- Multi-hip: three sets × 10 repetitions
- Leg press, 70° to 10°: three sets × 10 repetitions

Techniques to Increase Muscle Strength, Power, and Endurance

- See the preceding

Neuromuscular Dynamic Stability Exercises

- See the preceding

Plyometrics

- Week 24 for peripheral meniscus repairs only. Must have completed running program.
- Level surface box hops on four-square grid. Double-legged hops, land in knee flexion; four levels.
- Single-leg hops
- Vertical box hops

Functional Exercises

- Week 16 to 20: peripheral meniscus repairs allowed to begin running program if tolerated. Patient must have less than 30% deficit in quadriceps and hamstrings peak torque on isometric and/or isokinetic testing to begin running.
- Week 24: peripheral meniscus repairs allowed to begin cutting, carioca, figure-eight agility, plyometrics (box hops, level, double-leg) if tolerated. Must have less than 20% deficit for quadriceps/hamstrings peak torque on isometric and/or isokinetic testing to begin plyometrics.

Sport-Specific Exercises

- Begin week 20 to 24 for peripheral meniscus repairs

Milestones for Progression to the Next Phase

- No pain, effusion
- Can perform ADL, walk for 20 minutes without pain
- Lachman less than 3 mm

Phase V (weeks 27 and beyond)

Clinical Pearl

Return to activity at 6 to 9 months for peripheral repairs, 9 to 12 months for complex, all inside and radial repairs.

Condition of the articular cartilage may also be a determining factor for functional progressions.

Goals

- Increase strength, endurance, lower extremity function
- Return to previous or desired activity level

Management of Pain and Swelling

- Cryotherapy as required

Therapeutic Exercises

- Patients encouraged to perform upper body and core strengthening according to future desired activity level
- Aerobic conditioning, three times per week for 20 to 30 minutes; select one activity per session.
  - Stationary bicycle
  - Water walking
  - Swimming, straight leg kicking
  - Walking
  - Stair climbing machine
  - Ski machine
  - Elliptical cross-trainer

Sensorimotor Exercises

- Balance board, two-legged, three times per day for 5 minutes
- Single-leg stance, unstable platform, three times per day for 5 minutes. Progress from two-legged to one-legged activity.
- Perturbation training
- Ball toss on plyoback, single-leg stance

Open and Closed Kinetic Chain Exercises

- Straight leg raises with rubber tubing, high speed: three sets × 30 repetitions
- Mini-squats, rubber tubing, 0° to 40°: three sets × 20 repetitions
- Knee extension, active with resistance, 90° to 30°: three sets × 10 repetitions
- Hamstring curls, with resistance, 0° to 90°: three sets × 10 repetitions
- Multi-hip: three sets × 10 repetitions
- Leg press, 70° to 10°: three sets × 10 repetitions

Techniques to Increase Muscle Strength, Power, and Endurance

- See the preceding

Neuromuscular Dynamic Stability Exercises

- See the preceding

Plyometrics

- Week 30 for complex meniscus repairs. Must have completed running program.
- Level surface box hops on four-square grid. Double-legged hops, land in knee flexion. Four levels.
- Single-leg hops
- Vertical box hops

Functional Exercises

- Week 24: complex meniscus repairs: allowed to begin running program if tolerated. Patient must have less than 30% deficit in quadriceps and hamstrings peak torque on isometric and/or isokinetic testing to begin running.
- Week 30: complex meniscus repairs: allowed to begin cutting, carioca, figure-eight agility, plyometrics (box hops, level, double-leg) if tolerated. Patient must have less than 20% deficit in quadriceps and hamstrings peak torque on isometric and/or isokinetic testing to advance to cutting.

Sport-Specific Exercises

- Begin week 30 for complex meniscus repairs

Criteria for Return to Sport

- No knee joint pain or swelling
- Full range of knee motion
- Less than 3 mm increase on Lachman test
- Less than or equal to 10% deficit quadriceps and hamstrings strength isokinetic testing
- Less than or equal to 15% deficit lower limb symmetry single-leg hop testing
- Successful completion running and functional training
- Complete trial of function, monitor for overuse symptoms
- Patient education for re-evaluation if any future knee problems occur

After Return to Sport

Continuing Fitness or Rehabilitation Exercises

- Aerobic conditioning is recommended according to patient activity levels.
- Lower extremity strengthening to be advanced or maintained as required.

Exercises and Other Techniques for Prevention of Recurrent Injury

- For patients returning to high-risk athletic activities, completion of at least 6 weeks of additional plyometrics, jump retraining, agility, strengthening (Sportsmetrics, Cincinnati Sportsmedicine Research and Education) Foundation strongly advised.[6]

Evidence

The authors' postoperative rehabilitation program following combined ACL reconstruction and meniscus repairs has been used in the following clinical studies.

Buseck MS, Noyes FR: Arthroscopic evaluation of meniscal repairs after anterior cruciate ligament reconstruction and immediate motion. *Am J Sports Med* 19:489–494, 1991.

The healing rate of 79 meniscus tears that underwent follow-up arthroscopy an average of 12 months postoperatively was determined in 66 patients. All had also undergone ACL allograft reconstruction. Fifty-one meniscus repairs were done for tears located in the periphery or outer third region and 28 for tears that extended into the central avascular region. The healing rates for tears in the periphery or outer third region were 94% complete, 4% partial, and 2% failed. The healing rates for tears in the central avascular region were 54% healed, 32% partially healed, and 14% failed. The ACL reconstruction restored normal stability in 68%, nearly normal stability in 28%, and failed in 4%. The results allowed recommendation for routine repair of meniscus tears located in the periphery as well as those that extend into the central region, including flap and double longitudinal tears. The use of immediate motion and early weight bearing did not adversely affect the healing of either the ACL reconstructions or meniscus repairs. (Level III evidence)

Noyes FR, Barber-Westin SD: A comparison of results in acute and chronic anterior cruciate ligament ruptures of arthroscopically assisted autogenous patellar tendon reconstruction. *Am J Sports Med* 25:460–471, 1997.

A prospective study was done in 94 consecutive patients who underwent B-PT-B autograft ACL reconstruction. Forty-six meniscus tears were also concurrently repaired. At a mean of 28 months postoperatively, normal knee stability was restored in 85% of knees with chronic ACL ruptures and 92% of knees with acute ruptures. We found that 89% of the menisci repaired had no evidence of failure or tibiofemoral joint symptoms. One patient had a knee motion complication. The study showed that patients who had early ACL reconstruction had superior results in regard to symptoms and activity levels. (Evidence levels are given for each reference)

Noyes FR, Barber-Westin SD: Arthroscopic repair of meniscus tears extending into the avascular zone with or without anterior cruciate ligament reconstruction in patients 40 years of age and older. *Arthroscopy* 17:822–829, 2000.

A prospective study was performed in 27 patients aged 40 to 58 years who underwent ACL B-PT-B autograft reconstruction and meniscus repair. At a mean of 34 months postoperatively, none of the ACL grafts had failed. We found that 87% of the meniscus repairs were asymptomatic for tibiofemoral symptoms and had not required subsequent surgery. Three repairs failed and required partial meniscectomy and one with tibiofemoral symptoms related to the repair had been treated conservatively. There were no infections, knee motion limitations, or other complications. In athletically active patients, the recommendation was made to preserve meniscal tissue whenever possible and restore knee joint stability regardless of age, but based on current and future activity levels. (Level IV evidence)

Noyes FR, Barber-Westin SD: Arthroscopic repair of meniscal tears extending into the avascular zone in patients younger than twenty years of age. *Am J Sports Med* 30:589–600, 2002.

A prospective study was conducted on 71 meniscal repairs in 64 knees for tears extending into the central third avascular region in patients less than 20 years of age. Forty-seven had a concurrent ACL reconstruction with either a B-PT-B autograft (n = 27) or allograft (n = 20). At a mean of 51 months postoperatively, none of the ACL autografts had failed, whereas five of the allografts had failed. We found that 75% of the patients had no tibiofemoral compartment symptoms at follow-up. In 25%, patients had tibiofemoral symptoms that led to arthroscopy or were deemed clinical failures for the meniscus repair on examination. There were no complications or limitations of knee motion. (Level IV evidence)

Rubman MH, Noyes FR, Barber-Westin SD: Arthroscopic repair of meniscal tears that extend into the avascular zone. A review of 198 single and complex tears. *Am J Sports Med* 26:87–95, 1998.

A study was performed in 177 patients who underwent 198 meniscus tears that extended into the central avascular region. A total of 126 knees also had ACL reconstruction using either allografts (72 knees) or B-PT-B autografts (54 knees). At a mean of 42 months postoperatively, 80% of meniscus repairs were asymptomatic for tibiofemoral joint symptoms and had not failed clinically. The remaining 20% had tibiofemoral symptoms related to the repair that required follow-up arthroscopy. The ACL graft failure rates were 4% for the autografts and 15% for the allografts. There were statistically significant differences in the rates of meniscus repair healing for tibiofemoral compartment of the repair, time from repair to follow-up arthroscopy, and the presence of tibiofemoral joint symptoms. There were no limitations of knee motion or complications other than one infection, which resolved with treatment. (Level IV evidence)

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Multiple Choice Questions

QUESTION 1. Which of the following details of the operative procedure do not affect the rehabilitation program?

A. Location of meniscus tear
B. Condition of the articular cartilage
C. ACL semitendinosus-gracilis versus patellar tendon autograft
D. Use of all-inside meniscus repair technique

QUESTION 2. Which procedure does not routinely require a postoperative brace?

A. Complex meniscus repair
B. Peripheral meniscus repair
C. Radial meniscus repair
D. All-inside meniscus repair

QUESTION 3. What major goal is expected to be achieved by postoperative week 6?

A. No problems with activities of daily living
B. Initiation of light jogging
C. At least 0° to 135° of knee motion
D. May swim with straight leg kicking

QUESTION 4. What milestone is not required for patients to progress to Phase IV?

A. No problems with daily activities
B. Full range of knee motion
C. Walking tolerance: 20 minutes
D. Able to do light jogging without problems

QUESTION 5. What is the first exercise in the beginning plyometric program?

A. Vertical box hops
B. Single-leg box hops
C. Level surface box hops, 4-square grid, double-legged
D. Level surface hops, single-leg

Answer Key

QUESTION 1. Correct answer: **C** (see Summary Surgical Technique)

QUESTION 2. Correct answer: **B** (see Phase I)

QUESTION 3. Correct answer: **C** (see Phase II)

QUESTION 4. Correct answer: **D** (see Phase III)

QUESTION 5. Correct answer: **C** (see Phase IV)

BEYOND BASIC REHABILITATION: RETURN TO CATCHING AFTER MENISCAL REPAIR

Kenny Patterson, MPT, and William Raasch, MD

ASPECTS OF CATCHING THAT REQUIRE SPECIAL ATTENTION IN REHABILITATION

- A baseball catcher requires full knee range of motion (ROM) and strength in order to successfully perform the necessary baseball skills.
- Baseball is highly repetitive in nature necessitating immense muscular activation, muscular endurance, and power while the knee is under axial and rotational loads.
- Catching/Receiving/Blocking—A majority of time the knee is weight bearing and subject to extremes of flexion and rotation when receiving or blocking the pitch (Figures 30-27 to 30-30).
- Throwing—The strength of the throw relies on power generated from the entire body through the kinetic chain (Figure 30-31).
- Hitting—Hitting for power, like throwing, requires coordinated lower body movement with the knee subject to significant rotational stress (Figure 30-32).
- Base Running/Sliding—Rounding a base or sliding into one may create significant axial loads while the knee is undergoing rotation (Figure 30-33).



FIGURE 30-27. Primary stance, no one on base.



FIGURE 30-28. Signal stance.



FIGURE 30-29. Secondary stance, block/throw stance.



. **FIGURE 30-30.** Blocking.

.



FIGURE 30-31. Throwing.

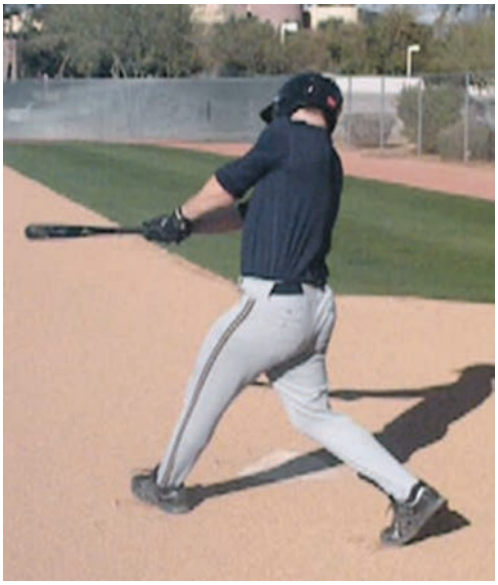


FIGURE 30-32. Hitting.



FIGURE 30-33. Base running/sliding

Introduction

- Meniscal tears are common injuries seen in orthopaedic and sports medicine clinics.
- Arthroscopic treatment is the standard of care for the symptomatic knee and meniscal repair the treatment of choice.[1–12]
- The meniscus plays an important role in joint surface preservation and knee function. The meniscus provides stress reduction, shock absorption, lubrication, nutrition, and joint congruency.[13,14]
- In addition, the literature supports the role of the meniscus in neuromuscular control by providing proprioceptive input for joint position, direction, velocity, and acceleration.[15–17]
- This specific injury is being reviewed in the context of returning a catcher to baseball activities owing to the high demands placed on the knee joint in a position that places the meniscus at risk for reinjury.
- With deep squatting (Figure 30-34) and heel sitting (Figure 30-35), the knee, while in extreme flexion is subject to high rotational loads.
- Under these conditions, the risk of reinjury following meniscal repair must be considered carefully when allowing the athlete to return to play.
- Minimal evidence exists in the current literature on healing time frames, strength capacity, or the effect of weight bearing to a healing or repaired meniscus.[18]
- Rehabilitation following meniscal repair is controversial, with a wide spectrum of proposed rehabilitation protocols.[15,19–23] Currently, treatment options following meniscal repair can be roughly divided between a conservative and an accelerated approach.
- The conservative approach includes partial to nonweight bearing for the first 4 to 6 weeks with a postoperative brace limiting flexion.
- Passive ROM is restricted from 0° to 90° degrees for the first 4 weeks.[24,25]
- During the first 6 weeks, the knee joint axial loads and shear forces are minimized by limiting ROM, hamstring activation, and weight bearing. The imposed restrictions are based on the literature reporting an increase in compressive loads to the posterior horn of the meniscus, with 85% of the axial load transmitted through the meniscus in 90° of flexion and only 50% in full extension.[18,26,27]
- Limiting hamstring activation is based on evidence that resisted knee flexion results in displacement and excessive loading of the posterior horn.[17,24,26]
- Subsequently, weight bearing with deep knee flexion is restricted for 4 months resulting in a typical return to play at the 6-month mark.[24,25]
- In the accelerated approach, knee ROM, hamstring activation and weight bearing are unrestricted and progressed to individual tolerance in the early stages of rehabilitation.
- Authors have shown similar success rates with meniscal repair under these conditions and have reported return to play in as little as 10 weeks.[19,20]
- Various modifications to the aggressive approach including limiting weight bearing in flexion greater than 90° and holding off on any impact loading until the 3-month mark.
- With either approach, rehabilitation guidelines emphasize neuromuscular rehabilitation and sport specific training for safe return to play.[15,18,32,33]
- It is evident that restoring function and regaining sport specific skills are critical for successful return to competition.
- The athlete must be educated and cautioned on the early return to strenuous activity, impact loading, deep knee flexion, and cutting/pivoting to lower the incidence of reinjury.
- Any rehabilitative approach must at some level, be individually tailored to the injury, demands, and goals of the athlete.

Literature

- Currently, to the authors' knowledge, there is no specific literature on returning a catcher following meniscal repair. The authors found a similar case report



FIGURE 30-34. Deep squat.



FIGURE 30-35. Heel sitting.

presented in JOSPT (Feb 2006) involving a professional ice hockey goaltender return to sport following lateral meniscal repair.[32]

- Axe et al.[34,35] designed and provided clinical commentary on a complete set of data-based interval throwing programs including simulated game and progression instructions for the baseball athlete to include the specialized position of catcher. These programs can also be utilized following injuries to body regions other than upper extremities to gradually increase the stresses and loads to injured area.
- Barrett and Burton[36] provide an analysis of a quantitative breakdown of the number and type of throws as well as distances required of individual fielders. The vast majority of throws were made between 46 and 60 feet principally by pitchers and catchers. Catchers accounted for 29% of throws made by positions from data compiled.[37]
- Baseball is a sport abundant with personal experiences and testimonials. Odgers and Axe[38] state "In an unpublished study, Mick Smith from the University of Miami found that during a collegiate game, a catcher throws 221 times with 131 from the squatting position. Furthermore, the catcher can expect to perform 238 squat repetitions and sprint 30 yards for an average of 15 times during each outing." The authors contribute that catchers throw from mechanically disadvantageous positions and maintain a squatting position for more than 1 hour over the course of a game.[10]
- The authors include material to provide a brief snapshot of what a catcher might encounter during a typical game and to encourage those professionals involved with the care of athletes to understand the mechanics, movements, and skills required of the athlete and sport.
- Specificity of training is the foundation for resistance and functional training programs.[39]

Advanced Rehabilitation Program

- Isokinetic training (Figure 30-36) for knee flexion and extension are employed during the latter stage of moderate protection phase to offer accommodative resistance at various speeds and progressed until the athlete is given full clearance to return to sport.
- Isokinetic testing is initiated in the advanced strengthening phase and performed at periodic intervals (approximately every 4 to 6 weeks) in the stages of rehabilitation progression and standardized to enhance the reliability of data acquired. Comparisons of bilateral strength variables of torque, total work, and unilateral muscle ratios (ham/quad) are collected.
- Published normative values for unilateral hamstrings to quadriceps ratios have been defined.
- The isokinetic testing protocol is utilized on the Biodex Multi Joint System 3 (Biodex Medical Systems, Shirley, NY) at speeds of 180°/second and 300°/second advocated by Wilk et al.[40]
- Clinically, isokinetic rehabilitation and training are based on Davies' VSRP (velocity spectrum rehabilitation protocol).[40–42]
- Plyometric and agility exercises are an effective and necessary component integrated into the advanced stages of rehabilitation to ensure neuromuscular training and functional progression to return to sport.
- Following medical clearance from the physician and criteria achieved for readiness and advancement, discussed later in this chapter, plyometrics are initiated.
- The prescription starts with exercises plyometric in nature (submaximal, low intensity, low impact, decreased weight) that encompasses agility and foot work drills.
- In conjunction, core and upper extremity plyometrics are introduced and prescribed to facilitate transfer of energy through the kinetic chain and integration of total body movement patterns required of the baseball athlete.
- As the athlete becomes proficient and masters these treatment strategies, plyometrics are advanced accordingly, ultimately to high-intensity sport-specific drills in preparation to return to sport.
- The Shuttle MVP (Figure 30-37) is used extensively throughout this author's program design owing to its versatility, variable resistance, and unloading features of body weight. The Shuttle MVP provides a safe, controlled environment for closed kinetic chain

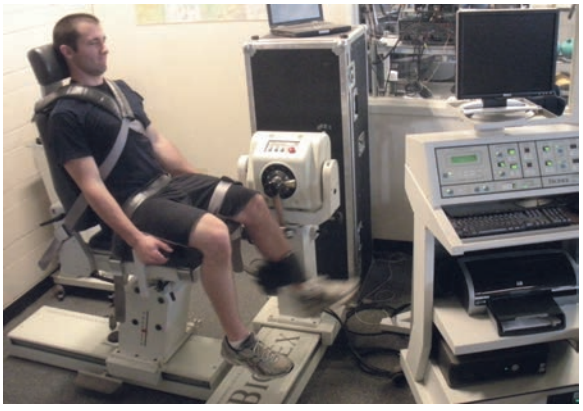


FIGURE 30-36. Biodex Isokinetic.



FIGURE 30-37. Shuttle MVP. **A,** Start position. **B,** Jump.

TIMELINE 30-4: **Beyond Basic Rehabilitation: Return to Catching after Meniscal Repair**

PHASE I: Maximal Protection/Immediate Rehabilitation (weeks 0 to 6)

- Goals
  - Protect anatomic repair
  - Minimize knee joint effusion
  - Gently increase ROM per guidelines, emphasis on extension
  - Encourage/Regain quadriceps control
  - Prevent negative effects of immobilization

Stage 1: Immediately post-op to week 2

- Cryotherapy, compression, elevation
- IFC for pain/effusion
- NMES/Biofeedback for quad activation and control
- Brace locked at 0° for ambulation and sleeping only (brace may or may not be prescribed by MD)
- Brace may be unlocked while sitting, ROM, etc.
- ROM (passive 0°-90° (gradual increase in flexion ROM based on symptoms)
- PROM / AAROM, CPM (continuous passive motion, LLLD for ext)
- Patellar mobilizations
- Flexibility exercise for hamstrings and gastroc/soleus complex
- Ankle pumps, ankle circles, alphabet
- Strengthening exercises:
- Quad sets
- SLR flexion
- Hip abduction/adduction
  - Knee extension 60°-0°
  - Weight bearing: 25%-50% WB as tolerated with 2 crutches. Avoid active knee flexion

Stage 2: Weeks 2–4

- Continue use of cryotherapy and compression
- Brace locked for ambulation (if prescribed)
- Patellar mobilization/scar massage
- Manual Therapy—soft tissue/joint mobilization peri-articular knee structures
- IFC for pain/effusion
- NMES/Biofeedback for quad activation and control
- ROM guidelines (no forced flexion, CPM, LLLD for ext)
- Gradually increase PROM
  - Week 2: 0–100/105°
  - Week 3: 0–115/120°
  - Week 4: 0–125/135°
- Weight bearing guidelines—continue to lock brace (if prescribed)
  - Week 2: 50% WB
  - Week 3: FWB as tolerated
- Discontinue crutches when safe and proper gait (usually 3–4 weeks)
- Continue PROM to AAROM to AROM (no posterior knee pain exercises) and LE flexibility exercises (hamstrings, gastroc/soleus complex)
- Strengthening exercises
  - Ankle/foot strengthening—gastroc/soleus, invertors/evertors, foot intrinsics
  - Multiangle quad isometrics
  - SLR (all 4 planes)
  - Knee extension 90°–0°
  - CKC minisquats 0°–45°
  - CKC wall squats
  - CKC weight shifts (diagonal)
- Balance/proprioception training—cup walking, weight shifting; double leg progressing to single leg activities; UE supported to UE unsupported; stable to less stable surfaces; eyes open/closed; avoid rotation
- Stationary bicycle for ROM stimulus (once ROM appropriate)
- Avoid twisting, loaded/WB CKC squatting >90° flexion, and pivoting for 10–12 weeks to minimize shear forces.
- No deep squatting for 5–6 months
- Avoid isolated resistance to knee flexion for 6 weeks
- Core stability and upper body exercises implemented at 4 weeks modified and dosed to protect meniscal repair
- Cardiovascular training—upper body ergometer (UBE)
- Home ex program (HEP to include ROM, quad facilitation, symptom reduction, and gait training)

Stage 3: Weeks 4–6

- Continue use of cryotherapy and compression as needed
- Continue PROM to AAROM to AROM (no posterior knee pain exercises and LE flexibility exercises (hamstrings, gastroc/soleus complex)
- Maintain 0°-135° ROM; goal full ROM by 8 weeks unloaded/WB if not achieved
- Manual Therapy—soft tissue/joint mobilization as needed peri-articular knee structure for pain/effusion as needed
- NMES/Biofeedback for quad activation and control as needed
- Progress strengthening exercises
- Ankle/Foot strengthening—gastroc/soleus, invertors/evertors, foot intrinsics
- Leg press 60°–0°; Shuttle MVP
- Knee extension 90°–40°
- Hip Abduction/adduction
- Wall squats 0°–60°
- Wall sits 30°–45°
- Vertical squats 0°–60°
- Lateral stepups
- Balance/proprioception training (nonimpact, perturbations, oscillatory)
- Wobble/tilt/rocker board (i.e., squats)
- BAPS
- Mini tramp
- Shuttle MVP (wobble board, air-ex pad, half foam roll, DynaDisc)
- Power Plate (vibration)
- Stationary Bicycle (if ROM permits)
- Pool program (if accessible, ROM, nonimpact, gait, balance/proprioception, flexibility, and gentle OKC/CKC strengthening aquatic exercises)
- Discontinue brace at weeks 4–5 (if applicable)
- Core stability and upper body exercises implemented at 4 weeks modified and dosed to protect meniscal repair
- Cardiovascular training—upper body ergometer (UBE)
- Home ex program (HEP to include ROM, quad facilitation, symptom reduction, and gait training if needed)
- Avoid twisting, pivoting, running, and loaded/WB CKC squatting >90° flexion

(Adapted with permission from previously established protocols: Meniscus Repair Rehabilitation Protocol. La Crosse, WI: 2008. [Accessed March 4, 2008 at http://www.gundluth.org/upload/docs/Services/SportsMedicine/knee-meniscus%20repair-2008.pdf]; Meniscus Repair Rehabilitation. Advanced Continuing Education Institute, 2004. [Accessed February 15th, 2012 at http://www.advancedceu.com])

TIMELINE 30-4: Beyond Basic Rehabilitation: Return to Catching after Meniscal Repair (Continued)

PHASE II: Moderate Protection/Intermediate Rehabilitation (weeks 6 to 12)

- Goals
  - Normalize ROM of knee
  - Normalize weight bearing and gait
  - Minimize joint effusion
  - Gradual progression of therapeutic and functional exercise for strength, endurance, neuromuscular control, balance/proprioception, and flexibility
  - Prepare for advanced and sport-specific activities
- Continue use of ice and compression as needed
- Maintain 0°-135° ROM if achieved
- Continue ROM if not achieved; goal full ROM by 8 weeks unloaded/WB
- No forceful WB stretching into flexion until 8 weeks (initiate progressive loaded WB stretch beyond 90° at 10 weeks)
- Avoid twisting, pivoting, and loaded/WB CKC squatting >90° for 10–12 weeks to minimize shear forces
- No deep squatting for 5–6 months
- Manual therapy—soft tissue/joint mobilization as needed periarticular knee structures
- IFC for pain/effusion if needed
- NMES/Biofeedback for quad activation and control if needed
- Flexibility exercises for hamstrings, gastroc/soleus, quadriceps, ITB, iliopsoas, adductors if indicated
- Closed kinetic chain exercises progress from 0°-60° to 0°-90°: leg press, stepups, partial lunges, varied squats, etc. as tolerated
- Pool program (if accessible, ROM, flexibility, OKC/CKC strengthening, CV conditioning, balance/proprioception)
- Treadmill walking program (forward, lateral, retro; no incline)
- Initiate Hamstring strengthening 0°–90° (light resistance initially)
- Incorporate total leg strengthening, balance/proprioception, and neuromuscular control in functional activities
- Continue/progress strengthening exercises listed above
  - Machine weights (multihip x 4 way, leg curl, leg ext, leg press, calf raise)
  - Shuttle MVP
  - Inertial Exercise Trainer (Impulse)
  - Power Plate
- Continue/progress balance/proprioception training/exercises listed above
  - Static to dynamic activities
  - Supported to unsupported
  - Isolated to multiple functional movement patterns
  - Add BOSU
  - Core stability and upper body exercises as recommended and tolerated
- Week 7:
  - Precor EFX Elliptical Trainer
  - Stationary bike at resistance/intensities for CV training
- Week 8:
  - Isokinetic quadriceps/hamstrings VSRP 150°–300°/sec, submax to max, progressing to 90°/sec
  - Treadmill walking program (forward, lateral, retro) progressing inclination at this time incrementally by 5% as tolerated (max 10–12%)
  - Manual stretch into increasing knee flexion (>90° to end range flexion utilizing static to PNF stretching techniques) contract-relax, agonist contract-relax, hold relax in durations ranging from 10 sec to 30 sec. Self-stretch with use of strap in prone, supine, and side lying postures with various degrees of hip flex/ext taught to improve/maintain quadriceps flexibility and knee flexion end ranges in unloaded WB status.
- Week 9:
  - Stepper/stairmaster
- Week 10:
  - Weight-bearing stretch with increasing knee flexion activities
  - Shuttle MVP weight-bearing/loaded stretch into increasing knee flexion (bilaterally until full, symmetrical, and zero symptoms of pain/swelling)
  - Resistance increased in increments of 5% of body weight starting with no resistance progressing to 100%. Consider utilizing Knee Saver, firm wedged pad, bilaterally between buttocks and lower leg.
  - Kneeling squat exercise (sit back to heels utilizing Knee Savers in full kneeling progressing to half kneeling until full, symmetrical and zero symptoms of pain/swelling)
  - Slide board

PHASE III: Controlled Advanced (weeks 12 to 18)

- Goals
  - Progress strength, endurance, power, balance/proprioception, neuromuscular control, and flexibility
  - Maintain full ROM
  - Emphasize advanced and sport specific activities/skills on MD approval
  - Prepare to return to full unrestricted sport/activities
- Continue and progress all strengthening and endurance exercises listed in Phase II
- Continue and progress balance/proprioception and neuromuscular training listed in Phase II
- Continue with stretching and flexibility exercises listed in Phase II
- Emphasize advancement of exercise in terms of functional demands and sport-specific drills/activities
- Pool program (if accessible, ROM, flexibility, OKC/CKC strengthening, CV conditioning, balance/proprioception, impact loading, jogging/running, kicking, plyometrics)
- Week 12:
  - Isokinetic Test (180°/sec & 300°/sec)
  - Interval throwing program (Nonshoulder/elbow injury—catcher/position player)
  - Interval hitting program
  - Exercises plyometric in nature (low impact, low intensity); Shuttle MVP
  - Agility/Foot work drills (low impact, low intensity), cones, agility ladder, jump rope
  - Functional Grid (Figure 30-50)
  - TRX (suspension training, Figure 30-51)
- Week 13:
  - Hurdle Activities—over/under dynamic mobility (Figure 30-52)
- Week 14:
  - Interval treadmill jogging/walking program (return to running program)
  - Supported catching drills (receiving, blocking, physio ball, stool, plyo boxes [Figure 30-53])
  - Ball pick ups
- Week 16:
  - Isokinetic Test (180°/sec & 300°/sec)
  - Plyometric exercises (moderate impact, moderate intensity)
  - Agility/foot work drills (cutting/pivoting)
  - Functional grid (lunges, balance, bounding, plyometrics)
  - Team on-field controlled/limited activities (i.e., team stretch, conditioning, batting practice, throwing, jogging/running)

PHASE IV: Return to Sport/Activity (weeks 18 to 24)

- Criteria for return to sport activity
  - MD approval
  - Full nonpainful ROM, no joint effusion
  - Satisfactory clinical exam
  - Satisfactory isokinetic testing 90% compared to uninvolved
  - Satisfactory functional testing 90% compared to uninvolved
  - Successful completion of sport-specific drills
- Week 18:
  - Sprint work/base running
  - Unsupported catching drills (receiving/blocking/throwing; see Box 30-5)
  - Reaction ball (z ball)
  - Functional tests at 50% intensity
- Week 19:
  - Functional tests at 75% intensity
- Week 20:
  - Functional testing (LE functional testing, Shuttle, Pro Agility 5/10/5)
  - Biodex test (180 deg/sec & 300 deg/sec)
  - Sliding drills (slide mat to base path/on-field)
  - Catching pens

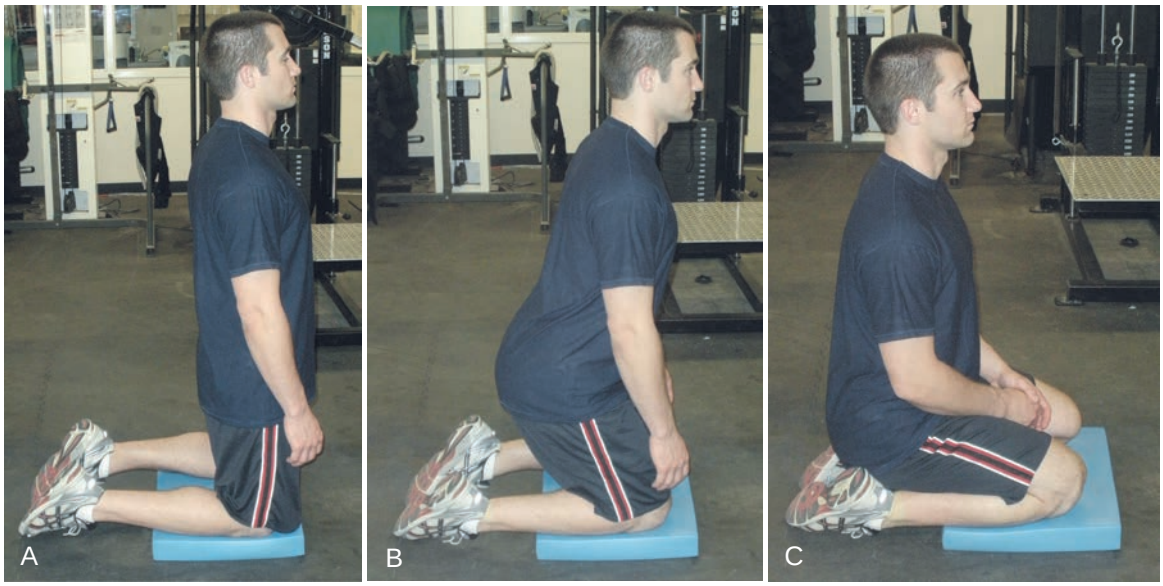


FIGURE 30-38. Kneeling squat. **A,** Start position. **B,** Middle position. **C,** End position.

activities and plyometrics. The Shuttle MVP is used in the early rehab phase within physician guidelines and throughout the rehabilitation phases until return to sport is achieved.

- The athlete is advanced by a criteria-based progression and rehabilitation timeline noted later in the chapter.
- At 10 weeks a progressive weight-bearing stretch into increasing knee flexion is initiated using the Shuttle MVP. Weight-bearing/loaded stretch into increasing knee flexion is progressed (bilaterally) until full, symmetrical, and zero symptoms of pain/swelling.
- Resistance is increased in increments of 5% of body weight, starting with no resistance and progressing to 100% body weight. Time under tension ranges from 3 to 5 seconds to 60 seconds to approximate varied time spent in squatting position for catcher. This is performed daily until criteria are met.
- Once the athlete achieves criteria bilaterally, single leg is progressed in a similar manner to approximately two-thirds body weight until full, symmetrical, and zero symptoms on the Shuttle MVP.
- At the time the athlete progresses to single leg on the Shuttle MVP, a kneeling squat exercise (Figure 30-38), sitting back on the heels and returning to full kneeling, is instructed and executed following the same parameters as before until criteria are met of full, symmetrical, and zero symptoms.
- Full kneeling is progressed to half kneeling (Figure 30-39) as tolerated.
- In this author's clinical experiences application of a neoprene sleeve and Knee Saver (Figure 30-40), firm wedged pad, during this progressive loading of end-range knee flexion expedites and minimizes setbacks. The authors speculate a strong psychological

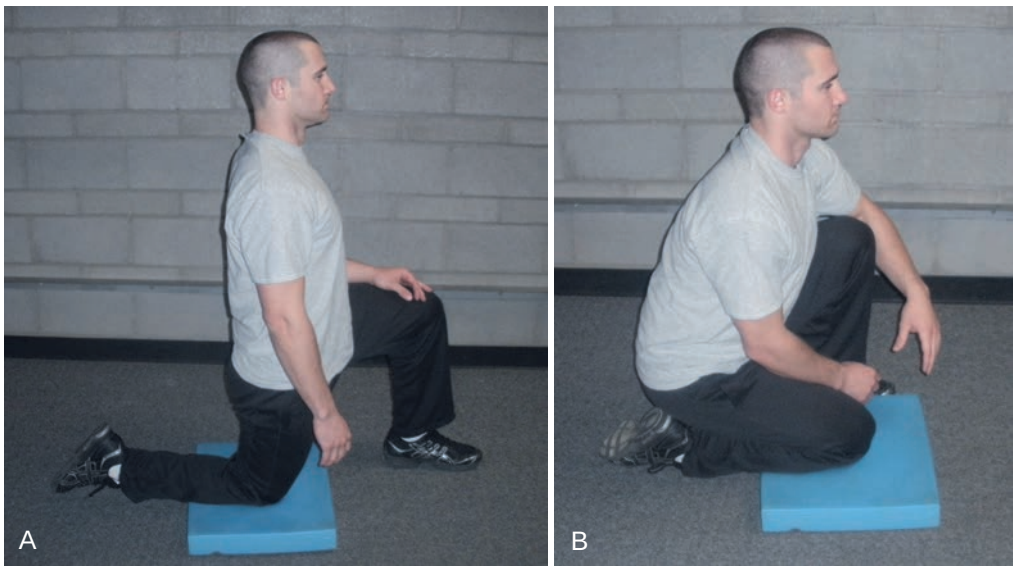


FIGURE 30-39. Half kneeling squat. **A,** Start position. **B,** End position.



FIGURE 30-40. Knee savers.

component giving a sense of security, improved performance, and favorable subjective responses. The literature suggests neoprene sleeves can enhance/provide proprioceptive stimuli.[43–46]

- The authors are unaware of any known literature on the efficacy or scientific data of the Knee Saver. Based on our clinical observation, the Knee Saver does provide sensorimotor (tactile feedback/reminder), mechanical support, and psychological benefit to the rehabbing athlete during this phase of achieving fully loaded positions/movements in extreme knee flexion. The Knee Saver is utilized bilaterally as well as unilaterally between the buttocks and lower leg for the treatment strategies listed previously and throughout program design. The potential benefits, inherent limitations, and dependence of the neoprene sleeve and Knee Saver are strongly communicated to the athlete.
- The combination of weight bearing and increasing knee flexion must be carefully balanced, monitored, and progressed throughout the athlete's rehabilitation.
- Regaining end-range flexion in fully loaded/weight-bearing positions is imperative for this athlete to return to catching after meniscal repair. The reader is reminded that the goal is symmetrical knee ROM bilaterally not only in supine position but also in weight-bearing positions required of athlete.
- The Inertial Exercise Trainer (Impulse Training Systems; Newnan, GA) (Figure 30-41) is incorporated early as a treatment strategy and progressed to high-performance sport-specific movement.



FIGURE 30-41. Impulse inertial training.



FIGURE 30-42. Power plate.

- Inertial exercise offers a unique form of exercise/training from the traditional methods. Tonic and phasic applications are utilized with varying weight progressing to no weight (gravity-free and low friction) to isolate single joints and/or involve multiple joints.[47] Evidence supports implementation of inertial exercise for neuromuscular training.[47–49]
- Vibration training or whole body vibration on the Power Plate Pro 5 (Power Plate^{R})[50] is implemented at 6 weeks in combination with conventional resistance.
- The vibration platform produces triplanar vertical vibration at a frequency between 25 and 50 Hz. Training variables are manipulated just as traditional methods with use of the Power Plate (Figure 30-42) generally three times per week utilizing 3 to 5 therapeutic exercises in a single vibration session. The authors prescribe frequency varying between 30 and 50 Hz consisting of short bouts of 30 to 90 seconds.
- The athlete is systematically progressed from static positions to dynamic movements or performed encompassing a mixture of the two.
- The literature suggests that vibration training should be viewed as a potential mode of training and intervention.[51–57]

Advanced Strength and Conditioning Program

Periodization

- Undulating

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- Training continuum
- Flexibility/joint mobility for joint stability
- Training with optimum posture
- Sensorimotor and balance training
- Core training
- Cardiorespiratory training
- Multiplanar training activities
- Training for optimum muscle balance
- Training for optimum muscle functional strength
- Training for optimum muscle functional power
- Neuromuscular dynamic stability exercises
- Training for speed, agility, quickness (SAQ)
- Plyometric training
- Functional training
- Sport-specific training

Training Principles Used in the Design of the Program

- Principle of progression
- Principle of overload
- Principle of variation
- Principle of individualization
- Principles of specificity—specific adaptation to imposed demands (SAID)

Application of Acute Training Variables

- To properly design the athlete's program following meniscal repair, a "needs analysis"[58] is performed comprised of physiological and biomechanical requirements of the rehabilitating athlete, sport, and catcher position. This comprehensive analysis is utilized to address specific strength, flexibility, range of motion, power, endurance, and speed in order to maximize performance and successful return to sport.
- It is the author's opinion that exercise selection incorporates mixed modes and various forms of exercise/resistance separate or in combination of traditional forms to provide optimal acute and chronic physiological adaptations (i.e., vibration training, inertial exercise, TRX, aquatics, etc.).
- This author advocates undulating (nonlinear) periodization for program design. It allows multiple variables to be manipulated and prescribed during the phases of rehabilitation program. A general outline[59] that established and described utilizing undulating periodization in the different phases of rehabilitation provides the premise and groundwork (Table 30-1).
- Collectively, the acute training variables are the basic components of the program design. The acute variables determine the amount of stress placed on the athlete and concomitantly what adaption the body will undergo and gain.
- All acute variables are interdependent of one another and manipulated accordingly to achieve desired result. Initially the bulk of therapeutic exercises and drills are two to three sets of 15 repetitions or bouts of 25- to 30-second intervals to foster development of muscular endurance and joint stabilization.
- Rest intervals typically are 30 to 90 seconds depending on load to promote endurance and stability adaptations.
- Essential to the success of the rehab/training sessions, and ultimately the return to sport, is training intensity. Effort level must be regulated and monitored accordingly to construct the desired physiological responses.
- The customary repetition maximum loading schemes are used on occasion when the athlete's loading capabilities can safely and effectively handle the progressive increase to determine their repetition maximum. The authors' preference to determine load of rehabilitating athlete is guided by clinical observation of movement, function, and muscle performance without compensation during prescribed therapeutic exercises and drills.
- In addition, the athlete's feedback and perceived exertion are monitored diligently using the OMNI-RES scale between 4 and 7.
- Repetition tempo is generally slow to moderate to achieve the objective of endurance, stability, and strength (i.e., slow: 2 to 3 sec/2 sec/4 to 5 sec concentric/isometric/eccentric to moderate: 2 sec/0 sec/2 sec concentric/isometric/eccentric).
- Volume of training is inversely proportional to intensity of training.
- Training is cumulative and must avoid/prevent overtraining.
- Training frequency consists of 3 to 5 days per week with active recovery days between.
- Rehab/training sessions are approximately 60 to 90 minutes in length over a 4 to 6 (peripheral tears) to 6 to 8 (complex tears) -month period with 6 to 8 weeks generally dedicated to return to sport and sport-specific activities/phases as discussed in this chapter.

Sport-Specific Training (Interval Sport Program)

Periodization

- Undulating

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- Training continuum
- Flexibility/joint mobility for joint stability
- Training with optimum posture
- Sensorimotor and balance training
- Core training
- Cardiorespiratory training
- Multiplanar training activities
- Training for optimum muscle balance
- Training for optimum muscle functional strength
- Training for optimum muscle functional power
- Neuromuscular dynamic stability exercises
- Training for SAQ
- Plyometric training
- Functional training
- Sport-specific training

Table 30-1 Utilization of Nonlinear Undulating Periodization in Different Phases of Rehabilitation

Phase	Training Emphasis	Nonlinear Periodization Phase	Parameter Trained	Training with Team
Phase I: Immediate Rehabilitation	Low intensity endurance of stabilizing muscles Training of joint above and/or below for stability and endurance	I. Setting foundation with emphasis on muscle endurance	I. Monday: Endurance Wednesday: Hypertrophy Friday: Strength	I. Cardiovascular (CV) endurance training (e.g., stationary bike for injured UE or trunk. Upper body ergometer [UBE] for injured LE or trunk) II. Weight room training of noninjured areas with protection of injured area III. Lower-level sport related skills of noninjured areas (e.g., free throws or ball tossing for injured LE; ball passing drills for soccer player with injured [UE])
Phase II: Intermediate Rehabilitation	Low to high intensity endurance of stabilizing muscles (dependent on their specific function) Progression from low to high intensity strength for muscles responsible for movement of affected area (dependent on contraindications and precautions, etc.)	I. Emphasis on increasing muscle size and continued strength training II. Strength gain emphasis prior to transition to power training	I. Monday: Hypertrophy Wednesday: Strength Friday: Hypertrophy II. Monday: Strength Wednesday: Endurance Friday: Strength	I. Weight room training of noninjured areas; continue CV endurance, progressing to long duration lower intensity interval CV activity (bike, UBE, etc.) II. Interval CV activity increasing in intensity (decreasing duration) with emphasis on energy system most relevant to athlete's sport. III. Sport related skills as prior; initiation of sport related skills of injured area (patterns of movement, low-intensity drills, etc.)
Phase III: Advanced Rehabilitation	Continued endurance emphasis for stabilizing muscles High intensity strengthening progressing Low to high intensity power progression of movement muscles (dependent on prevention, etc.)	I. Strength gain emphasis prior to transition to power training (short duration emphasis) II. Begin transition to power	I. Monday: Strength Wednesday: Endurance Friday: Strength II. Monday: Strength Wednesday: Power Friday: Strength	I. Interval training emphasis on proper energy system and incorporating total body movement patterns II. Sport related skills—Progressed to game intensity as per athlete readiness and tolerance
Phase IV: Return to Function	Continued as in phase III; with increased emphasis on clients functional requirements (i.e., power for jumping athletes; endurance for long distance running athletes, etc.)	I. Continued progression of strength and power phase	I. Monday: Power Wednesday: Strength/Hypertrophy Friday: Power	I. Sport related skills at game intensity progressed to normal practice and eventually return to game competition

Training Principles Used in the Design of the Program

- Principle of progression
- Principle of overload
- Principle of variation
- Principle of individualization
- Principles of specificity—SAID

Application of Acute Training Variables

The interval sport programs are designed to return the athlete from surgery/injury by progressing through graduated sport-specific activities. Progressive exposure to the demands of the sport are monitored and afford individual variability based on the athlete's injury, skill level, and goals.

The interval sport programs are integrated into the rehabilitation sessions on an every other day basis to allow for rest and recovery. Alternate days incorporate upper body, core/stability, and cardiovascular training. Core lower extremity exercises (strength, plyometrics, neuromuscular drills) are performed on the same day of interval sport programs. This cycle is repeated throughout the week with designated rest/off days.

- Interval sport programs are performed first (priority) after adequate warmup followed by dosed/prescribed rehabilitation for that day.
- To progress to the next step of the interval sport program, the athlete must be able to perform a set number of consecutive sessions without pain/dysfunction. If pain or difficulty, the athlete returns to the previous level.
- In addition, the athlete is closely monitored for appropriate mechanics and fatigue which can affect progression.
- The authors recommend commencing interval sport programs (i.e., hitting, throwing, running) separately over a period of time to acclimate and monitor for signs and symptoms prior to initiating another interval

sport program. The authors assert that the interval sports programs presented are only guidelines that can be modified to address the situational needs of the individual performing them. There is no set timetable for completing the interval sport programs.

- The hitting program is divided into five phases (Box 30-2). The step-wise progression provides the gradual tissue load required for the dynamic forces of the bat swing.
- Phase I begins with dry swinging both from the right and left sides to provide biomechanical force production in the kinetic chain. The athlete's tibiofemoral joints have the opportunity to act in the lead/front leg or back leg manner in swinging a bat. This is only done in phase I unless the athlete is a switch hitter. Swing intensity and volume are progressed through a series of steps. The athlete progresses through each step only if pain free and demonstrates good quality movement and execution.
- Phase II is hitting off tee with increasing intensity and number of swings.
- Phase III integrates soft toss.
- Phase IV batting practice usually off coach or machine.
- To prepare for game hitting, Phase V incorporates hitting against live pitching and simulation of an at bat.
- The interval throwing program (Box 30-3) has two phases.
- The long toss program, Phase I, consists of 17 progressive steps.
- The athlete typically performs each step twice before progressing and should successfully complete Phase I prior to initiating Phase II.
- Distance is sequentially progressed by 15-foot increments starting at 45 feet and concluding at 180 feet.
- The number of throws is progressive in nature, culminating at 75 throws at the 90-foot phase in a single session.
- Commencing at the 105-foot phase, the number of throws are reduced with increasing distances.[60]
- The author warns not to neglect the number of throws for warmup and/or "nonrecorded" throws such as in catching drills or catching bullpens.
- A "crow hop" method is taught and instituted during the interval throwing program. Although there is general consensus to teach and use the "crow hop" method for proper body mechanics of throwing, varied opinions exist on the footwork sequence and the author is unaware of any published literature on the "crow hop" method.
- Phase II is initiated on successful completion of the long toss program.
- It is position specific for the catcher and incorporates the unique throwing demands required to bases and mound from the squat, kneeling, and standing positions.
- Four steps are included in Phase II with step four participating in a simulated game.
- Each step is performed a minimum of twice before advancing.
- The "pop time" for a catcher, time from receiving pitch and throwing to second base, is a measure often taken to gauge quickness and strength of catcher's arm. The general consensus among baseball scouts and coaches for a catcher's "pop time" is 1.85 seconds or less (excellent), 1.95 to 2.0 seconds (average), and 2.05 seconds or above (low).
- The return to running program (Box 30-4) has four phases that increase loads and require progressive adaptations for the athlete to achieve prior to advancing to the next level.
- Phase I, the walking program, is formally introduced on the treadmill and performed three to five times per week until successfully completed.
- The walking program is a precursor and criterion to be achieved prior to Phase II, walk/jog. It is worth noting that the design of the return to running program, initially, does not facilitate cardiovascular fitness and must be supplemented with appropriate cross-training strategies.
- Step 2 progresses treadmill inclination in 2% to 5% increments as tolerated.
- Step 3 incorporates various surfaces/terrain outdoors to be negotiated (i.e., grass, dirt, sand, etc.). The goal is to walk briskly for 1 mile and/or 30 minutes without symptoms of pain, effusion, or antalgic gait.
- Phase II is comprised of a straight-line walk/jog combination. For discussion, running speed is a quarter to

BOX 30-2 Interval Hitting Program

Phase I: Dry Swings

Step 1: 50% effort (1 set 25 swings R/L)
Step 2: 50% effort (2 sets 25 swings R/L)
Step 3: 75% effort (2 sets 25 swings R/L)
Step 4: 80% to 90% effort (2 sets 25 swings R/L)

Phase II: Off a Tee

Step 5: 50% effort (1 set 25 swings R/L)
Step 6: 50% effort (2 sets of 25 swings R/L)
Step 7: 75% effort (2 sets of 25 swings R/L)
Step 8: 80% to 90% effort (2 sets 25 swings R/L)
Step 9: 80% to 90% effort (2 sets 25 swings R/L)

Phase III: Soft Toss Swings (Front/Side Toss)

Warm up using a tee
Step 10: 50% to 60% effort (1 set 25 swings R/L)
Step 11: 65% to 75% effort (2 sets 25 swings R/L)
Step 12: 80% to 90% effort (2 sets 25 swings R/L)
Step 13: 80% to 90% effort (2 sets 25 swings R/L)

Phase IV: Batting Practice Swings (Coach/Machine BP)

Warm up using a tee
Warm up with soft toss swings
Step 14: 50–65% effort (2 sets 25 swings)
Step 15: 70–75% effort (2 sets 30 swings)
Step 16: 80–90% effort (2 sets 30–35 swings)
Step 17: 80–90% effort (2 sets 30–35 swings)

Phase V: "Live" Batting Practice (Off Pitcher)

Step 18: 80–90% effort (10–15 pitches)
Step 19: 80–90% effort (10–15 pitches)
Step 20: 80–90% effort (10–15 pitches)
Hit 3–4 times per week with a day off in-between

BOX 30-3 Interval Throwing Program

Phase I: Long Toss

STEP 1

45-ft Phase
A. Warm-up
B. 25 throws
C. Rest 5–10 min
D. Warm-up
E. 25 throws

STEP 2

45-ft Phase
A. Warm-up
B. 25 throws
C. Rest 5–10 min
D. Warm-up
E. 25 throws
F. Rest 5–10 min
G. 25 throws

STEP 3

60-ft Phase
A. Warm-up
B. 25 throws
C. Rest 5–10 min
D. Warm-up
E. 25 throws

STEP 4

60-ft Phase
A. Warm-up
B. 25 throws
C. Rest 5–10 min
D. Warm-up
E. 25 throws
F. Rest 5–10 min
G. 25 throws

STEP 5

75-ft Phase
A. Warm-up
B. 25 throws
C. Rest 5–10 min
D. Warm-up
E. 25 throws

STEP 6

75-ft Phase
A. Warm-up
B. 25 throws
C. Rest 5–10 min
D. Warm-up
E. 25 throws
F. Rest 5–10 min
G. 25 throws

STEP 7

90-ft Phase
A. Warm-up
B. 25 throws
C. Rest 5–10 min
D. Warm-up
E. 25 throws

STEP 8

90-ft Phase
A. Warm-up
B. 25 throws
C. Rest 5–10 min
D. Warm-up
E. 25 throws
F. Rest 5–10 min
G. 25 throws

STEP 9

105-ft Phase
A. Warm-up
B. 20 throws
C. Rest 5–10 min
D. Warm-up
E. 20 throws

STEP 10

105-ft Phase
A. Warm-up
B. 20 throws
C. Rest 5–10 min
D. Warm-up
E. 20 throws
F. Rest 5–10 min
G. 20 throws

STEP 11

120-ft Phase
A. Warm-up
B. 20 throws
C. Rest
D. Warm-up
E. 15 throws

STEP 12

120-ft Phase
A. Warm-up
B. 20 throws
C. Rest 5–10 min
D. Warm-up
E. 15 throws
F. Rest 5–10 min
G. 10 throws

STEP 13

135-ft Phase
A. Warm-up
B. 15 throws
C. Rest 5–10 min
D. Warm-up
E. 10 throws

STEP 14

135-ft Phase
A. Warm-up
B. 15 throws
C. Rest 5–10 min
D. Warm-up
E. 10 throws
F. Rest 5–10 min
G. 5 throws

STEP 15

150-ft Phase
A. Warm-up
B. 15 throws
C. Rest 5–10 min
D. Warm-up
E. 10 throws

STEP 16

165-ft Phase
A. Warm-up
B. 15 throws
C. Rest 5–10 min
D. Warm-up
E. 10 throws

STEP 17

180-ft Phase
A. Warm-up
B. 10 throws
C. Rest 5–10 min
D. Warm-up
E. 5 throws
Initiate Phase II: Catcher

Phase II: Catcher

STEP 1

A. Warm-up to 130–150 ft
B. 15 throws from 60 ft
C. 10 throws from 90 ft
D. 10 throws from 120 ft
E. Rest 5–10 minutes
F. 10 throws from squat at 60 ft
G. 10 throws from squat at 90 ft'
H. 5 throws from squat at 120 ft

STEP 2

A. Warm-up to 130–150 ft
B. 15 throws to mound from squat after pitch
C. 5 throws to each base from squat after pitch
D. Rest 5–10 minutes
E. 15 throws to mound from squat after pitch
F. 5 throws to each base from squat after pitch

STEP 3

A. Warm-up to 130–150 ft
B. 15 throws to mound from squat after pitch
C. 10 throws to each base from squat after pitch
D. Rest 5–10 minutes
E. 5 throws to each base after bunt
F. 15 throws to mound standing (pitch out)

STEP 4

Simulated game

BOX 30-4 Return to Running Program

Phase I: Walking Program

STEP 1: NO INCLINE

Treadmill walking program: forward, lateral, retro at a comfortable pace progressing to aggressive/brisk walk without pain/effusion

A. Warm-up
B. Forward walking x 4 min
C. Lateral side stepping left x 2 min
D. Lateral side stepping right x 2 min
E. Retro walking x 2 min
F. Cool-down

STEP 2: PROGRESSIVE INCLINE (INCREMENTS OF 2% TO 5% AS TOLERATED, MAX 10% TO 12% INCLINATION)

Treadmill walking program: forward, lateral, retro at a comfortable pace progressing to aggressive/brisk walk without pain/effusion

A. Warm-up
B. Forward walking x 4 min
C. Lateral side stepping left x 2 min
D. Lateral side stepping right x 2 min
E. Retro walking x 2 min
F. Cool-down

STEP 3: VARIOUS SURFACES/TERRAIN (ON-FIELD/OUTSIDE)

Walking program: forward, lateral, retro at a comfortable pace progressing to aggressive/brisk walk without pain/effusion (total time 30 minutes)

A. Warm-up
B. Forward walking
C. Lateral side stepping
D. Lateral side stepping
E. Retro walking
F. Cool-down

Phase II: Walk/Jog

STEP 1

Jog ¼ mile, Walk ¾ mile, comfortable pace (¼ – ½ speed)

STEP 2

Jog ½ mile, Walk ½ mile, comfortable pace (¼ – ½ speed)

STEP 3

Jog ¾ mile, Walk ¼ mile, comfortable pace (¼ – ½ speed)

STEP 4

Jog 1 mile, comfortable pace (¼ – ½ speed)

STEP 5

Jog 1 mile, comfortable pace (¾ speed; Goal 7.5- to 8-minute mile)

Phase III: Sprint/Straight Ahead Running

STEP 1

Run ½ speed 180 ft x 10 reps

STEP 2

Run ½ speed first 45 ft; ¾ speed middle 90 ft; last 45 ft ½ speed x 10 reps

STEP 3

Run ½ speed first 45 ft; full speed middle 90 ft; last 45 ft ½ speed x 10 reps

STEP 4

Lead off position (start)—run ¾ speed 90 ft x 10 reps

STEP 5

Lead off position (start)—run full speed 90 ft x 10 reps

Phase IV: Base Running/Sliding

STEP 1

Incorporate base running and sliding

- Single
- Double
- Triple
- Homerun
- Home to first thru the bag
- First to third with lead
- Tag and score from third
- Score from second
- Sliding (feet first—single leg bent knee)

half (jog) the athlete's normal speed progressing to three-quarter (half speed sprint) to full speed (sprint). The purpose of this phase is to provide a general cardiovascular fitness (aerobic baseline, normalize mechanics, and gradually increase the loads imparted on the knee with jogging/running.

- The goal is to jog a 7.5 to 8 minute mile at conclusion of Phase II.
- Phase III initiates the sprint program and is designed based on the requirements of the sport. Consequently, short duration and high intensity sprinting are the desired task of this phase.
- The standing position is assumed initially for the start position of sprinting. A distance of 180 feet is used and broken into 45-foot segments. This allows for jogging the first 45 ft, manipulated intensity (half, three-quarter, full speed) of sprint the middle 90 ft, and the last 45 ft for deceleration.
- Typically each step is performed 2 to 3 times before advancing to an every-other-day basis.
- Once full sprinting is accomplished at the middle 90 ft, the starting position is altered to the "lead off" position to stress the acceleration aspect of base running and distance is decreased to 90 feet (base to base).
- Full-speed sprinting is allowed from start to finish. Readers are reminded that progressive sport-specific agility drills and foot work are concomitantly being administered to address changes in direction (cutting, pivoting) but are not included specifically in the return to running program.

- The final component, Phase IV, focuses on base running and sliding. Simplistically, the athlete performs the various scenarios encountered in base running, which can be viewed/treated as simulated games and/or conditioning.
- There is limited published literature on running speeds for professional baseball players. The average MLB player ran 4.33 ± 0.15 seconds from home to first reported by Coleman.[61]
- Of note, the author included catchers with a time of 4.48 ± 0.11 seconds. Subsequently the goal desired with the return to running program's latter stage is for the catcher to run from home to first ranging from 4.37 to 4.59 seconds.
- Sliding is a necessary and often neglected aspect of base running. It has been recognized as a significant cause of injuries in softball and an important source of lost participation time in collegiate baseball and softball.[62]
- Corzatt et al.[63] describes sliding as the ability to sprint along a base path and suddenly convert a vertical body to a nearly horizontal one. This study also identified four distinct phases of sliding mechanics: sprint, attainment of sliding position, airborne position, and landing.
- The two basic sliding techniques used are head-first and feet-first.
- A third type, the diveback, is used to return to a base as opposed to running from one base to the next. The diveback is typically performed head-first and of lower velocity secondary to the sprint phase being absent.
- Although there is potential for injury with each technique, the head-first slide is discouraged because of the potential to be more dangerous, with upper extremities, head, and cervical spine at risk. Head-first sliding offers no speed advantage compared with feet-first sliding.[64] The single bent-leg (feet-first) sliding technique (see Figure 30-33) is advocated and taught until the athlete has mastered it.
- The catching drills (Box 30-5) are an integral part to ready the athlete for return to catching. The authors provide suggested drills that can be performed in multiple settings and adapted to fit accessibility of equipment, location, etc. The catching drills provided are by no means all-inclusive but offer a good source for the reader to incorporate into a sport-specific program for a catcher.
- Another point to consider is utilizing catching bullpens (generally 25- to 35-pitch pens) as a training strategy for readiness to return to sport. The catcher is a key position in baseball.
- The three most important physical skills for a catcher are receiving, blocking, and throwing. The catcher's ability to receive and block pitches properly is paramount to a pitcher's success.

Application of Chronic Training Variables

- The chronic training variables are applied in similar fashion as acute training variables in an undulating periodization model.
- In the latter stages of rehabilitation, manipulation of the intensity can be daily to weekly but is characterized by high-intensity low-volume training drills/activities.
- The purpose is to continually provide a stimulus for desirable adaptions and prevent accommodation and overtraining. The focus shifts to the energy requirements and sport-specific skills with high-intensity power parameters.
- Once the athlete returns to sport competition, the goal is to preserve strength, power, and sport performance levels with moderate intensities and volume with a maintenance program.

Sports Performance Testing

General Information

- General history
- Subjective questionnaires
- Medical history
- Sports injury history
- Surgical history
- Chronic conditions/medication

Specific Tests

- Static and dynamic postural assessments (Table 30-2), as well as active and passive ROM assessments (Table 30-3), are performed at the first postoperative visit and are continued throughout the entire rehab process.
- Because of position-specific ROM demands imposed on a catcher, qualitatively and quantitatively, ROM of foot/ankle, knee, and hip in progressive-loaded/weight-bearing positions are assessed with particular attention of knee around 10 weeks postoperative with increasing knee flexion (Table 30-4).
- Isometric strength testing is performed using either standard manual muscle testing techniques or a hand-held dynamometer at approximately 4 weeks postoperative.
- Isokinetic testing (180°/sec and 300°/sec) of knee flexion and extension is performed starting at approximately 12 weeks postop to determine muscular performance and balance.
- The Functional Movement Screen is utilized by the author. The FMS[65] has been shown to have good interrater,[66,67] intersession,[66] and intrarater reliability. A retrospective examination of professional football players revealed that players who scored a 14 or below on the FMS score increased their risk of sustaining an injury by 36%.[68] A score of 15 or greater is recommended for the competitive athlete.
- Additionally, the authors assess isometric strength and conduct knee isokinetic testing (180°/sec and 300°/sec) commencing at approximately 12 weeks postop to determine muscular performance and balance. Isometric strength is performed using standard manual muscle testing techniques, hand-held dynamometer, and/or isokinetic device (isometric mode) approximately 4 weeks postop and selectively at regular intervals throughout rehabilitation.
- The lower extremity functional test (Figure 30-43),[69] horizontal jump test[69] (Figure 30-44), single hop for distance test, triple hop test, and the wall sit test

BOX 30-5 Catcher Drills

Receiving

1. **Barehanded Drill**—Partner straight on in front of catcher from 10 feet away
   - Underhand toss at left knee x 10–15 reps
   - Underhand toss at right knee x 10–15 reps
   - Underhand toss alternating left/right knee x 10–15 reps
   - Underhand toss randomly left/right knee x 10–15 reps
   - On/off balance beam
2. **Balance Beam Drill** (see Figure 30-45)—Partner straight on in front of catcher from 10 feet away (underhand tossing)
   - Receiving stance x 15–20 reps various locations within strike zone
   - Spread stance (Figure 30-46) x 15–20 reps (facing Lt/Rt)
   - Weight-shifting/Sway x 15–20 reps Lt/Rt (balls tossed outside of knees)
3. **Angled Receiving Drill** (see Figure 30-46)—Partner/Machine thrown from mound
   - Catcher angled/facing third base; fastballs thrown at left knee; catcher rotates to right gradually until receiving pitches facing mound x 10–15 reps (pitches)
   - Catcher angled/facing first base; fastballs thrown at right knee; catcher rotates to left gradually until receiving pitches facing mound x 10–15 reps (pitches)
4. **Walkup Drill**—Partner/Machine thrown from mound
   - Catcher at 60 feet, catch/receive 5 pitches
   - Progressively move up decreasing distance every 3–5 pitches till approximately 40–45 ft (catch 5 pitches at this distance)
   - Return quickly to start position (60-ft catching/receiving 5 to end session)
5. **Machine Catching/Receiving**—Partner/Machine thrown from mound
   - Fastball, curveball, slider at left knee x 10–15 pitches each
   - Fastball, curveball, slider at right knee x 10–15 pitches each

Blocking

1. **Dry Blocks** (see Figure 30-47)—Place three baseballs (left, center, right) approximately 3 feet in front of the catcher. Catcher performs proper blocking technique behind each baseball commencing at middle baseball (i.e., middle - left - middle - right - middle)
2. **Mirror Blocks**—Requires 2 catchers facing each other. Designate leader and have other catcher mimic blocking techniques.
3. **All Pitch Blocking** (see Figure 30-48)—Machine/Partner thrown (fastball, curveball, slider)
   - Halfway Position—Mitt on the ground, then quickly proceed to get to knees prior to pitch arriving x 10–15 reps
   - Full Position (block/throw stance x 10–15 reps)
4. **Angled Blocking**—Focus on getting down quickly, sliding, and squaring up to the baseball; develops range of catcher x 10–15 reps.
5. **Rapid Fire**—Catcher blocks baseball and returns to block/throw stance in rapid succession x 5–8 reps

Throwing

1. **Quick Footwork Drill**—Catcher begins in block/throw stance. Partner flips baseball and catcher performs footwork for throwing returning to original stance as quickly as possible x 5 reps
2. **Quick Transfer Drill**—Partner flips baseball at catcher's chest area (upper right to facilitate the transfer of baseball to throwing hand), bring mitt/ball toward hand vs hand toward mitt/baseball and throwing into net 5–8 feet away x 10–15 reps. Can be performed standing or in block/throw stance.
3. **Footwork/Throw Drill** (see Figure 30-49)—Machine/Partner thrown baseball, the catcher starts in his block/throw stance and performs footwork after receiving pitch and throwing into net 5–8 ft away. This can be done with any pitch (fastball, curveball, slider).

(described in the section return to sport criteria) assess movement performance.

- Functional tests are performed with increasing submaximal effort and used in training sessions as well to ensure proper sequencing with repeated measures prior to maximal effort testing.
- Sport-specific testing comprises successful completion of interval hitting (Box 30-2), interval throwing (Box 30-3), return to running (Box 30-4), and catching drills (Box 30-5; Figs. 30-46 to 30-50).

Specific Criteria for Progression to the Next Stage to Determine Readiness for Catching

The criteria to progress from Phase I (Maximal Protection Phase) to Phase II (Moderate Protection Phase) are the following:

- Knee PROM of 0 to 90°
- Tolerance of at least 75% to 100% weight bearing
- Normal gait, with or without assistive device
- Independent quad control

Table 30-2 Static/Dynamic Postural Assessments

Position	Body Region	Specific Assessments
Standing Alignment (posterior view)	Ankle	Equal weight distribution Feet pointed forward, or are they rotated (toe in or toe out) Medial longitudinal arch height Abductor hallucis hypertrophy Calcaneal positioning (eversion/inversion)
	Knee	Genu varum/genu valgum, Q-angle
	Hip	Equal weight distribution Greater trochanter height PSIS height
	Spine	Scoliosis Lateral shift
Standing Alignment (lateral view)	Ankle	Feet pointed forward; rotated (toe in or toe out) Medial longitudinal arch height Abductor hallucis hypertrophy
	Knee	Genu recurvatum or lack of full extension
	Hip	Innominate rotation Anterior/Posterior pelvic tilt Innominate anterior/posterior positioning (bilateral comparison)
	Spine	Lumbar lordosis Thoracic kyphosis
Standing Alignment (anterior view)	Ankle	Equal weight distribution Feet pointed forward, or are they rotated (toe in or toe out) Medial longitudinal arch height Abductor hallucis hypertrophy
	Knee	Genu varum/genu valgum, Q-angle Patellar alignment
	Hip	Iliac crest height Greater trochanter height ASIS height

The criteria to progress from Phase II (Moderate Protection Phase) to Phase III (Controlled Advanced Phase) are the following:

- No effusion
- Knee PROM of 0 to 135° (or equal to uninvolved side)
- Normal gait using no assistive device
- Able to maintain single leg balance stance for at least 15 seconds
- Able to maintain a single leg squat to 60 degrees of knee flexion for at least 5 seconds with no wavering or loss of balance
- Satisfactory clinical exam

The criteria to progress from Phase III (Controlled Advanced Phase) to Phase IV (Return to Sport/Activity) are the following:

- Isokinetic quadriceps strength of at least 75% of uninvolved side
- Able to tolerate closed kinetic chain pivoting without pain or swelling
- Able to tolerate dynamic, closed kinetic chain, triplanar movements without compensation, swelling, or pain.
- Full, pain-free, symmetrical knee AROM/PROM

Table 30-3 AROM and PROM Assessments (non–weight bearing)

Body Region	Motion	ROM Norms[70]
Ankle	Dorsiflexion	0°–20°
	Plantarflexion	0°–50°
Knee	Flexion	0°–145° †
	Extension	0°
Hip	Flexion	0°–120°
	Extension	0°–20°
	Abduction	0°–45°
	Internal rotation	0°–40°
	External rotation	0°–40°

†Knee flexion limited to 0° to 90° during first 2 weeks postop; ROM progressed based on symptoms; goal of full, pain-free ROM at 6 weeks.

Specific Criteria for Release to Unsupervised Complete Participation in Catching

The criteria to progress from Phase IV to Returning to Sport are the following:

- Medical/Physician approval
- Successful completion of interval sport programs (hitting, catching drills, sliding, running, throwing)
- Satisfactory completion of the lower extremity functional test: time within 90% compared with normative data (less than 2 minutes—Females, less than 1½ minutes—Males) (see Figure 30-43)[69]
- Isokinetic quadriceps/ham strength of at least 90% of uninvolved knee
- Horizontal jump test greater than or equal to 90% height of uninvolved limb (see Figure 30-44)[69]
- Single leg hop test greater than or equal to 90% distance of uninvolved limb
  - Subjects will perform a single leg hop for distance with each lower extremity. After demonstration, each subject will be allowed one trial per leg. Beginning with the toes immediately behind the starting line, subjects will perform one hop to complete a trial. The hop will be measured from the starting line to the end of the toes after completion of a trial. Each limb will be tested two times with the maximal distance scored for each limb.
- Triple hop test greater than or equal to 90% of uninvolved limb
  - Perform a single leg triple hop for distance with each lower extremity. After demonstration, each subject will be allowed one trial per leg. The test will begin

Table 30-4 Full Weight-Bearing AROM Assessments

Body Region	Motion	Criteria
Knee	Primary stance (Figure 30-27) Secondary stance (Figure 30-29) Blocking position (Figure 30-30) Heel sitting (Figure 30-35) Half kneeling Heel sitting in half kneeling Full/Tall kneeling	Symmetrical Pain free With or Without Knee Saver No effusion

DOI/DOS: _____ Height: _____ in:
Gender: _____ Dominant R/L

JUMP/HOP TEST

Date: _____

Trial	1	2	3	Avg	%/HT
Both					
RU/I					
LU/I					
Initials					

Date: _____

Trial	1	2	3	Avg	%/HT
Both					
RU/I					
LU/I					
Initials					

Date: _____

Trial	1	2	3	Avg	%/HT
Both					
RU/I					
LU/I					
Initials					

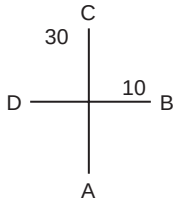
NORMS

	Female	Male
Both	90% of Ht	100% of Ht
Right	80% of Ht	90% of Ht
Left	80% of Ht	90% of Ht

LOWER EXTREMITY FUNCTIONAL TEST

Procedure:

1. Forward sprint (A-C-A)
2. Retro sprint (A-C-A)
3. Side shuffle right-face in (A-B-C-D-A)
4. Side shuffle left-face in (A-D-C-B-A)
5. Cariocas right-face in (A-B-C-D-A)
6. Cariocas left-face in (A-D-C-B-A)
7. Figure 8's right (A-B-C-D-A)
8. Figure 8's left (A-D-C-B-A)
9. 45 Cuts right-plant outside foot (A-B-C-D-A)
10. 45 Cuts left-plant outside foot (A-D-C-B-A)
11. 90 Cuts right-plant outside foot (A-B-C-D-A)
12. 90 Cuts left-plant outside foot (A-D-C-B-A)
13. Crossover 90 cuts left-plant inside foot (A-B-C-D-A)
14. Crossover 90 cuts left-plant inside foot (A-D-C-B-A)
15. Forward sprint (A-C-A)
16. Retro spring (A-C-A)



Data:

Date: _____ Time: _____ secs:

Date: _____ Time: _____ secs:

Date: _____ Time: _____ secs:

NORMS

Males	Females <25	Females >25
90 sec - good	100 sec - good	120 sec - good
100 sec - avg	120 sec - avg	150 sec - avg
125 sec - <avg	140 sec - <avg	180 sec - <avg

FIGURE 30-43. A, Lower extremity functional test.

with the toes immediately behind the starting line. The subject will perform three hops consecutively prior to the completion of a trial. The hop will be measured from the starting line to the end of the toes after the third hop on each trial. Each limb will be tested two times with the maximal distance scored for each limb.

- Maintain wall sit with knees flexed to 90 degrees for 3 minutes.

Recommended Ongoing Exercises

- Maintenance/preventative total body strength and conditioning program that addresses fundamental movement patterns and skills specific to the baseball athlete (i.e., squatting, running, hitting, throwing, etc.) and incorporates principles of dynamic stability and mobility, neuromuscular control, and proprioception.

Evidence

Bizzini M, Gorelick M, Drobny T: Lateral meniscus repair in a professional ice hockey goaltender: A case report with a 5-year follow-up. *J Orthop Sports Phys Ther* 36:89–100, 2006.

The purpose of this case report was to describe the outcomes of an accelerated, sport-specific, criterion-based rehabilitation protocol for a high-level athlete prescribed for an isolated lateral meniscus repair with a 5-year follow-up. The authors were able to return the athlete to sport 103 days

Procedure:

1. Patient stands on both legs.
2. Patient jumps side to side between two platforms, with the arms left free.
3. Allow one set of submax (easy side to side) warm-ups.
4. Each set consists of 20 jumps, with a 20-second rest period in between each set.
5. The objective is for the patient to complete the 20 jumps as quickly as possible.
6. The patient completes 3 sets of 20 jumps for the test. For each set the total elapsed time is recorded.

DATE	TOTAL ELAPSED TIME
Trial 1	
Trial 2	
Trial 3	
Average	

DATE	TOTAL ELAPSED TIME
Trial 1	
Trial 2	
Trial 3	
Average	

DATE	TOTAL ELAPSED TIME
Trial 1	
Trial 2	
Trial 3	
Average	

DATE	TOTAL ELAPSED TIME
Trial 1	
Trial 2	
Trial 3	
Average	

DATE	TOTAL ELAPSED TIME
Trial 1	
Trial 2	
Trial 3	
Average	

DATE	TOTAL ELAPSED TIME
Trial 1	
Trial 2	
Trial 3	
Average	

FIGURE 30-44. Horizontal jump test.

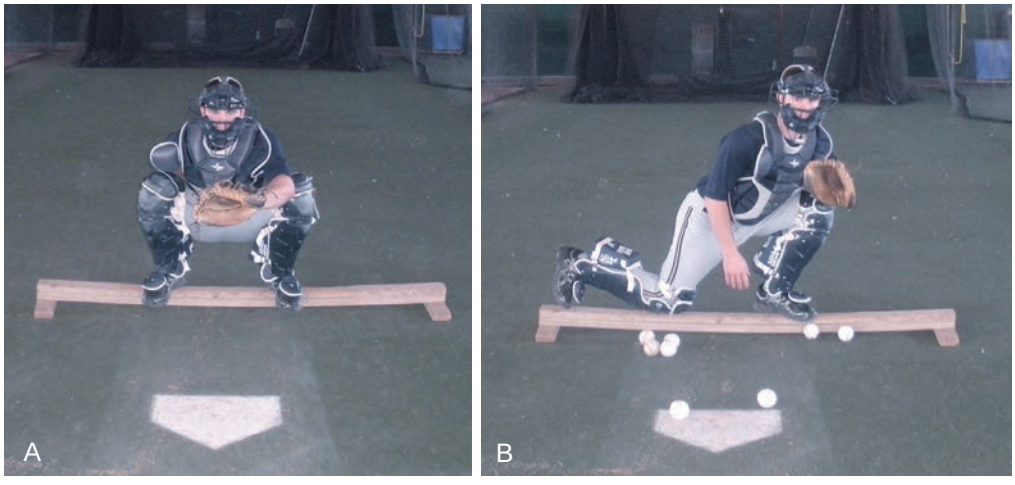


FIGURE 30-45. Balance beam drill. **A,** Receiving stance. **B,** Spread stance.

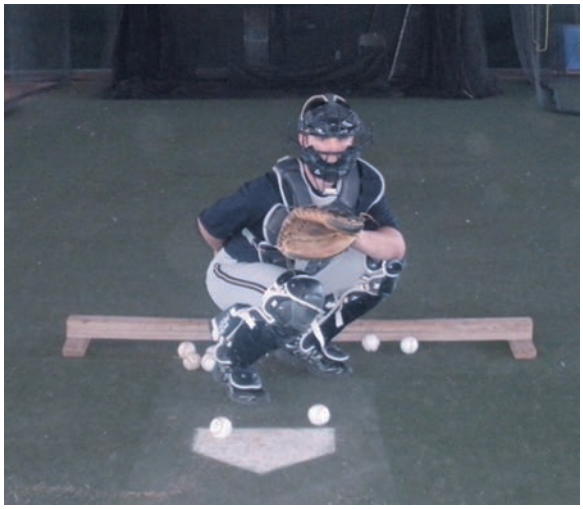


FIGURE 30-46. Angled receiving drill.



FIGURE 30-47. Dry blocks.



FIGURE 30-48. All pitching block.



FIGURE 30-49. Footwork/throw drill. **A,** Start position. **B,** End position.



FIGURE 30-50. Functional grid.



FIGURE 30-52. Hurdle drills.

postop using the specified protocol. They also determined that no reinjury of the lateral meniscus occurred up to 5 years after surgery. The authors conclude that the sport-specific, criterion-based rehabilitation program showed a safe return to sport and a good long-term outcome. (Level IV evidence)

Brindle T, Nyland J, Johnson DL: The meniscus: Review of basic principles with application to surgery and rehabilitation. *J Athl Train* 2:160–169, 2001.

The purpose of this article was to review the basic meniscal anatomy, histology, and biomechanical principles of the meniscus and discuss how they apply to current surgical and rehabilitation methods. They found that injuries to a healthy meniscus are usually produced by a compressive force coupled with transverse-plane tibiofemoral rotation as the knee moves from flexion to extension. The goal of meniscal surgery and rehabilitation is to restore a functional meniscus to prevent the development of degenerative osteoarthritis in the involved knee and restore patient function. Restoration of function is based on factors such as individual needs, type of surgical procedure, which meniscus was repaired, coexisting knee, type of tear, patient age, preoperative knee status, knee range of motion or strength, and patient athletic expectations and motivations. The authors believe progressive weight bearing and joint stress are necessary to enhance the functionality of the meniscal repair and prolonged knee immobilization after surgery can result in the rapid muscular atrophy and a longer road to recovery. The authors conclude that aquatic therapy may be ideal during all phases of rehabilitation after meniscal surgery (regardless of the exact procedure), providing the advantages of controlled weight bearing and mobility progressions. (Level V evidence)



FIGURE 30-51. TRX (suspension training).

Escamilla RF: Knee biomechanics of the dynamic squat exercise. *Med Sci Sports Exerc* 1:127–141, 2001.

The purpose of this review was to examine knee biomechanics during the dynamic squat exercise. The authors reviewed and discussed tibiofemoral shear and compressive forces, patellofemoral compressive force, knee muscle activity, and knee stability relative to athletic performance, injury potential, and rehabilitation. They found that low to moderate posterior shear forces were generated throughout the squat for all knee flexion angles and low anterior shear forces were generated between 0° and 60° knee flexion. They also found that patellofemoral compressive forces and tibiofemoral compressive and shear forces progressively increased as the knees flexed and decreased as the knees extended, reaching peak values near maximum knee flexion. The authors conclude that performing a squat in the functional range between 0° and 50° knee flexion may be appropriate for many knee rehabilitation patients, because knee forces were minimum in the functional range. Quadriceps, hamstrings, and gastrocnemius activity generally increased as knee flexion increased, which supports athletes with healthy knees performing deeper squats between 0° and 100° knee flexion (parallel squat. For athletes with healthy knees, performing the parallel squat is recommended over the deep squat, because injury potential to the menisci and cruciate and collateral ligaments may increase with the deep squat.

Mintzer CM, Richmond JC, Taylor J: Meniscal Repair in the Young Athlete. *Am J Sports Med* 26:630–633, 1998.

This study was performed to determine the success rate and outcome of meniscal repair in a young athletic population. Twenty-nine meniscal repairs in 26 patients 17 years of age or younger were performed using arthroscopic techniques. All patients were seen for follow-up at an average of 5 years (range, 2 to 13.5 years), with assessment including the SF-36 Health Status Survey, International Knee Documentation Committee, a Lysholm score, and thorough physical examination. They found that all 26 patients were asymptomatic and demonstrated clinically healed repairs at follow-up. The 100% success/healing rate found is higher than that reported in the adult population. These results support the concept of meniscal preservation by aggressively repairing torn tissue, especially in the young athletic population. (Level IV evidence)

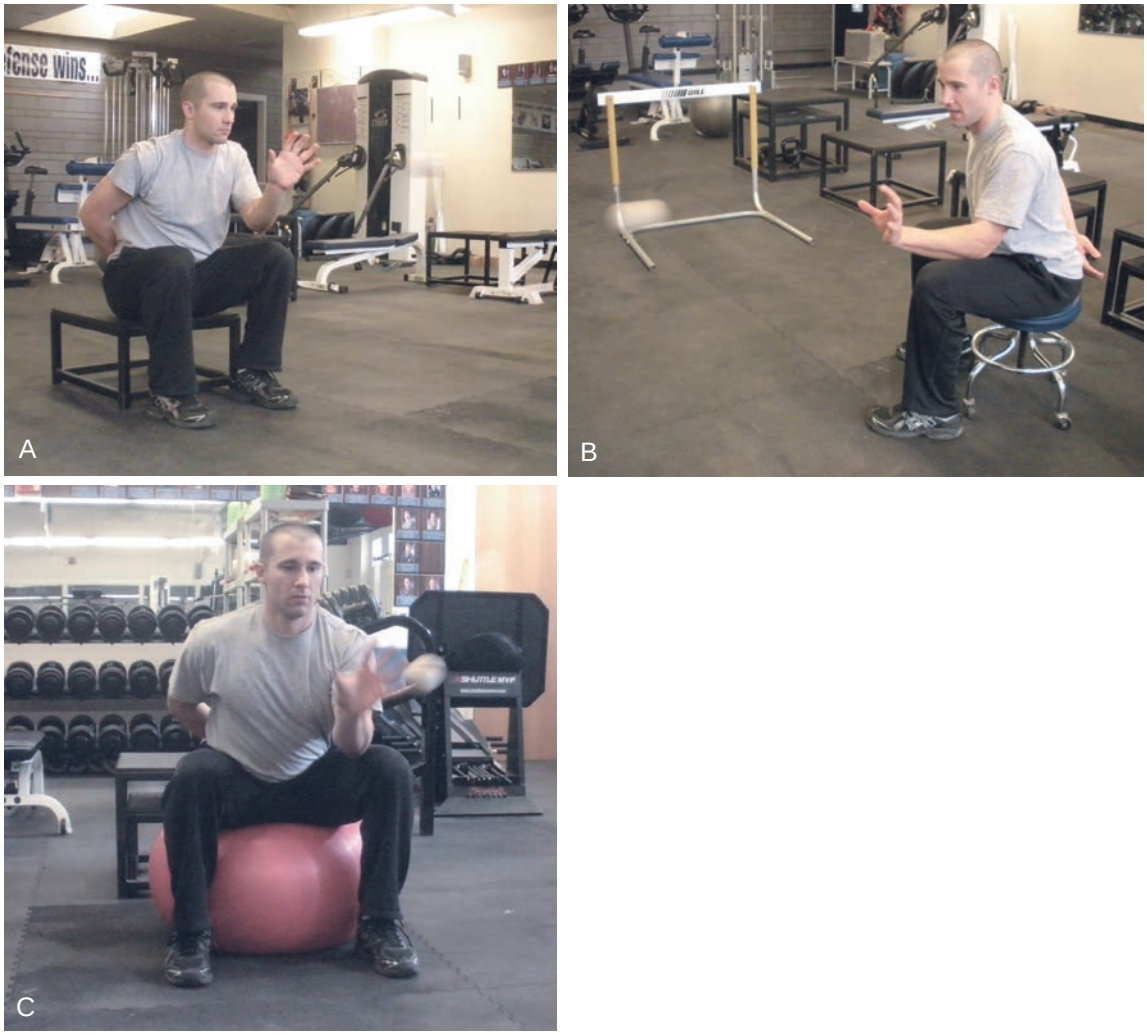


FIGURE 30-53. Supported catching drills. **A,** Plyo Box. **B,** Stool. **C,** Physio Ball.

Myer GD, Paterno MV, Ford KR, et al: Rehabilitation after anterior cruciate ligament reconstruction: Criteria-based progression through the return-to-sport phase. *J Orthop Sports Phys Ther* 36;385–399, 2006.

This review article discussed the history of ACL reconstruction rehabilitation as well as provided an algorithm for progressing a patient post ACL reconstruction. The outcome measures all have validity and reliability. In general, thinking has switched from prolonged postop immobilization to return to sport activities at 8 weeks. Animal studies have revealed that ACL grafts demonstrate their weakest point at 6 to 8 weeks postop. At 1 year postop the threshold for graft failure is 11% to 50% of a native ACL. There is a fine line in exercise progression and clinicians should respect the stress strain curve of tissue. Decreased strength, joint position sense, postural stability, and force attenuation have been documented for 6 months to 2 years following ACL reconstruction. (Level V evidence)

Myer GD, Paterno MV, Ford KR, et al: Neuromuscular training techniques to target deficits before return to sport after anterior cruciate ligament reconstruction. *J Strength Cond Res* 3:1–28, 2008.

The purpose of this scientific commentary was to present an example of a progressive return to sport protocol designed to help the athlete to progress through objective measures of neuromuscular control, strength, power, and lower extremity symmetry that are rehabilitative landmarks after ACL reconstruction. The proposed return to sport training protocol involves four phases, including Dynamic Stabilization and Core Strengthening, Functional Strengthening, Power Development, and Sports Performance Symmetry, and incorporates quantitative measurement tools that will provide the athlete with objective feedback and targeted goal setting. The authors offer rationale for exercise selection to provide the care provider with a flexible decision-making approach that will aid in the modification of return to sport training to meet the individual athlete's abilities and to target objectively measured deficits. They conclude that this algorithmic approach may improve the potential for athletes to return to sport after ACL reconstruction at the optimal performance level and with minimized risk of reinjury. (Level V evidence)

Shelbourne KD, Patel DV, Adsit WS, et al: Rehabilitation after meniscal repair. *Clin Sports Med* 15:595–612, 1996.

The purpose of this study was to compare patient outcomes following completion of traditional meniscus repair rehabilitation (non-weight bearing for 6 weeks with the knee in 45° degrees of flexion, running at 3 months, and return to sport

at 6 months with patient outcomes following completing an accelerated rehabilitation protocol (weight-bearing, walking and movement as tolerated; return to full activity upon involved knee reaching full ROM and 75% strength of uninvolved leg). Sixty-one patients with isolated meniscus repairs were separated into two groups, 39 participated in the accelerated group and 17 patients completed the conservative rehabilitation program. Patients who underwent accelerated rehabilitation achieved full ROM (6 vs 10 weeks) and returned to full activity (10 vs 20 weeks) sooner than patients who participated in a traditional rehab program. At long term follow up patients did not differ with respect to repair status, activity, and function. The average follow up was 4.5 years; 7 years for traditional and 3.5 years for accelerated. Limitations include, unequal group size, differing long term follow ups between groups, and age of groups; the accelerated group was older than the traditional group (28 vs 20 yrs). (Level V evidence)

Tiggelen DV, Coorevits P, Witvrouw E: The effects of a neoprene knee sleeve on subjects with a poor versus good joint position sense subjected to an isokinetic fatigue protocol. *Clin J Sport Med* 18:259–265, 2008.

The purpose of this randomized trial was to examine the effects of a neoprene knee sleeve on the joint position sense in locally fatigued subjects using the Cybex Norm isokinetic dynamometer. Sixty-four healthy subjects underwent four consecutive assessments of the same active joint-repositioning test under different conditions (braced, nonbraced, fatigued, and nonfatigued). They investigated the effects of side (braced vs control side), assessment sequence (one to four), and proprioceptive acuity ("good" versus "poor,") and their interactive effect on the joint position sense. At baseline (first assessment, the difference in repositioning error between both knees was not statistically significant. During the second and third assessments (when each subject on the experimental side wore an NKS, significant reduction in repositioning error was demonstrated on the experimental sides compared with the control side (P = 0.001 and P = 0.001). Once the brace was removed (fourth assessment), no statistically significant difference was observed between control and experimental sides. They also found that all subjects benefited from the braced condition after the fatigue test. The authors conclude that bracing is helpful in individuals with a poor baseline proprioceptive acuity in both fatigued and nonfatigued states, but only helpful when fatigued for subjects with a good joint position sense. The present findings suggest a rationale for using neoprene knee sleeves as a preventative measure or treatment in subjects and patients to enhance proprioceptive acuity in a fatigued state. (Level II evidence)

Wilk KE, Escamilla RF, Fleisig GS, et al: A comparison of tibiofemoral joint forces and electromyographic activity during open and closed kinetic chain exercises. *Am J Sports Med* 24:518–527, 1996.

The purpose of this cross sectional study was to investigate knee joint kinetics and muscles during open kinetic chain (OKC) (knee extension) and closed kinetic chain (CKC) (leg press and squat exercises). Ten healthy, resistance-trained, male subjects performed four repetitions using a 12-repetition maximal weight for each exercise. Knee compressive forces reached a maximum during CKC exercises; squat (6139 N), leg press (5762 N), followed by OKC knee extension (4598 N). These peak forces occurred at 91, 90, and 75 degrees knee flexion respectively. Posterior shear forces at the knee reached a maximums during the squat (1783 N), leg press (1667 N), and knee extension (1178 N). These occurred at 90, 94, and 91 degrees of knee flexion, respectively. A maximal anterior shear force of 248 N occurred during OKC knee extension at an angle of 14 degrees knee flexion.

Yao J, Lancianese SL, Hovinga KR, et al: Magnetic resonance image analysis of meniscal translation and tibio-menisco-femoral contact in deep knee flexion. *J Orthop Res* 26:673–684, 2008.

The purpose of this study was to clarify meniscal displacement and cartilage-meniscus contact behavior in a full extension position and a deep knee flexion position. The also assessed whether the meniscal translation pattern correlated with the tibiofemoral cartilage contact kinematics. Magnetic resonance (MR) images were acquired at both positions for 10 subjects using a conventional MR scanner. Subjects achieved a flexion angle averaging 139° ± 3°. Both medial and lateral menisci translated posteriorly on the tibial plateau during deep knee flexion. The posterior translation of the lateral meniscus (8.2 ± 3.2 mm) was greater than the medial (3.3 ± 1.5 mm). They report that this difference was correlated with the difference in tibiofemoral contact kinematics between medial and lateral compartments. They found that contact areas in deep flexion were approximately 75% those at full extension and the percentage of area in contact with menisci increased significantly due to deep flexion. The authors conclude that these results, in combination with information about force and pressure in the knee, may lead to a better understanding of the mechanism of meniscal degeneration and osteoarthritis associated with prolonged kneeling and squatting.

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Multiple-Choice Questions

QUESTION 1. The primary function(s) of mensci of the knee include which of the following?

A. Provide stress reduction and shock absorption.
B. Provide lubrication and nutrition.
C. Increase joint congruency and joint stability.
D. All of the above

QUESTION 2. As knee flexion angle increases, the compressive load transmitted through the posterior horns of each meniscus also increase, with _____% transmitted at 90° and _____% at 0° (full knee extension).

A. 25, 70
B. 85, 50
C. 60, 15
D. 90, 40

QUESTION 3. What essential goal must the athlete attain in order to successfully return to catching after meniscal repair?

A. Regaining full, symmetrical end-range flexion in fully loaded, weight-bearing positions
B. Full, symmetrical knee extension ROM in both non–weight-bearing and weight-bearing positions
C. Ability to perform a single leg squat beyond 120° knee flexion without loss of balance
D. None of the above

QUESTION 4. What type of periodization is incorporated by the author when implementing a rehabilitation program?

A. Undulating
B. Mesocycles
C. Macrocycles
D. Linear

QUESTION 5. According to Kiesel et al. (2007), athletes who scored a 14 or less on the FMS were ____ more at risk for injury?

A. 56%
B. 72%
C. 36%
D. 25%

Answer Key

QUESTION 1. Correct answer: **D** (found in Introduction)

QUESTION 2. Correct answer: **B** (found in Introduction)

QUESTION 3. Correct answer: **A** (found in Criteria to Progress from Stage to Stage section)

QUESTION 4. Correct answer: **A** (found in the Program Design section)

QUESTION 5. Correct answer: **C** (found in the Sport-Specific Testing section)

Chapter 31



Articular Cartilage Injury (Including Osteochondritis Dissecans) in the Young Athletic Knee

INTRODUCTION

Nathan A. Mall MD, Bryan M. Saltzman, MD, Andrew S. Lee, MD, and Brian J. Cole, MD, MBA

Epidemiology

Age

- Approximately 4% to 5% of the general population is thought to have focal, full-thickness cartilage defects.
  - Prevalence is higher in those undergoing arthroscopy, with one study finding 63% with chondral lesions, of which 19% were full thickness.
- A systematic review by Flanigan et al.[1] of 11 databases with athletes age 26 to 47 years (mean age of 33 years) demonstrated an overall prevalence of 36% for full-thickness focal chondral defects.
- DeHaven et al.[2] noted that athletes treated for internal derangement of the knee at University of Rochester Section of Sports Medicine over a 7-year period had a mean age of 22.9 years.
- Namdari et al.[3] analyzed 24 National Basketball Association (NBA) players between 1997 and 2006 and demonstrated a mean age of 28.6 years (range, 21 to 40) at which the athletes presented for surgical intervention of knee articular cartilage injury.
- Osteochondritis dissecans (OCD) has its prevalence highest in the 10 to 15 years age group; of note, in this demographic, 15% to 30% of cases involve bilateral knees.[4]

Sex

- Kujala et al.[5] noted the risk of knee osteoarthritis (OA) is five times higher in male former top athletes with previous knee injury than in the general population.
- Piasecki et al.[6] examined differences among high school athletes, determining that female basketball players sustained fewer cartilage lesions at the knee compared with males, yet there were no cartilage differences by gender with soccer or skiing.
- Stevenson et al.[7] demonstrated that in a cohort of 404 competitive alpine ski racers, female racers were 2.3 times more likely to have sustained a knee injury than were their male counterparts.

Sport

- Cartilage lesion location may be related to the player's sport.
  - Patellofemoral lesions are more common in basketball players, likely caused by contact forces from repeated jumping.
  - Increased participation by youth in such "cutting" (agility) sports as soccer, basketball, and football have reportedly increased the incidence of knee injuries.[8]
- In elite soccer players, 48% of lesions were found on the medial femoral condyle, 23% on the lateral femoral condyle, and 29% in the patellofemoral compartment.
- MRIs of collegiate and professional basketball players have demonstrated that 41% to 50% of players had abnormalities in their articular cartilage.

  - With 20 NBA players (40 total knees) from 1996 to 1999, Kaplan et al.[9] noted a prevalence of 47.5% for knee articular cartilage lesions.
  - In elite basketball players, the prevalence of asymptomatic articular cartilage lesions at the patellofemoral joint is from 35% to 41%.[9]
- 40.6% of retired NFL players under the age of 60 years reported arthritis of the knee in comparison with 11.7% of the general male population.[10]
  - A retrospective review of all National Football League (NFL) players between 1992 and 2006 revealed 118 knee articular cartilage injuries.[11]
  - During the 3-year period from 2005 to 2007, Hirshorn et al.[12] noted a prevalence of 20.1% for chondral injuries in the nation's top collegiate football players who had been asked to the NFL combine (a recruitment opportunity for players to display their abilities to prospective NFL teams).
  - In the 2005 NFL combine alone, Bradley et al.[13] reported that 2.4% of all football players (8 of 333) had osteochondral defects at the knee on initial medical evaluation.
- The knee joint is the most common joint injured in competitive alpine ski racing.[7]
- In a study by DeHaven et al.,[2] seven athletes with track injury sustained internal derangement of the knee (7.5% of total track injuries in this cohort) compared with eight athletes with baseball injury (10.3% of total baseball injuries in this cohort).

Position

- In evaluation of NFL combine athletes, the greatest prevalence of knee chondral injury was found with linebackers (32.2%), whereas the lowest prevalence of knee chondral injury was found with defensive backs (12.9%).[12]
  - Of note, linebackers in the Hirshorn et al.[12] report had the highest average body mass index (BMI) (31.9 kg/m^2), which in addition to this particular position's physical demands may help explain the high prevalence of articular cartilage injury in this football position.
- In their analysis of 118 NFL players' articular cartilage injury between 1992 and 2006, Brophy et al.[11] also reported that linemen had the greatest number of cartilaginous lesions (37% of total cohort).
- Namdari et al.[3] analyzed a cohort of 24 NBA players comprised of 11 guards, 10 forwards, and 3 centers who had knee articular cartilage damage.
  - Thus those positions that require fast cutting and agility movements over the course of a game seem to be overrepresented in this injury type.

Pathophysiology

Intrinsic Factors

- Athletes can suffer cartilage injury following repetitive microtrauma secondary to overuse or abnormal joint demands.
- Cartilage defects in younger athletes are typically caused by acute traumatic injury or injury secondary to osteochondritis dissecans (OCD).
  - The articular cartilage organization is similar to that of an open physis, and injuries likewise typically occur through the zone of provisional calcification.
- The cause of OCD is not delineated, with avascularity, repetitive trauma, and genetics all cited as independent causes; it may be multifactorial.
  - Genetic predisposition is a factor for articular cartilage injury, particularly with osteochondritis dissecans.[14,15]
  - Subchondral bone biomechanics plays a role in development of osteochondritis dissecans if the subchondral bone remains devascularized, which then subsequently fragments and increases mobility of the bone and overlying articular cartilage.[15]
- Joints that naturally have irregularly shaped articular surfaces are more likely to be injured in young athletes because of asymmetric loading and wearing patterns.[16]
- Increased BMI is strongly associated with knee articular cartilage injury in NFL quarterbacks, offensive tackles, and defensive backs.[12]
  - Research shows that young athletes with BMI greater than 30.5 kg/m^2 and weight greater than 222.5 lbs are at significantly increased risk for knee chondral damage.[12]
  - However, height is *not* a significant independent risk factor for cartilage injury.[12]
- Full-thickness cartilage defects do not heal and are likely to expand circumferentially over time; however, the natural history of cartilage defects has not been well studied.

Extrinsic Factors

- Participation in competitive sports, causing high intensity, direct joint impact
  - Consecutive arthroscopies (993) in Norway noted full-thickness cartilage lesions in 11% of knees, with sports participation as the most reported activity (49%).
- Delay in surgery
  - Church and Keating[17] noted an increase in degenerative changes in patients operated on with more than 12 months delay after injury as compared with less than 12 months delay.
- Intense physical activity and high-level sports contribute to osteochondritis dissecans.[18]

Traumatic Factors

- Traumatic cartilage damage is often found in the setting of an anterior cruciate ligament (ACL) tear.
  - Several studies have found changes in cartilage thickness and proteoglycan content in both the lateral and medial compartment following ACL injury.
- Fractures involving the articular surface necessitate precise reduction and fixation; 3-mm incongruities in the surface may involve increased local contact stress leading to OA posttraumatic OA.

- Abrasive wear on the knee joint with continued athletic activity results in superficial fibrillation of the cartilage, which progresses to subchondral bone.[19]
- Acute, large shear force as a sudden traumatic experience can disrupt the deep cartilage ultrastructure at the knee joint, ultimately damaging the cartilage.[19]
- Athletics with high levels of torsional loading, twisting, pivoting, rapid deceleration, and high impact forces increase susceptibility to developing articular cartilage damage owing to the effects of these combating force vectors on the integrity of the knee joint.[20]
- The NFL linebacker position must quickly pivot and exert lower extremity force in the course of a game; these rapid shear forces are proposed to be the cause for articular damage in this cohort.[12]
- Articular cartilage injuries in soccer players are hypothesized as follows[19]:
  - Extreme stresses befall the articular cartilage of the knee with the combination of high movement velocity and abrupt deceleration.
- Articular cartilage injuries in basketball players are hypothesized as follows[1]:
  - Plyometric jump training (an important component of competitive basketball) involves a strong contraction-extension mechanism at the patellofemoral joint.
  - Repetitive jumping causes repetitive stresses at the joint, which may cause patellofemoral joint damage at the articular cartilage.
- OCD in the elbow is typically seen more frequently in those that subject the elbow to repetitive trauma (gymnasts, pitchers); however, this relationship is not as obvious in OCD of the distal femur or talus.

Classic Pathological Findings

(See Figures 31-1 to 31-3.)

- MRI demonstrates a typical focal cartilage defect with adjacent bone edema on T2-weighted MRI sequence.
- Injury to articular cartilage in youth athletes occurs through the zone of provisional calcification at the joint.[15]



FIGURE 31-2. Full-thickness cartilage loss of on posterior MFC depicting denuded articular surface.

- In a full-thickness chondral injury, chondrocytes increase synthesis of extracellular matrix in an effort to repair the damaged section of cartilage.[20]
- The healing response to a full-thickness chondral injury begins with hematoma formation, followed by stem cell migration to produce type I collagen and allow vascular growth—note that this "healed cartilage" is less resilient to shear forces, easily damaged, and more likely to result in OA than is the original hyaline cartilage layer.[21]
- Outerbridge Classification of Cartilage Lesions[22]
  - Grade 0: Normal
  - Grade 1: Intact surface cartilage with softening and swelling
  - Grade 2: A partial-thickness defect with fissures on the surface that do not reach subchondral bone or exceed 1.3 cm in diameter
  - Grade 3: Fissuring to the level of subchondral bone in an area with a diameter greater than 1.3 cm
  - Grade 4: Exposed subchondral bone
- Chondral lesions are painful because the nerve endings of the subchondral bone after injury to overlying

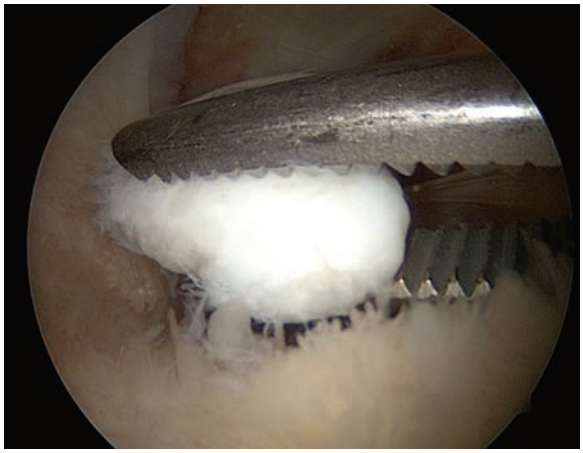

FIGURE 31-1. Arthroscopic photograph of a loose osteochondral fragment, which can produce mechanical symptoms in the knee.

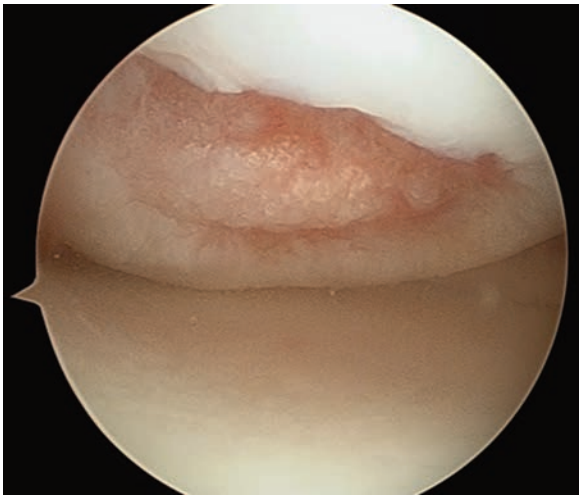

FIGURE 31-3. Chondral lesion.

articular cartilage become stimulated by the forces now faced by denuded bone.[19]
- Cartilaginous lesions that are full thickness can worsen as a result of structural changes in subchondral bone, intraarticular inflammatory cytokine release post damage, and stress forces concentrated around the rim of a chondral defect.[1]

Clinical Presentation

History

- Typically pain is present with weight bearing.
- Mechanical symptoms can be present if there is a flap of cartilage, a large cartilage defect, or a loose body.
- Swelling is classically reported with increased activity.
- Aching of joint after standing or during/after periods of inactivity
- Stiffness after periods of inactivity[23]
- Sensation of "giving way"
- Sensation of "catching"[23]
- Pain with stairs and steps, bent knee activity, and stiffness rising from a seated position can be present with patellofemoral cartilage defects, but characteristically also are associated with swelling.
- Levy et al.[19] reported from studies in young soccer players that the specific motions causing pain from chondral lesions were dependent on the location of the injury.
  - Patellar/trochlear lesions: pain with jumping, deceleration, extension phase of kicking
  - Anterior condylar lesions: pain with extension phase of kicking
  - Central condylar lesions: pain during pivoting, lateral movements
  - Posterior condylar lesions: pain with flexion phase of kicking, planting of the nonkicking leg
- In osteochondritis dissecans, patients often present with effusion, catching/locking (especially if loose body is present in the joint), and anterior knee pain.[14]
  - Adolescents with osteochondritis dissecans can, however, have vague symptoms.
- Some athletes will complain of a specific traumatic event from which the symptoms arose (i.e., slide tackle in soccer), whereas others will complain of insidiously progressive symptoms.[19]

Physical Examination

Abnormal Findings

- Swelling is a frequent sign of cartilage injury.
- Condyle defects may or may not have joint line tenderness, but frequently have tenderness to palpation on the medial or lateral condyle.
- Patellar or trochlear defects can present with anterior knee pain.
- Reduced active and passive range of motion (ROM)[24]; may be limited if a loose body is present or a significant effusion is limiting terminal flexion and extension.
- Functional strength loss at the knee joint[24]
- Crepitus can be evident.
  - A study by Ike et al.[25] of 20 athletes with knee joint chondral injury demonstrated a sensitivity of 54% with specificity of 100% for transmitted bony crepitus during clinical examination when the joint had tibial bare bone only, and a sensitivity of 88% with specificity of 100% for bone-on-bone rubbing owing to cartilage loss from injury.
- In particular, osteochondritis dissecans will demonstrate the following[14]:
  - Limited ROM
  - Effusion
  - Positive Wilson's test (reproducible pain with internal rotation of the tibia plus passive extension of the knee)
- A careful ligamentous examination should be performed because cartilage defects have been associated with ACL and other ligamentous deficiencies.
- Must evaluate overall limb alignment, and if clinical concern is present for malalignment, standing pelvis to ankle radiographs should be obtained.

Pertinent Normal Findings

- In the absence of concomitant ligamentous damage, there should be no increased ligamentous laxity on examination in comparison with the contralateral knee.[19]

Imaging

- Plain radiographs can
  - Help differentiate between more diffuse cartilage loss
  - Identify an OCD and/or a loose body if enough bone is present on the loose fragment
- X-rays are an important primary tool for assessment of the knee joint.
  - Those with K&L (Kellgren and Lawrence classification) grade 2 or more defined as OA
  - X-ray grading: Grade 0, no changes; Grade 2, definite osteophytes and possible narrowing of joint space; Grade 3, moderate multiple osteophytes, definite joint space narrowing, sclerosis and deformity; Grade 4, large osteophytes, marked narrowing of joint space, severe sclerosis and deformity of bone ends (Figure 31-4).
  - Evidence of osteochondritis dissecans lesions can be viewed with X-ray, most commonly on the lateral portion of the medial femoral condyle, and should be evaluated with standard weightbearing AP, lateral, and Merchant views[14] (Figure 31-5).
- Bilateral standing alignment radiographs should be obtained when clinical concern for varus or valgus alignment is present.
  - Weightbearing axis from the center of the femoral head to the midbody of the talus should be drawn and its intersection with the tibial plateau noted.
  - If this line falls into zone 2 or 3, realignment should be considered in the setting of a cartilage defect.
  - In some cases weightbearing axes falling into zone I may also benefit from realignment.
- MRI can be used to
  - Confirm the diagnosis

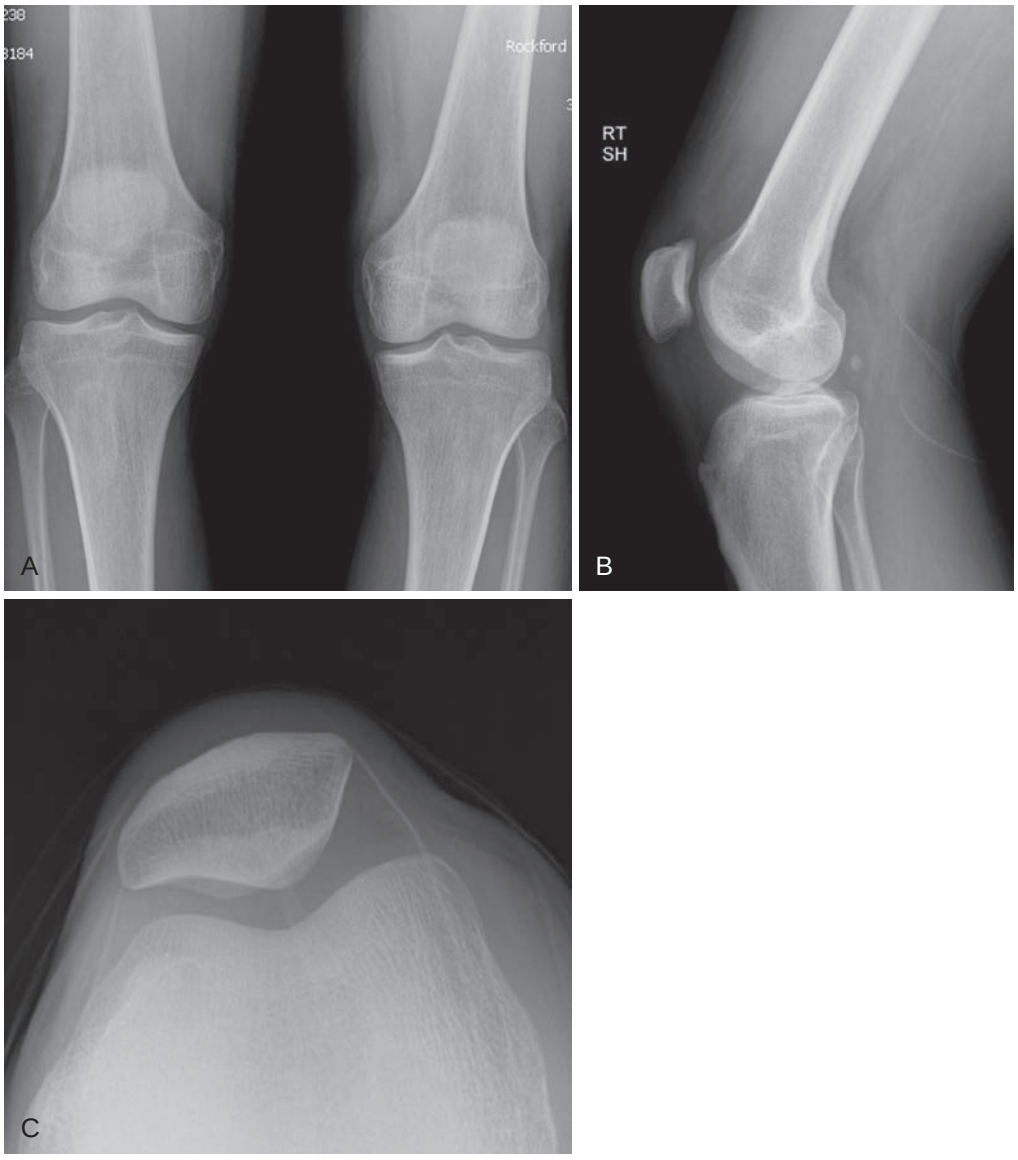

FIGURE 31-4. Radiographs with alternate views are important in delineating pathology and any observable changes: (**A**) Anteroposterior; (**B**) Lateral; (**C**) Merchant view.

  - Better define the cartilage lesion size and depth
  - Identify any concomitant pathology such as a meniscal tear which may mimic an articular cartilage defect on examination
  - Identify subchondral edema
- MRI is a valuable tool for evaluation of cartilage surface, tissue thickness, and subchondral bone signal intensity at the knee joint.[20]
  - Accuracy of 90% in evaluating cartilage injury in comparison with gold standard arthroscopy
  - Sequences utilized in assessing chondral pathology at the knee are T2 or intermediate (proton density) weighted fast spin-echo sequences.
  - Demonstrates chondral injury as regions of linear fissuring and surface irregularities with high signal joint fluid visible in the chondral defect
  - Depth, location, and size of the cartilage injury, as well as any concomitant bony or ligamentous damage can be determined through this means of imaging (Figure 31-6).
  - MRI grading
    - Grade 1, abnormal intrachondral signal but normal chondral surface
    - Grade 2, mild surface irregularity and/or focal loss of less than 50% thickness
    - Grade 3, severe surface irregularity with focal loss of 50% to 100% thickness
    - Grade 4, complete loss of articular cartilage with exposure of subchondral bone[26] (Figure 31-7).
- The gold standard imaging study for knee cartilage injury is arthroscopy.
  - Per Bachmann et al.,[27] the sensitivity for determining chondral injury with arthroscopy increases in proportion to the grade of the defect: I is 14%, II is 32%, III is 94%, IV is 100% (Figures 31-8 and 31-9).



FIGURE 31-5. Full body radiograph from pelvis to ankle allows for noting limb alignment, varus or valgus angulation.



FIGURE 31-6. MRI T2 Coronal view of meniscal injury with subchondral edema on the femoral condyle.

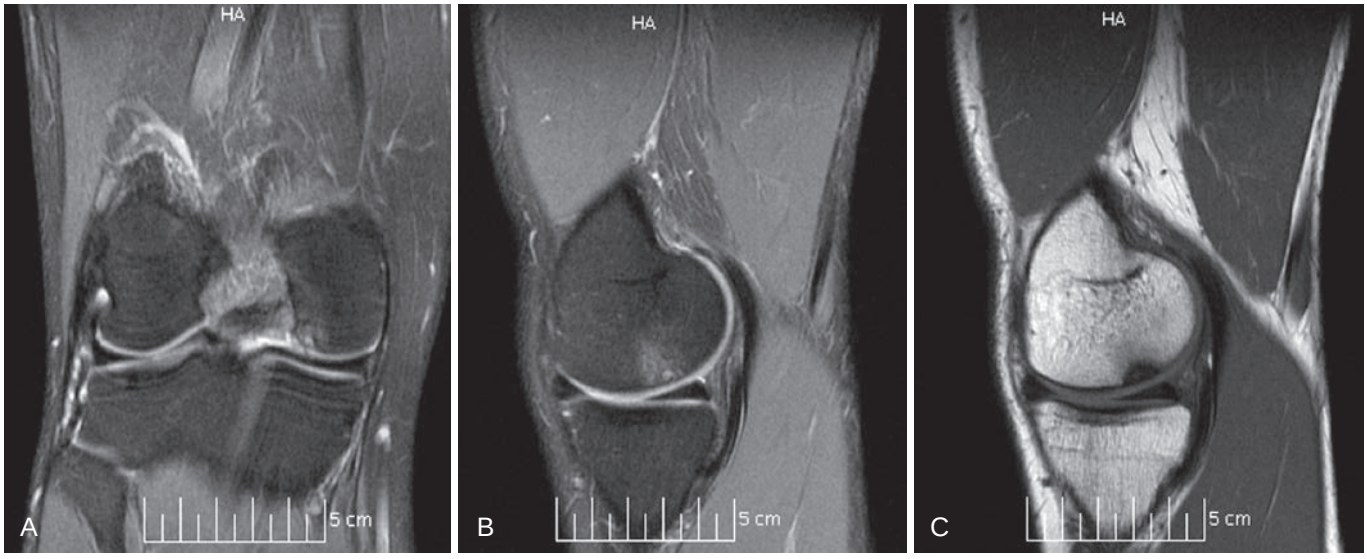

FIGURE 31-7. MRI of a 28-year-old physically active male reporting medial compartment pain with past history of skating injury, subchondral edema, and changes noted (**A**-**C**).

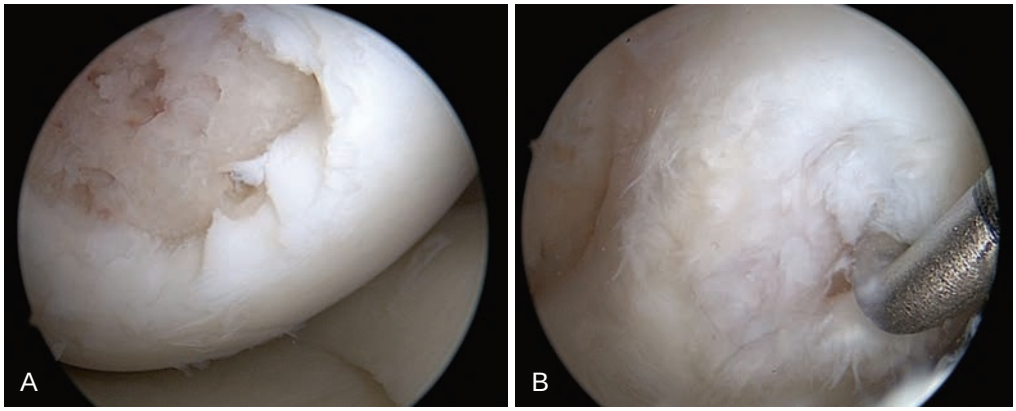

FIGURE 31-8. Arthroscopic display (**A**) and examination (**B**) of a grade IV (full-thickness) articular cartilage defect, located at the medial femoral condyle

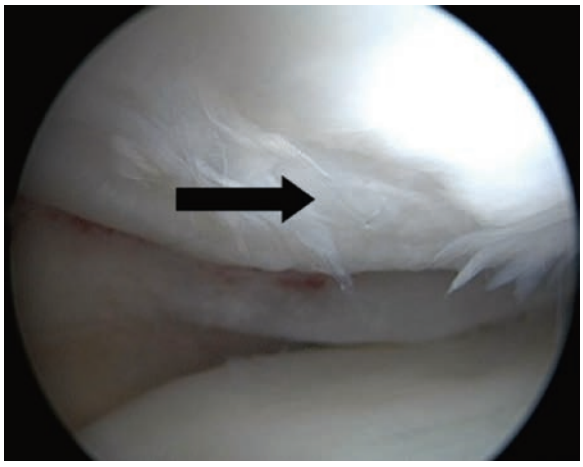

FIGURE 31-9. Grade IV lesion (*arrow*) of a 21-year-old female athlete with meniscal deficiency.

Differential Diagnosis

- Patellofemoral pain and cartilage defects of the patella or trochlea can produce similar symptoms.
  - Typically, these can be differentiated by the presence or absence of swelling.
- Generalized arthritis not amenable to cartilage restoration or repair
- Synovial impingement syndrome[14]
  - Pathologic plica
    - Pain aggravated by knee flexion and relieved with extension
    - Examination may reveal a thick, palpable cord
    - Normal radiographs, MRI with prominent plica
  - Hoffa syndrome
    - Swelling in the region of the knee fat pad
    - Tender to palpation in area of the fat pad
    - Positive Hoffa maneuver: apply compression to the sides of the fat pad while bringing knee into extension, causing pain/apprehension
- Osteochondroses/tendinitis (common in young athletes)[14]
  - Osgood-Schlatter
    - Tenderness, swelling, bony prominence evident around tibial tuberosity
  - Sinding-Larsen-Johansson
    - Tender to palpation focally near inferior pole of the patella
  - Patellar tendinitis
    - Pain focally in inferior pole of patella exacerbated by activity or palpation
    - Occurs often after a period of increased activity, intensity of sports training
    - Symptoms begin during activities only, but progress to occur with ADLs
    - Pain elicited on examination with decline squat test, which focuses stress on the patellar tendon
- Hip pathology[14]
  - For example, slipped capital femoral epiphysis, stress fracture
  - May present with referred pain to the knee joint
  - Significant pain at the hip when examined, which will not occur in the instance of focal knee cartilaginous injury
- Tumors[14]
  - For example, osteosarcoma, osteoid osteoma
  - Insidious onset not attributable by patient to any specific trauma from athletic endeavors
  - Will be evident with radiographic examination
- Meniscus tear[14]
  - Patient can often relay an instance during sport activities when he/she experienced a traumatic twisting movement at the knee while the knee was bent.
  - Maneuvers post injury that mimic this motion (such as getting out of a car) will elicit pain.
  - Examination demonstrates pain with squatting, positive McMurray test (pressing on joint line while stressing the meniscus), and present Cooper's sign (reported pain with turning over in bed at night).
- Ligamentous injury[14]
  - Instability is the major complaint
  - Many different examination techniques can deduce which ligament has sustained damage (Lachman test, anterior drawer test, pivot shift test, etc.).

Treatment

Nonoperative Management

- Nonsteroidal antiinflammatory medications
- Local ice/heat therapies
- Bracing, crutches to prevent weight bearing
- Weight reduction has the best evidence for improvement in pain and function
- Activity modification, such as resting from athletic activities
- Oral nutraceutical agents such as chondroitin sulfate, glucosamine, hyaluronic acid-based products either orally or by injection (have not be shown to be a cost-effective treatment)[20]
- Physical therapy for strengthening of the core, quadriceps; stretching of the anterior hip, hamstrings
  - Physical therapy can help strengthen the extremity and facilitate weight loss.

Guidelines for Choosing Among Nonoperative Treatments

- Asymptomatic partial-thickness chondral injuries can be managed conservatively.[20]
- Undisplaced intact chondral lesions may be treated nonsurgically.[20]
- Osteochondritis dissecans deemed stable can be managed nonsurgically.[14]
- Failure of conservative therapy with continued pain and symptoms related to the cartilage defect
  - Patients can have patellofemoral pain or pain related to other pathology intrinsic or extrinsic to the knee, which should be monitored.

Surgical Indications

- Relative indications[20]
  - Symptomatic (pain, swelling) partial-thickness or undisplaced intact chondral lesions

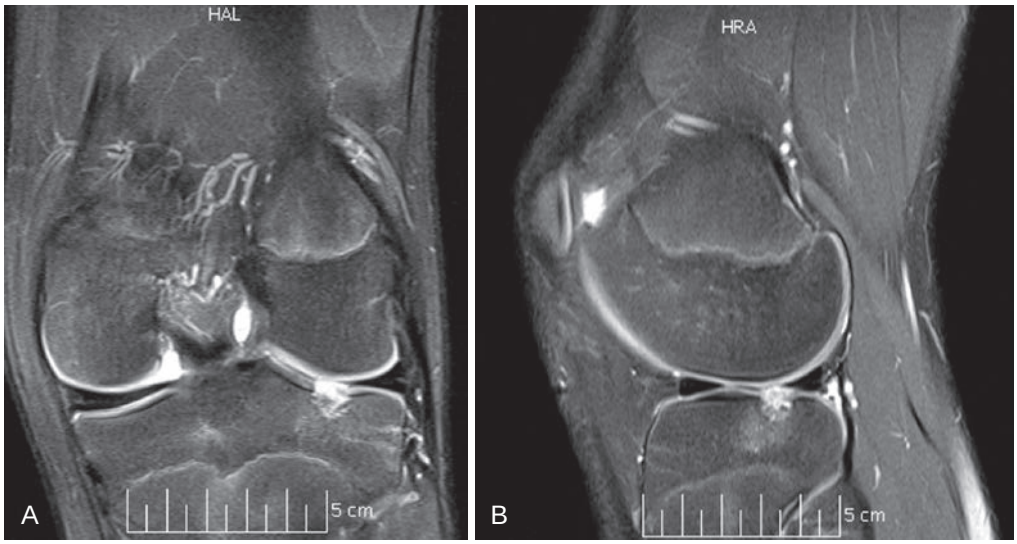

FIGURE 31-10. A 15-year-old male runner with past history of lateral right knee pain received microfracture of lateral tibial plateau as seen by (**A**) coronal and (**B**) sagittal MRI images.

- Absolute indications[14]
  - Those injuries that fail conservative treatment
  - Unstable lesions

Aspects of History, Demographics, or Exam Findings that Affect Choice of Treatment

- Length of time symptoms have been present has demonstrated an inverse relationship with outcomes.
- Patient age is a significant prognostic factor, but may be more related to physiologic age rather than chronologic age.
- Activity level and size of the lesion are factors in algorithms to determine treatment for symptomatic cartilage defects.
- Improved results have been demonstrated in patients with BMI less than 30.
- Indications for specific surgical interventions
  - Microfracture surgery[20]
    - For small, symptomatic articular cartilage lesions
    - Minimal costs in comparison to other techniques for those patients for whom invasive techniques are required but finances are an issue (Figure 31-10).
  - Autologous chondrocyte implantation (ACI)[20]
    - Requires a high level of patient compliance (involves 2 operations); best treatment for patients adherent to medical regimens and requests
    - Prolonged recovery time including many weeks of non–weight-bearing
  - Autologous and allogeneic osteochondral transplants[20]
    - Full-thickness osteochondral lesions if the knee is well-aligned and entirely stable on physical examination (Figure 31-11).

Aspects of Clinical Decision Making When Surgery Is Indicated

- Best surgical treatment option must be chosen for the athlete based on expected time to recovery, and patient adherence to pre- and postsurgical demands (i.e., physical therapy).
- Staging arthroscopy and ACI biopsy better delineate lesion size and location, depth, and concomitant pathology within the knee.
  - Lesions amenable to microfracture or osteochondral autografting can be performed at the time of staging arthroscopy
  - Some studies demonstrate that prior microfracture or other treatment may reduce the efficacy of ACI following clinical failure, leaving osteochondral allograft as the treatment of choice in most revision settings.
- Significant bony injury noted as bone edema on MRI warrants a procedure that addresses both injuries: either an osteochondral autograft for smaller lesions or osteochondral allograft for larger lesions.
  - Deeper lesions typically respond better to allograft or autograft fill; however, "sandwich" ACI techniques have been described with relatively good reported results.

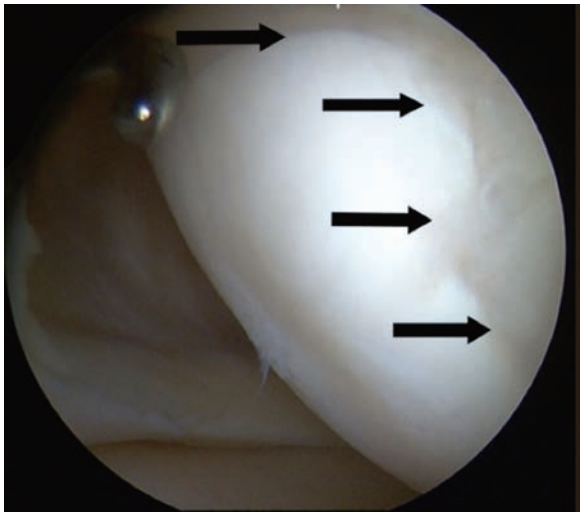

FIGURE 31-11. Osteochondral allograft to MFC in a 37-year-old male athlete with recurrent knee pain displaying excellent integration (*arrows* showing regions of integration).

- Microfracture, ACI, and other cell-based therapies have demonstrated reduced efficacy in patients with prolonged symptoms (greater than 1 year) or multiple prior procedures, which may influence the decision to use an osteochondral allograft.
- Patellofemoral defects are difficult to fill with osteochondral autograft or allograft because of the complex morphology that is patient specific despite adequate sizing (Figure 31-12).
- Lateral patellar facet lesions are typically treated with a concomitant anteromedialization of the tibial tubercle to help offload this area of the compartment, whereas medial facet lesions may benefit from a more vertical osteotomy and straight anteriorization (Figure 31-13).
- Loose bodies derived from OCD lesions of the weightbearing aspects of the femoral condyles may be amenable to fixation despite having relatively little bone on the loose fragment. Likelihood of healing is higher in younger individuals
- A survey among NFL team physicians by Brophy et al.[11] regarding knee articular cartilage injury demonstrated the following:
  - The most popular treatment for this type of injury was microfracture (43.3% of team physicians), second debridement (31.4%), then nonoperative management (13.2%), mosaicplasty (6%), osteochondral allograft (3.5%), and ACI (2.6%).
  - Size of the chondral injury was the most important factor to these physicians in making decisions about surgical management.

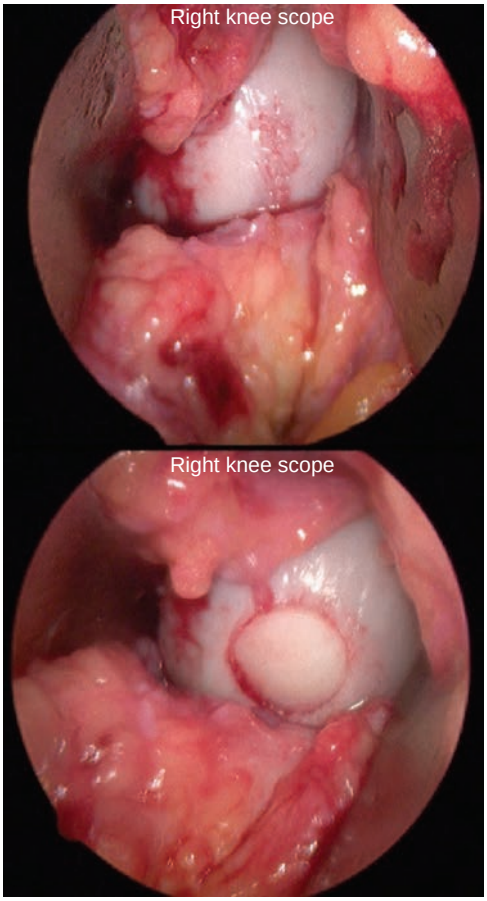

FIGURE 31-12. Osteochondral autograft transplantation (top) site of lesion before and (bottom) postimplantation.



FIGURE 31-13. Radiograph of ACL reconstruction with BPTB autograft and prior history of right anteromedialization procedure.

Evidence

Flanigan DC, Harris JD, Trinh TQ, et al: Prevalence of chondral defects in athletes' knees: A systematic review. *Med Sci Sports Exerc* 42:1795–1801, 2010.

This was a systematic review of studies that evaluated the prevalence of articular cartilage injury in athletes and was specific to the knee joint. (Level IV evidence)

Frobell RB: Change in cartilage thickness, posttraumatic bone marrow lesions, and joint fluid volumes after acute ACL disruption: a two-year prospective MRI study of sixty-one subjects. *J Bone Joint Surg Am* 93(12):1096–1103, 2011.

This study investigated the change in cartilage thickness and resolution of bone bruise over time following an ACL injury. Patients were extracted from a larger study investigating acute reconstruction versus delayed reconstruction versus nonoperative treatment following and ACL tear. (Level IV evidence)

Gudas R, Stankevicius E, Monastyreckiene E, et al: Osteochondral autologous transplantation versus microfracture for the treatment of articular cartilage defects in the knee joint in athletes. *Knee Surg Sports Traumatol Arthrosc* 14(9):834–842, 2006.

This prospective randomized clinical study compared the outcomes of mosaic type osteochondral autologous transplantation (OAT) and microfracture (MF) procedures in the treatment of 60 highly competitive, well-trained athletes under 40 years old (mean 24.3 years) with knee joint cartilage defects. At a mean 37.1 months follow-up, both MF and OAT procedures showed positive clinical results, but OAT was consistently statistically superior with respect to "excellent/good results" (OAT 96% of patients vs. MF 52%), Hospital for Special Surgery and International Cartilage Repair Society scores, and return to sports at preinjury level (93% vs. 52%). (Level I evidence)

Micheli LJ, Moseley JB, Anderson AF, et al: Articular cartilage defects of the distal femur in children and adolescents: treatment with autologous chondrocyte implantation. *J Pediatr Orthop* 26:455–460, 2006.

This registry-based, multicenter observational prospective study of 37 patients assessed the outcome of ACI in adolescents who had sustained symptomatic chondral lesions, at mean age 16 years (range, 11 to 17). At various follow-up time points (between 2 and 4.3 years), 88% of patients rated to have "good" or "excellent" level successful interventions from the procedure. (Level IV evidence)

Mithofer K, Minas T, Peterson, L, et al: Functional outcome of knee articular cartilage repair in adolescent athletes. *Am J Sports Med* 33:1147–1153, 2005.

This case series of 20 adolescent athletes evaluated the outcome of ACI in patients with full-thickness articular cartilage lesions of the knee who had failed previous surgical (1+ operations) or nonsurgical management. At minimum 2 year follow-up (mean 47 months), 96% rated their results as being "good" or "excellent" with significant increases in postoperative Lysholm and Tegner activity scores, and 60% returned to a level of athletic competition that was equal or superior in comparison to pre-injury level. (Level IV evidence)

Mithofer K, Peterson L, Mandelbaum BR, et al: Articular cartilage repair in soccer players with autologous chondrocyte transplantation: functional outcome and return to competition. *Am J Sports Med* 33(11):1639–1646, 2005.

This case series of 45 soccer players evaluated the autologous chondrocyte transplantation surgery as a treatment option for articular knee cartilage injury. At 41 months after the surgery, 72% of these players reported good to excellent results with significant subjective improvement through Tegner activity rating scale; 33% returned to play soccer with 80% of those playing again at the same preinjury skill level. Those players returning to soccer were significantly younger than those who weren't able to return, and had less time between onset of symptoms and date of surgery. (Level IV evidence)

Mithofer K, Williams RJ, Warren RF, et al: High-impact athletics after knee articular cartilage repair: A prospective evaluation of the microfracture technique. *Am J Sports Med* 34(9):1413–1418, 2006.

This case series of 32 athletes—all of whom sustained articular cartilage injury while involved in high-impact, pivoting sports—assessed whether microfracture surgery could return athletes to their respective high-impact sports. At final follow-up, 66% of athletes reported good to excellent results, with significant increases from preoperative state in activities of daily living, Marx activity rating scale, and Tegner activity scores. Consistent among the 47% of the cohort who returned to regular athletic competition was an age of less than 40 years, chondral lesion less than 200 mm^2 in size, preoperative symptoms of less than 12 months duration, and lack of previous surgical procedures. (Level IV evidence)

Namdari S, Baldwin K, Anakwenze O, et al: Results and performance after microfracture in National Basketball Association athletes. *Am J Sports Med* 37(5):943–948, 2009.

This case control study evaluated 24 NBA athletes who underwent microfracture (MF) surgery after sustaining knee articular cartilage injury. Ultimately, 33% of this cohort did not return to play in the NBA, whereas 58% returned to play for more than one additional season. In comparison with control NBA athletes, those undergoing MF had a significant drop in points scored per game, and were 8.15 times less likely to continue in the NBA. (Level III evidence)

Nho SJ, Pensak MJ, Seigerman DA, et al: Rehabilitation after autologous chondrocyte implantation in athletes. *Clin Sports Med* 29:267–282, 2010.

This article describes the pathophysiology of cartilage injuries and expounds on the biology of cartilage healing. It then describes the keys to proper rehabilitation to maximize cell viability, incorporation of the graft, and return to play.

Riyami M, Rolf C: Evaluation of microfracture of traumatic chondral injuries to the knee in professional football and rugby players. *J Orthop Surg Res* 4:13, 2009.

This case series of 24 professional male football and rugby players evaluated the short-term outcome of microfracture surgery in the treatment of full-thickness articular cartilage defects in the knee. At mean 6.2 months follow-up, 83.3% of players had resumed full athletic training. Function and MRI knee scores progressively improved at 6, 12, and 18 months postoperative. (Level IV evidence)

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Multiple-Choice Questions

QUESTION 1. A 21-year-old woman presents to her doctor with complaints of progressively worsening right knee pain since an episode of trauma while engaged in an athletic competition against her brother. It is determined through physical exam and imaging techniques that she has sustained damage to the articular cartilage of her right knee. In which of the following sports would she be more than twice as likely to sustain knee injury as compared to her brother?

A. Softball
B. Alpine ski racing
C. Squash
D. Ice skating

QUESTION 2. A 6 foot 8 inch collegiate football starting offensive tackle, weighing in at 320 lbs, presents to the team orthopedic surgeon with complaints of swelling and catching in his left knee. The symptoms have been present since his freshman year of college (he is currently a junior) and have not changed much in character. His father played in the NFL for 13 years also as an offensive tackle, and is left with osteoarthritis in his bilateral hips and knees. Which of the following is NOT an independent risk factor for the development of chondral injury in this athlete?

A. His BMI
B. Weight
C. Genetics
D. Height

QUESTION 3. A 14-year-old female soccer player complains to her physical therapist of new-onset left knee pain after kicking the soccer ball with enough force to fly 100 feet in practice 2 days ago. Which of the following collagen types is most likely being produced at this time at the site of injury by the patient's migrating stem cells?

A. Type I
B. Type II
C. Type III
D. Type IV

QUESTION 4. A 23-year-old professional NBA basketball player presents to the team orthopedic surgeon after landing awkwardly on his right knee in practice earlier that day. His doctor decides to order an MRI of the right lower extremity. Evaluation of the images demonstrates a mild irregularity at the chondral surface with loss of 32% thickness by computer measurements. What MRI Grade would this lesion be deemed?

A. Grade 1
B. Grade 2
C. Grade 3
D. Grade 4

QUESTION 5. A 16-year-old recreational basketball player presents to the monthly free orthopedic clinic at his local hospital. He had been given an appointment to return for a follow-up of his right knee pain 6 months ago, after he first presented with symptoms of joint pain and swelling 7 months ago. The patient reports that he hasn't been able to come in because he has to work 70 hours a week as a waiter to keep his job and pay to stay in his apartment. Now that he has finally returned the doctor orders an MRI of his right knee, which demonstrates a small chondral lesion of the articular cartilage. After discussing many different treatment options, it is decided that surgery will be performed. Which of the following is the most appropriate surgical intervention for this patient?

A. Microfracture
B. Autologous Chondrocyte Transplantation
C. Autologous Osteochondral Transplant
D. Allogeneic Osteochondral Transplant

Answer Key

QUESTION 1. Correct answer: **B** (see Epidemiology—Sex)

QUESTION 2. Correct answer: **D** (see Pathophysiology—Intrinsic Factors)

QUESTION 3. Correct answer: **A** (see Pathophysiology—Classic Pathologic Findings)

QUESTION 4. Correct answer: **B** (see Clinical Presentation—Imaging Studies)

QUESTION 5. Correct answer: **A** (see Treatment)

NONOPERATIVE REHABILITATION OF ARTICULAR CARTILAGE INJURIES

Andreas H. Gomoll, MD, and Reginald B. Wilcox III, PT, DPT, MS OCS

GUIDING PRINCIPLES OF NONOPERATIVE REHABILITATION

- Individualization
- Interdisciplinary team approach
- Restore the biomechanics of the knee
- Minimize pain and joint effusion
- Restore muscle function
- Restore soft tissue length
- Enhance proprioception and neuromuscular control
- Control loads across the lower extremity

Introduction

- These guidelines are for the postinjury rehabilitation course of a patient that has sustained an articular cartilage injury or undergone a restorative procedure. It is by no means intended to be a substitute for one's clinical decision making regarding the progression of a patient's postoperative course based on their physical exam/findings, individual progress, and/or the presence of postinjury complications. If a clinician requires assistance in the progression of a postinjury patient he or she should consult with the referring physician.
- The timelines are approximate ranges. The treating clinician should take into consideration patient/athlete presentation and achievement of clinical milestones in each phase.
- The acutely injured athlete will likely start with phase I of this guideline. However, the athlete who has been experiencing more of a subacute or chronic knee injury as the result of an articular cartilage lesion may begin this rehabilitation plan in phase II if pain and effusion are minimal and the athlete demonstrates little to no range of motion impairments.
- Following an articular cartilage injury, continuous monitoring of pain and effusion in response to all activity progression (exercise, weight-bearing, etc.) is vital to a successful rehabilitation process.

Phase I (weeks 0 to 4)

Protection

- Protected weight bearing with crutches is recommended to reduce the mechanical forces through the knee, to allow for a reduction in pain and effusion. The length of crutch use is determined by the location and severity of the lesion. Typically the individual with a large lesion on a weight-bearing surface of the knee will require a longer protected weight-bearing period.
- If patients present with a concomitant ligamentous injury, a significant inhibition of quadriceps function, and/or require some additional support beyond protected weight bearing, drop-lock rehabilitative hinged knee bracing is indicated to provide adequate stability to the knee during the acute phase of recovery and rehabilitation. If such a brace is needed, it would be locked in full extension for weight bearing activities and unlocked for non–weight-bearing activities.
- Individuals with persistent knee joint effusion may benefit from a compressive knee sleeve to assist in controlling effusion both during activities of daily living as well as exercise progression.

Management of Pain and Swelling

- The reduction of pain and joint effusion is crucial for restoring normal quadriceps function.[1]
- Treatment for pain/effusion
  - Cryotherapy (continuous cool system or ice packs) (Figure 31-14)
  - Elevation
  - High-voltage electrical stimulation
  - Cold laser
  - Compressive knee sleeve
  - Transcutaneous electrical nerve stimulation
  - Controlled passive range of motion
  - Analgesic and antiinflammatory medication. The latter can be contraindicated after certain procedures such as osteotomy and cartilage transplantation.



FIGURE 31-14. Cryotherapy and intermittent compression applied through a continuous cool device (Gameready; Coolsystems Corporation, Berkeley, CA) with elevation for effusion management.

Techniques for Progressive Increase in Range of Motion

- The early restoration of normal patellofemoral as well as tibiofemoral range of motion (ROM) is crucial to creating an optimal environment of healing for the knee.
- Specifically full knee extension, which for some individuals means a few degrees of hyperextension, is needed to ensure normal joint arthrokinematics to reduce patellofemoral and tibiofemoral contact pressure as well as minimize strain and fatigue of the quadriceps.[2] Full knee extension should be achieved within the first 2 weeks of therapy.
- Unless a mechanical block is noted, knee flexion range of motion typically will gradually progress toward normal as pain and effusion resolve.
- When regaining ROM following an articular cartilage injury it is important to not introduce shear forces while the joint is under compression, as this may have adverse effects on the lesion. ROM exercises should be done in a controlled manner. Evidence from both human and animal studies following articular cartilage repair supports early active and passive motion exercises to enhance tissue healing and reduce the potential risk of adhesions.[3] Unloading and immobilization have been reported to have a negative effect on the healing of articular cartilage.[4] Hence it is advised following an articular cartilage lesion that is going to be managed conservatively that one begins a controlled progressive range of motion program to promote healing and prevent further injury or degeneration.
- If an individual has access to a pool, it is recommended that aquatherapy be part of the rehabilitation plan. The buoyancy factor of water significantly decreases the amount of weight-bearing forces during pool exercises compared with land exercise.[5] After surgery, aquatherapy should be delayed until wound healing has occurred, usually after 2 weeks.

Manual Therapy Techniques

- Medial-lateral patella mobilizations performed by the therapist and patient to restore normal patella mobility
- Superior-inferior patella mobilizations performed by the therapist and patient to restore normal patella mobility (Figure 31-15)
- Tibiofemoral and tibiofibular mobilizations directed at restoring normal motion performed by the therapist

Soft Tissue Techniques

- Soft tissue mobilization is performed to prevent the development of scar tissue/adhesions from forming.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- General flexibility exercises performed by the therapist and patient to restore normal length of musculotendinous units
  - Hamstrings
  - Gastrocnemius/soleus
  - Hip abductors/adductors
  - Hip flexors
  - Quadriceps (once good quadriceps muscle function is restored and joint effusion is minimal)
- If an individual is having difficulty regaining the appropriate muscle length/integrity through therapist and self-guided stretching alone, then modalities such as moist heat and ultrasound may be used as an adjunctive intervention to facilitate greater gains.[6]

Other Therapeutic Exercises

- During phase I of rehabilitation injured athletes should actively participate in core stability strengthening, their typical upper body strengthening routine, and a cardiovascular conditioning program as their injured knee allows. Their injured knee should be supported and protected from further injury during all exercise.

TIMELINE 31-1: **Nonoperative Rehabilitation of Articular Cartilage Injuries**

PHASE I (weeks 0 to 4)	PHASE II (weeks 4 to 8)
• Protected weight-bearing with crutches • Drop-lock knee brace • Compressive sleeve • PT modalities for pain & effusion management • A/AA/PROM-knee extension to full; flexion to at least 120° as tolerated • Manual therapy and soft tissue techniques as indicated • Aquatherapy, if available • General lower extremity stretching; caution with quadriceps stretching • Moist heat & ultrasound for tissue warm-up for stretching if indicated • Quadriceps sets • 4-way straight leg raises as tolerated • NMES to quadriceps if poor contraction noted • 4-way angle strengthening with elastic band • Stationary bike without resistance if ≥ 95°–100° of flexion • TBS/TAS/TLS activities as tolerated with knee protected	• Weight bearing as tolerated • Progression off crutches • Unlocked knee brace • Compressive sleeve if indicated • PT modalities for pain & effusion management if indicated • A/AA/PROM-knee extension and flexion to full as tolerated • Manual therapy and soft tissue techniques as indicated • Progressed aquatherapy, if available • General lower extremity stretching; caution with quadriceps stretching • Quadriceps sets • 4-way straight leg raises with weights as tolerated • NMES to quadriceps if poor contraction noted • 4-way angle strengthening with elastic band • Weight shifting drills • Balance activities • Bilateral leg press; limit 0°–90° • Functional drills (i.e., step-ups) • Stationary bike with progressed resistance and time • TBS/TAS/TLS activities as tolerated with knee protected

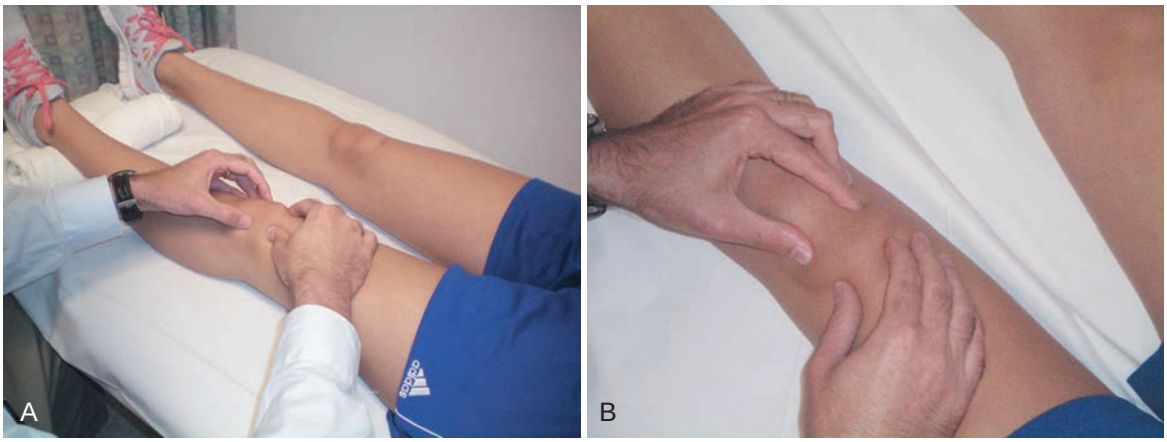

FIGURE 31-15. Therapist performed medial-lateral (**A**) and superior-inferior (**B**) patella mobilizations to enhance patella femoral motion.

Activation of Primary Muscles Involved

- Initially quadriceps muscle function restoration is key to early rehabilitation. The injured athlete should commence quadriceps sets, straight leg raises (begin with the locked knee brace if there is an active extension lag, then discontinue the brace for exercise when no lag is present), short (SAQ) and long arc (LAQ) AROM exercises. A/AA/PROM of knee to full extension and flexion as tolerated (avoid active knee extension (SAQ, LAQ, etc.) for 3 to 4 weeks if patellofemoral lesion is present); when active knee extension exercises are initiated they need to be completed within a range of motion that does not engage or compress the lesion. Hence it is important for the therapist and surgeon to communicate regarding the location of the lesion.
- If one is having difficulty initiating and/or maintaining an adequate quadriceps contraction with any of these exercises, the use of neuromuscular electrical stimulation (NMES) and/or biofeedback is indicated[7,8] (Figure 31-16).
- It is imperative that the injured athlete and the therapist make sure to not solely focus on the quadriceps. A balanced strengthening approach is needed to restore appropriate lower extremity function. A gradually progressed program of trunk, hip, and ankle exercises is needed to control normal lower extremity forces and excess forces through the injured knee.
- Lower extremity musculature needs to become strong following articular cartilage injury, to assist in absorbing normal lower extremity shock and dissipating applied loads across the knee joint.
- Throughout the early rehabilitation course, strengthening exercises should be chosen appropriately in order to minimize high sheer stress in conjunction with compressive forces. Hence the start of closed chain therapeutic exercises is delayed.

TIMELINE 31-1: **Nonoperative Rehabilitation of Articular Cartilage Injuries** (Continued)

PHASE III (weeks 8 to 12)	PHASE IV (weeks 12 +)
• DC drop-lock knee brace & crutches • Unloader OA knee brace and orthotics if indicated • A/ROM-knee extension and flexion to full as tolerated for maintenance • Manual therapy and soft tissue techniques as indicated • Progressed aquatherapy, if available • Swimming program; if pool is available • General lower extremity stretching • 4-way straight leg raises with weights as tolerated for exercise warm-up • Standing hip strengthening with either elastic band or circuit training equipment • Progressed weight-shifting drills • Balance activities • Perturbation training • Bilateral leg press progressed to unilateral leg press; limit 0°–90° • Functional drills (i.e., step-ups) • Stationary bike with progressed resistance and time • Elliptical trainer • Stairmaster • Walking program • TBS/TAS/TLS activities as tolerated	• Continue with maintenance program of lower extremity strengthening/stretching • TBS/TAS/TLS activities as tolerated • Begin and progress sports specific agility drills • Progress balance drills • Individualized impact loading program • Plyometric program • Return to pre-injury sports program as directed by physician and physical therapist as tolerated depending upon symptom presentation and size of lesion

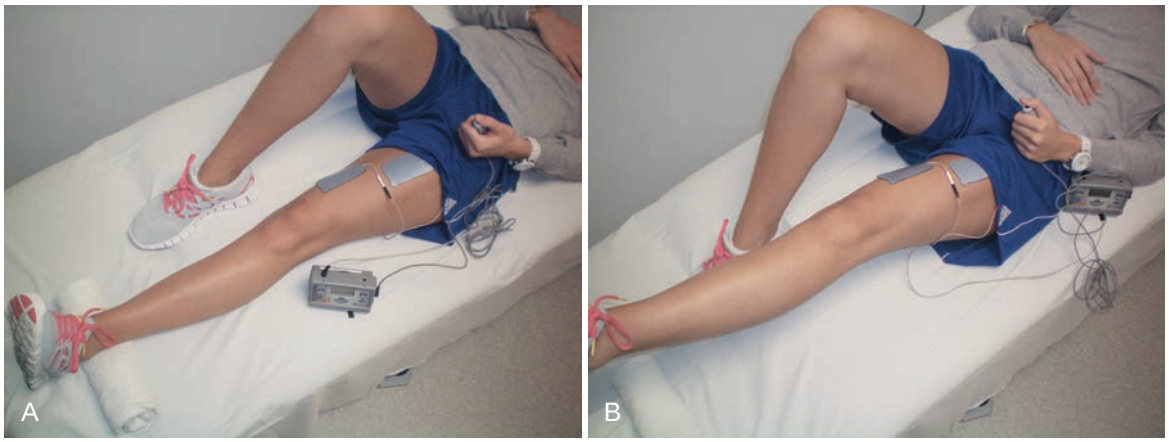

FIGURE 31-16. Neuromuscular electrical stimulation (300PV; Empi Corporation, St Paul, MN) applied to the quadriceps muscle during quadriceps sets (**A**) and straight leg raises (**B**).

Open and Closed Kinetic Chain Exercises

- Closed kinetic chain (CKC) exercises: Typically not indicated in the first phase of rehabilitation because of the weight-bearing stress they incur across either the femoral or tibia lesion following the acute injury.
- Open kinetic chain (OKC) exercises
  - A/AA/PROM of knee to full extension and flexion as tolerated. (Avoid active knee extension for 3 to 4 weeks if patellofemoral lesion is present; and for more than 6 months after cell-based cartilage repair in the patellofemoral joint to allow for tissue maturation.)
  - Hip, hamstring, calf stretching
  - 4-way ankle strengthening with elastic band
  - Quadriceps sets
  - Multiangle quadriceps/hamstring isometric contractions to start at 90° of flexion, as it is unlikely to produce excessive compressive or shear forces across most articular cartilage lesions. Caution is recommended with any isometric contractions between 20° and 75°, as there may be high compressive forces on most lesions in this range.
  - 4-way straight leg raises
    - Supine
    - Side lying for abductors
    - Side lying for adductors
    - Prone
  - Stationary bike without resistance if greater than or equal to 95° to 100° of flexion

Techniques to Increase Muscle Strength, Power, and Endurance

- To enhance the overall muscular function of the hip and knee musculature, it is advisable to work with a high-repetition low load to enhance muscular endurance and reduce the risk of injury. When progressing such exercises as the 4-way straight leg raises, athletes are advised to work up to 2 to 3 sets of 15 to 20 reps with no knee extension lag. When able to complete up to 60 repetitions in total, a progression in load (i.e., adding ankle weights in 1-lb. increments) is indicated.

Functional Exercises

- Gait training with crutches with protected weight bearing
- Encourage gradually progressed periods of time on feet with crutches to promote a return to daily activities.

Milestones for Progression to the Next Phase

- Minimal to no knee joint line tenderness
- Minimal knee pain at rest and/or light activities
- A steady reduction in knee joint effusion with no persistent effusion following progressively more challenging activities of daily living and/or therapeutic activities
- Full knee extension ROM comparable with the contralateral knee
- At least 120° of knee flexion
- Normal passive and active patellofemoral mobility. Passive patella mobility is assessed with the patient's knee in a relaxed and extended position. Active patella mobility is assessed during functional activities.
- Adequate quadriceps control (i.e., able to do at least 15 to 20 straight leg raises without a brace or lag and able to ambulate household distances with least assistive device with natural knee flexion and extension ROM).

Phase II (weeks 4 to 8, depending on lesion size and location)

- Note on rehabilitation after cell-based cartilage repair procedures (microfracture, autologous chondrocyte implantation [ACI, Carticel])
  - Generally speaking, cell-based repair procedures require a slower progression to allow for tissue maturation, which is initially very soft and vulnerable to shear forces. Therefore progression to phase II mostly does not occur until 12 weeks postop, while continuing to focus on restoration of motion and patellar mobility, reduction of swelling, and recruitment of

quadriceps and hamstring muscles through isometrics and electrical stimulation.

Protection

- At this point in rehabilitation the injured athlete should be ready to progress to weight bearing as tolerated. However, this timeframe will be dictated by the size, nature, and location of the lesion as well as the quantity of ROM restoration and overall muscular strength. In order to begin weaning from bilateral crutches the athlete should have full knee extension, at least 100° of knee flexion, have no lag with a straight leg raise or with walking. He/she may need one crutch or cane in the contralateral upper extremity for some assistance to avoid a pronounced limp for community distances. Those individuals with a large lesion on the weight-bearing surface of the femur may need to stay with bilateral crutches for another week or 2 to minimize pain and joint effusion.
- If the athlete has good quadriceps control, the drop-lock rehabilitative hinged knee brace is set for full motion and worn for an additional 2 weeks as he/she progresses overall activity level.
- Individuals with persistent knee joint effusion may still benefit from a compressive knee sleeve to assist in controlling effusion during both activities of daily living as well as exercise progression.

Management of Pain and Swelling

- If persistent pain and effusion are limiting rehabilitation progress, the continued use of the following interventions is still warranted. However, as each week passes the need for each intervention should be reduced.
  - Cryotherapy (continuous cool system or ice packs)
  - Elevation
  - High-voltage electrical stimulation
  - Cold laser
  - Compressive knee sleeve
  - Transcutaneous electrical nerve stimulation
  - Controlled passive range of motion
  - Analgesic medication

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Continue with medial-lateral patella mobilizations performed by the therapist and patient to restore normal patella mobility if still limited.
- Continue with superior-inferior patella mobilizations performed by the therapist and patient to restore normal patella mobility if still limited.
- Continue with tibiofemoral and tibiofibular mobilizations directed at restoring normal motion performed by the therapist if still limited.

Soft Tissue Techniques

- Continue with soft tissue mobilizations to prevent the development of scar tissue/adhesions from forming if soft tissue integrity has not been normalized.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- General flexibility exercises performed by the therapist and patient to restore normal length of musculotendinous unit
  - Hamstrings
  - Gastrocnemius / soleus
  - Hip abductors/ adductors
  - Hip flexors
  - Quadriceps stretching is typically appropriate at this stage of rehabilitation as long as there is good quadriceps muscle contraction and normalized patellofemoral movement.
- At this stage of rehabilitation the muscle length/integrity should be near normal, and adjunctive modalities such as moist heat and ultrasound are typically not warranted. Continued therapist and athlete guided stretching should be all that is needed to maintain appropriate tissue length.

Other Therapeutic Exercises

- During phase II of rehabilitation the injured athlete should continue to actively participate in core stability strengthening, their typical upper body strengthening routine and a cardiovascular conditioning program. Upright and/or recumbent exercise biking should be tolerated easily at this point of rehabilitation. If the injured athlete has successfully transitioned to full weight bearing without an assistive device, the gradual introduction of single line walking on a treadmill or stable ground can be introduced followed by the use of an elliptical trainer.

Activation of Primary Muscles Involved

- Continued focus on quadriceps muscle function restoration is crucial to rehabilitation. The injured athlete should be able to do repetitive progressed 4-way straight leg raises with weight and without a lag and the knee brace. Progression toward a graduated bilateral to unilateral leg press machine should commence during phase II to enhance functional quadriceps and general lower extremity strength prior to beginning higher level closed chain therapeutic exercises. It is still important that the injured athlete and their therapist make sure to not solely focus on the quadriceps. A balanced strengthening approach is needed to restore appropriate lower extremity function. A gradually progressed program of trunk, hip, and ankle exercises is needed to control normal lower extremity forces and excess forces through the injured knee.

Sensorimotor Exercises

- All the following therapeutic activities would be indicated once the injured athlete has regained appropriate quadriceps control, has little to no effusion, and can tolerate at least partial weight bearing without side effects for up to an hour.
  - Weight shifting side to side drills
  - Weight shifting forward and backward drills

- Weight shifting diagonal drills
- Bilateral mini-squats; limit 0° to 45°
- Bilateral minisquats on an unstable surface (wobble board, tilt board, air disc, etc.); limit 0° to 45°
- Balance activities onto and off from various unstable surfaces

Open and Closed Kinetic Chain Exercises

- OKC exercise
  - A/AA/PROM of knee to full extension and flexion as tolerated (avoid active knee extension (SAQ, LAQ, etc.) for 3 to 4 weeks if patellofemoral lesion is present); when active knee extension exercises are initiated, they need to be completed within a range of motion that does not engage or compress the lesion. Hence it is important for the therapist and surgeon to communicate regarding the location of the lesion.
  - Hip, hamstring, calf stretching
  - 4-way ankle strengthening with elastic band
  - Quadriceps sets
  - Multi-angle quad/hamstring isometric contractions
  - 4-way straight leg raises
    - Supine
    - Side lying for abductors
    - Side lying for adductors
    - Prone
- CKC exercises: When selecting closed chain exercises for a specific patient, knowledge of the defect location is critical, as it has been shown that different activities require various contacts on the tibiofemoral joint.[9,10] If the lesion is located in the anterior aspect of the tibiofemoral joint, full knee extension with CKC exercises needs to be avoided. Conversely if the lesion is in the posterior aspect of the joint, loading greater than 45° of flexion with CKC exercises should be initially avoided.
  - Leg press (allows for graded weight-bearing through the knee) in advance of doing minisquats; limit 0° to 90° (Figure 31-17)



FIGURE 31-17. Exercise such as a bilateral leg press assist the athlete in functional lower extremity strengthening while getting used to weight bearing through the involved knee.

  - Lunges
  - Step-ups
  - Step-downs
  - Stationary bike without resistance if greater than or equal to 95° to 100° of flexion. One needs to make sure the seat height is appropriate for any given lesion. The lower the seat height, the higher the patellofemoral joint compressive forces are. The higher the seat height, the less is the overall knee flexion range of motion. Initially seat height should be set high and then progressively lowered to normal seat height as range of motion progresses.

Techniques to Increase Muscle Strength, Power, and Endurance

- To continue to enhance the overall muscular function of the hip and knee musculature, it is advisable to work with a high-repetition low load to enhance muscular endurance and reduce the risk of injury. When progressing both OKC and CKC exercises athletes should work up to 2 to 3 sets of 15 to 20 reps with proper form without pain. When able to complete up to 60 repetitions in total, a progression in load and/or activity is indicated.

Neuromuscular Dynamic Stability Exercises

- See preceding Sensorimotor Exercises section.

Functional Exercises

- Gait training as needed to ensure proper gait mechanics without assistive device(s). Once able to fully weight bear without crutches without residual pain and/or effusion, a walking program can commence.

Milestones for Progression to the Next Phase

- Full flexion and extension ROM
- Full weight bearing with all activities
- No knee joint line tenderness
- Minimal to no knee pain with moderate activities
- No knee joint effusion following progressively more challenging activities of daily living and/or therapeutic activities
- Adequate strength
  - Hamstrings within 20% of contralateral extremity (as measured either via a comparison between isometric hand-held dynamometry and/or isokinetic dynamometry)
  - Quadriceps within 30% of contralateral extremity (as measured either via a comparison between isometric hand-held dynamometry and/or isokinetic dynamometry)
- Balance testing within 30% of contralateral extremity (as measured by assessing differences between single leg stance time and the Star Excursion Balance Test)
- Able to bike for 30 minutes or longer

Phase III (weeks 8 to 12)

Protection

- Most patients with a large lesion on a weight-bearing surface with uncorrected abnormal alignments and/or meniscus injury may benefit from an unloader osteoarthritic brace to unload the involved compartment. If an athlete has poor dynamic foot posture (i.e., excessive pronation in stance phase), the use of foot orthotics may be indicated in order to minimize the applied load across the articular cartilage of the knee. It is also recommended that athletes begin their low-impact activities with well-cushioned shoes and work out on softer surfaces in order to acclimate to returning to activities that produce normal to high ground reaction forces.

Management of Pain and Swelling

- At this stage of rehabilitation pain/effusion should not be an issue. The athlete may have some transient pain/minor effusion following a newly progressed activity. If so the use of Cryotherapy (continuous cool system or ice packs), elevation, and high-voltage electrical stimulation can be used following exercise to assist with pain/effusion reduction.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- At this stage of rehabilitation ROM deficits should not be an issue. If the athlete is prone to joint and/or soft tissue tightness, provide instruction in periodic self-mobilization of the patellofemoral, tibiofemoral, and tibiofibular joints prophylactically.

Soft Tissue Techniques

- At this stage of rehabilitation soft tissue deficits should not be an issue. If the athlete is prone to joint and/or soft tissue tightness, instruction in periodic self-massage/soft tissue techniques prophylactically is warranted.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- At this stage of rehabilitation the muscle length/integrity should be normal, and general flexibility exercises performed by the athlete to maintain normal length of the musculotendinous unit prior to and following exercise are:
  - Hamstrings
  - Gastrocnemius / soleus
  - Hip abductors/ adductors
  - Hip flexors
  - Quadriceps

Other Therapeutic Exercises

- During phase III of rehabilitation the injured athlete should continue to actively participate in core stability strengthening, typical upper body strengthening routine, and a cardiovascular conditioning program. Upright and/or recumbent exercise biking and a progressed walking program on either a treadmill, elliptical trainer, or outdoors on stable ground should be tolerated well.

Activation of Primary Muscles Involved

- At this stage of rehabilitation a continued balanced strengthening approach is needed to restore appropriate lower extremity function. A gradually progressed program of trunk, hip, and ankle exercises is recommended to control normal lower extremity forces and excessive forces through the injured knee.

Sensorimotor Exercises

- All the following therapeutic activities should be progressed in terms of difficulty (i.e., repetitions, time, intensity, etc.).
  - Weight-shifting side to side drills
  - Weight-shifting forward and backward drills
  - Weight-shifting diagonal drills
  - Bilateral minisquats; limit 0° to 45°
  - Bilateral minisquats on an unstable surface (wobble board, tilt board, air disc, etc.); limit 0° to 45° (Figure 31-18)
  - Balance activities onto and off from various unstable surfaces
  - Perturbation drills

Open and Closed Kinetic Chain Exercises

- OKC exercises
  - 4-way straight leg raises for an exercise warmup
    - Supine
    - Side lying for abductors
    - Side lying for adductors
    - Prone



FIGURE 31-18. Minisquats on an unstable wobble board. The athlete is instructed to perform the minisquat while minimizing wobble board movement.

- LAQ
- Stationary bike with gradually progressed resistance and time
- Can begin swimming program

- CKC exercises:
  - Leg press (allows for graded weight bearing through the knee) in advance of doing minisquats; limit 0° to 90°
  - Bilateral squats; limit 0° to 60°
  - Lunges
  - Step-ups
  - Step-downs
  - Progressed walking program (treadmill, elliptical trainer, or outdoors) in terms of distance, cadence, incline, etc.
  - Can begin use of Stairmaster
  - Wall sits
  - Standing hip strengthening (abduction/adduction) with either resistive bands or circuit training equipment

Techniques to Increase Muscle Strength, Power, and Endurance

- To continue to enhance the overall muscular function of the hip and knee musculature it is advisable to work with a high-repetition low load to enhance muscular endurance and reduce the risk of injury. When progressing both OKC and CKC exercises, athletes should work up to 2 to 3 sets of 15 to 20 reps with proper form without pain. When able to complete up to 60 repetitions in total, a progression in load and/or activity is indicated.

Neuromuscular Dynamic Stability Exercises

- See preceding Sensorimotor Exercises section.

Functional Exercises

- As long as the athlete is tolerating the previously started walking program, this walking program should be advanced in terms of time, distance, intensity, and terrain as tolerated.

Sport-Specific Exercises

- Agility and sport specific activities can commence at this stage of rehabilitation as long as clinically the athlete's knee is progressing as expected and that pain and effusion are under control. Such activities should be sport specific and initiated at about 50% effort and progressed to full effort into phase IV of rehabilitation as tolerated. Initiate to full effort only when such activities do not induce recurrent or persistent pain or effusion.

Milestones for Progression to the Next Phase

- Full nonpainful ROM
- No knee joint effusion following progressively more challenging activities of daily living and/or therapeutic activities
- Adequate strength
  - Hamstrings within 10% of contralateral extremity (as measured either via a comparison between isometric hand-held dynamometry and/or isokinetic dynamometry)
  - Quadriceps within 10% of contralateral extremity (as measured either via a comparison between isometric hand-held dynamometry and/or isokinetic dynamometry)
- Balance testing within 20% of contralateral extremity (as measured by assessing differences between single leg stance time and the Star Excursion Balance Test)
- Able to walk for 1 hour or longer

Phase IV (weeks 12+)

Protection

- Continued use of unloader osteoarthritic brace to unload the involved compartment and foot orthotics if previously recommended, minimizing the applied load across the articular cartilage of the knee

Management of Pain and Swelling

- At this stage of rehabilitation pain/effusion should not be an issue. The athlete may have some transient pain/minor effusion following a newly progressed activity. If so the use of Cryotherapy (continuous cool system or ice packs), elevation, and high-voltage electrical stimulation can be used following exercise to assist with pain/effusion reduction.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- At this stage of rehabilitation ROM deficits should not be an issue. If the athlete is prone to joint and/or soft tissue tightness, provide instruction in periodic self-mobilization of the patella femoral, tibiofemoral, and tibiofibular joints prophylactically.

Soft Tissue Techniques

- At this stage of rehabilitation soft tissue deficits should not be an issue. If the athlete is prone to joint and/or soft tissue tightness, instruction in periodic self-massage/soft tissue techniques prophylactically is warranted.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- At this stage of rehabilitation the muscle length/integrity should be normal, and general flexibility exercises performed by the athlete to maintain normal length of the musculotendinous unit prior to and following exercise are:
  - Hamstrings
  - Gastrocnemius / soleus
  - Hip abductors/ adductors
  - Hip flexors
  - Quadriceps

Other Therapeutic Exercises

- During phase IV of rehabilitation the injured athlete should continue to actively participate in core stability strengthening, typical upper body strengthening routine, and a cardiovascular conditioning program. Upright and/or recumbent exercise biking and a progressed jogging program on either a treadmill, elliptical trainer, or outdoors on stable ground should be tolerated well.

Activation of Primary Muscles Involved

- At this stage of rehabilitation a continued balanced strengthening approach is needed to restore appropriate lower extremity function. A gradually progressed program of trunk, hip, and ankle exercises is recommended to control normal lower extremity forces and excess forces through the injured knee.

Sensorimotor Exercises

- Progressed weight-shifting side to side drills
- Progressed weight-shifting forward and backward drills
- Progressed weight-shifting diagonal drills
- Bilateral minisquats; no range of motion limit as long as asymptomatic
- Bilateral minisquats on an unstable surface (wobble board, tilt board, air disc, etc.); no range of motion limit as long as asymptomatic
- Progressed balance activities onto and off from various unstable surfaces
- Perturbation drills

Open and Closed Kinetic Chain Exercises

- OKC exercises
  - 4-way straight leg raises for an exercise warmup
    - Supine
    - Side lying for abductors
    - Side lying for adductors
    - Prone
  - LAQ
  - Stationary bike with progressed resistance and time
  - Swimming program
- CKC exercises
  - Progressed leg press from bilateral press to unilateral press as tolerated (allows for graded weight-bearing through the knee)
  - Bilateral squats; typically would limit 0° to 80°, but this range of motion should be adjusted based on the location of the lesion.
  - Lunges
  - Step-ups
  - Step-downs
  - Progressed running program (treadmill, elliptical trainer, or outdoors) in terms of distance, cadence, incline, etc.
  - Standing hip strengthening (abduction/adduction) with either resistive bands or circuit training equipment

Techniques to Increase Muscle Strength, Power, and Endurance

- To continue to enhance the overall muscular function of the hip and knee musculature, it is advisable to work with a high-repetition low load to enhance muscular endurance and reduce the risk of injury. When progressing both OKC and CKC exercises athletes should work up to two to three sets of 15 to 20 reps with proper form without pain. When able to complete up to 60 repetitions in total then a progression in load and/or activity is indicated.

Neuromuscular Dynamic Stability Exercises

- See preceding Sensorimotor Exercises section.

Plyometrics

- Plyometrics should be started with slow, controlled movements and then progressed to more explosive type activities. The rationale behind a plyometric program is to train the musculature, connective tissue, and nervous system to perform through cycles of stretch-shortening with proper technique and mechanics. It has been shown that modifiable knee injury risk factors of decreased landing forces, decreased varus/valgus moments, and enhanced muscle activation have resulted from plyometrics, dynamic balance and strengthening programs, stretching, body awareness and decision-making drills, and core stabilization drills.[11]

Functional Exercises

- As long as the athlete is tolerating the progression from a walking program to a jogging/running program, this program should be advanced in terms of time, distance, intensity, and terrain as tolerated (Box 31-1).

Sport-Specific Exercises

- The overall timing of return to full preinjury athletic activity is dependent upon the athlete, lesion type and location, other comorbidities, and the specific sports-related activities that the athlete needs to be able to achieve. During phase IV of rehabilitation the athlete should be in a position to begin sport-specific practices, first at 50% effort level and then progressed at no faster than a 10% incremental intensity per week until back to full intensity.

Milestones for Progression to Advanced Sport-Specific Training and Conditioning

- Full nonpainful ROM
- No knee joint effusion following progressively more challenging sport-specific drills and training
- Adequate strength
  - Hamstrings within 5% of contralateral extremity (as measured either via a comparison between

BOX 31-1 Return to Running Program*

Phase I: Walking Program

Patient should be able to walk, pain free, aggressively (roughly 4.2 to 5.2 miles per hour), in a controlled environment, preferably on a treadmill, before beginning the plyometric and walk/jog program.

Phase II: Plyometric Routine

A mile run typically consists of 1500 foot contacts, 750 per foot. This program integrates 470 foot contacts per leg, which would be equivalent to two thirds of the foot contacts during a mile run. Successful completion of this phase is a good indicator that an athlete is ready to attempt running a half to three-quarters of a mile distance.

EXERCISE	SETS	FOOT CONTACTS PER SET	TOTAL FOOT CONTACTS
Two-leg ankle hops: in place	3	30	90
Two-leg ankle hops: forward/backward	3	30	90
Two-leg ankle hops: side to side	3	30	90
One-leg ankle hops: in place	3	20	60
One-leg ankle hops: forward/backward	3	20	60
One-leg ankle hops: side to side	3	20	60
One-leg leg broad hop	4	5	20
	22		470

REST INTERVALS:

Between Sets: 90 seconds
Between Exercises: 3 minutes

GENERAL GUIDELINES

- Stretch Gastro, Soleus, Quads and Hamstrings between exercises.
- If a patient experiences pain or is unable to complete an exercise, stop, stretch, and apply ice to the involved area. Patient should be pain free the next day; attempt to restart the routine.

Phase III: Walk/Jog Progression

Patient should begin this program on level ground if:
1. Successfully completed Phase I and II
2. Does not have pain with normal daily activities

	WALK	JOG	REPETITIONS	TOTAL TIME
Stage I	5 minutes	1 minute	5 times	30 minutes
Stage II	4 minutes	2 minutes	5 times	30 minutes
Stage III	3 minutes	3 minutes	5 times	30 minutes
Stage IV	2 minutes	4 minutes	5 times	30 minutes
Stage V	Jog every other day with a goal of reaching 30 consecutive minutes; begin with 5 minutes of walking, gradually increasing the pace. End with 5 minutes of walking, gradually decreasing the pace to a comfortable walk.			

*When beginning a return to running program a runner and therapist should take into consideration the original injury/underlying health status in order to modify this program accordingly. A runner should progress through this program one phase at a time.

isometric hand-held dynamometry and/or isokinetic dynamometry)
  - Quadriceps within 5% of contralateral extremity (as measured either via a comparison between isometric hand-held dynamometry and/or isokinetic dynamometry)
- Balance testing within 10% of contralateral extremity (as measured by assessing differences between single leg stance time and the Star Excursion Balance Test)
- Able to complete full sport-specific workouts two to three times per week without recurrent pain and knee joint effusion

Performance Enhancement and Beyond Rehabilitation: Training/Trainer and Optimization of Athletic Performance

- Once an athlete has achieved the above milestones and has returned to athletic activity following conservative treatment of an articular cartilage lesion of the knee, it is advisable to continue a generalized core and lower extremity strengthening program. Such a program will ensure maximal muscular function to minimize stress through the knee joint.

- The continued use of the unloader brace and orthotics (if prescribed) are advised to assist in minimizing applied forces across the knee joint.

Specific Criteria for Return to Sports Participation: Tests and Measurements

- Before discussion of return to sports activity following conservative management of the athlete with an articular cartilage lesion, it is important for the clinician to know that, generally, the return to sport rate for those having undergone a surgical repair for an articular cartilage lesion is 73%.[12]
- It has also been shown that those with a smaller lesion, shorter duration of symptoms, less invasive surgical procedure, and fewer prior surgical procedures have a higher return to sports rate.[10]
- Currently there is no literature that reports return to sports following conservative management of the athlete with an articular cartilage lesion. One could predict based on the surgical literature that the younger athlete with the smaller lesion that is on a joint surface that withstands less weight-bearing forces will be more successful in returning to her/his previous sports activity.
- Specific criteria
  - Full nonpainful ROM
  - No knee joint effusion following progressively more challenging sport specific drills, training, and scrimmages
  - Adequate strength maintained after beginning sports specific training
  - Hamstrings within 5% of contralateral extremity (as measured either via a comparison between isometric hand-held dynamometry and/or isokinetic dynamometry)
  - Quadriceps within 5% of contralateral extremity (as measured either via a comparison between isometric hand-held dynamometry and/or isokinetic dynamometry)
  - Able to complete full sport-specific workouts three to four times per week without recurrent pain and knee joint effusion

Evidence

Alentorn-Geli E, Myer GD, Silvers HJ, et al: Prevention of noncontact anterior cruciate ligament injuries in soccer players. Part 2: a review of prevention programs aimed to modify risk factors and to reduce injury rates. *Knee Surg Sports Traumatol Arthrosc* 17:859–879, 2009.

This review article outlines the most recent literature regarding the effects of prevention programs to alter risk factors associated with noncontact ACL injuries in soccer players. Preseason injury prevention and in-season maintenance programs of plyometrics, dynamic balance, body awareness, decision making, and core strengthening have been shown to be the most successful in modifying injury risk factors. (Level IV evidence)

Delitto A, Rose SJ, McKowen JM, et al: Electrical stimulation verses voluntary exercise in strengthening thigh musculature after anterior cruciate ligament surgery. *Phys Ther* 68(5):660–663, 1988.

This prospective, randomized trial followed 20 patients after ACL surgery: 10 in the voluntary quadriceps exercise group and 10 in the electrical stimulation group. Those in the electrical stimulation group demonstrated higher percentages of flexion and extension torque when compared with the voluntary exercise group at 3 weeks postop. (Level I evidence)

Harrison RA, Hillman M, Bulstrode S: Loading of the lower limb when walking partially immersed. *Physiotherapy* 78:165, 1992.

This descriptive study reported on the buoyancy of the water and how it decreases the amount of weight-bearing forces to approximately 25% of the individual's body weight when submerged to the level of the axilla, and 50% of the individual's body weight when submerged to the level of the waist. (Level IV evidence).

Martelli S, Pinskerova V: The shapes of the tibial and femoral articular surfaces in relation to tibiofemoral movement. *J Bone Joint Surg Br* 84(4):607–613, 2002.

This study of cadaver knees using two techniques, MRI and computer interpolation of sections of the articular surfaces of the knee, reported the shapes of the tibial and femoral articular surfaces. These shapes suggest contact zones of the articular cartilage during typical knee movements. (Level IV evidence)

Mithoefer K, Hambly K, Della Villa S, et al: Return to sports participation after articular cartilage repair in the knee. *Am J Sports Med* 37(S1):167S–176S, 2009.

This systematic review of athletic participation after articular cartilage repair demonstrated that at an average of 42 months postop, up to73% of patients were able to return to their preinjury level. The time to return to sports ranged between 7 and 18 months. (Level III Evidence)

Patel VV, Hall K, Ries M, et al: A three-dimensional MRI analysis of knee kinematics. *J Ortho Res* 22(2):283–292, 2004.

This descriptive study described the normal, in vivo tibiofemoral joint kinematics in multiple weight-bearing positions of 10 volunteers using MRI techniques. (Level IV evidence)

Perry J, Antonelli D, Ford W: Analysis of knee joint forces during flexed-knee stance. *J Bone Joint Surg* 57A(7):961–967, 1975.

This cadaver based study described the forces of the quadriceps, patella, and tibia during flexed knee stance. They found that the quadriceps force was equivalent to 20% of the average maximum quadriceps strength at 15° and to 50% at 30°, compared with tests on five normal subjects. (Level IV evidence)

Robertson VJ, Ward AR, Jung P: The effect of heat on tissue extensibility: A comparison of deep and superficial heating. *Arch Phys Med Rehabil* 86:819–825, 2005.

This double-blind, prospective, repeated-measures trial compared the effects of deep heating and superficial heating on tissue extensibility. Twenty four subjects were randomized into 3 groups; deep heating, superficial heating, and no heating. The extensibility of the calf musculature was assessed following intervention. It was found that deep heating in the

absence of stretching increased the tissue extensibility more than the other 2 groups. (Level II evidence)

Rodrigo JJ, Steadman JR, Silliman JF: Improvement of full thickness chondral defects healing in the human knee after debridement and microfracture using CPM. *Am Knee Surg* 7:109–116, 1994.

This descriptive study reporting the effects of the use of a CPM following surgical intervention for the management of full-thickness articular surface defects found better gross healing of the lesion when evaluated by arthroscopic visualization as compared with those that did not use a CPM. This study suggests that those who include frequent range of motion activities following surgery and maybe even articular cartilage injuries can promote better healing. (Level IV evidence)

Snyder-Mackler L, Dellitto A, Bailey SL, et al: Strength of the quadriceps femoris muscle and functional recovery after reconstruction of the anterior cruciate ligament. A prospective, randomized clinical trial of electrical stimulation. *J Bone Joint Surg Am* 77:1166v1173, 1995.

This prospective randomized trial of 110 patients following ACL reconstruction were assigned to treatment with high intensity NMES, volitional exercise, low intensity NMES, or combined high and low intensity NMES. After 4 weeks the strength of the quadriceps femoris and the kinematics of the knee during stance phase were assessed. Those that received high intensity NMES (from either of the two groups) demonstrated significantly better quadriceps strength and kinematics of the knee. (Level I evidence)

Spenser JD, Hayes KC, Alexander IJ: Knee joint effusion and quadriceps reflex inhibition in man. *Arch Phys Med Rehabil* 65(4):171–177, 1984.

This descriptive study reported on the role of effusion in producing the reflex inhibition and atrophy of the quadriceps musculature following knee trauma. Ten subjects were assessed in this study following incremental injection of saline into the knee joint. All subjects demonstrated a reduction in the Hoffmann reflex amplitude following saline injection. The threshold for reflex inhibition of the vastus medialis was between 20 and 30 mL and between 50 and 60 mL for the rectus femoris and the vastus lateralis. (Level IV evidence)

Vanwanseel B, Lucchinett E, Stussi E: The effects of immobilization on the characteristics of articular cartilage: Current concepts and future directions. *Osteoarthritis Cartilage* 10(5): 408–419, 2002.

This descriptive animal-based study looking at the morphological, biomechanical, and biochemical properties of articular cartilage reports that thinning and softening of the cartilage is significant after 11 weeks of immobilization. The tissue deformation rate following this immobilization under load increased significantly. (Level IV evidence)

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Multiple-Choice Questions

QUESTION 1. Which of the following are considered key factors to consider when devising a nonsurgical rehabilitation program for a patient who has had an articular cartilage injury?

A. Minimize pain and joint effusion
B. Restore muscle function
C. Enhance proprioception and neuromuscular control
D. All the above

QUESTION 2. What type of joint forces should be avoided while performing exercises during the early phases of rehabilitation following articular cartilage injury?

A. Shear forces
B. Distraction forces
C. Compressive forces
D. A and C

QUESTION 3. Which muscle group should one be cautious with when stretching during the early phases of rehabilitation following articular cartilage injury?

A. Hamstrings
B. Hip abductors
C. Quadriceps
D. Gastrocnemius/Soleus

QUESTION 4. What type of knee brace may a patient with an articular cartilage lesion need during the later stages of rehabilitation and return to sports to unload a specific compartment of the knee?

A. Drop-lock rehabilitative brace
B. Compression sleeve
C. Neoprene hinged brace
D. Unloader OA brace

QUESTION 5. What signs and symptoms let the clinician know that the athlete is not tolerating a given activity level during the course of rehabilitation?

A. Recurrent effusion
B. Joint line tenderness
C. Residual pain leading to a limp with ambulation
D. All the above

Answer Key

QUESTION 1. Correct answer: **D** (see Introduction)

QUESTION 2. Correct answer: **D** (see Phase I)

QUESTION 3. Correct answer: **C** (see Phase I)

QUESTION 4. Correct answer: **D** (see Phase III)

QUESTION 5. Correct answer: **D** (see throughout all phases)

POSTOPERATIVE REHABILITATION AFTER FEMORAL CONDYLE OR TROCHLEAR GROOVE MICROFRACTURE

Luke T. O'Brien, PT, SCS, PES, and J. Richard Steadman, MD

Indications for Surgical Treatment

- Full-thickness defect (grade IV)
- Unstable full-thickness lesion
- Degenerative joint disease lesion
- Requires proper knee alignment

Brief Summary of Surgical Treatment

- Correct joint environment at time of surgery
- Rough shave to remove cartilage remnants
- Curettes to remove calcified cartilage layer
- Surgical awls—penetrate subchondral bone
- Perforations 3 to 4 mm apart
- Don't "connect the dots"
- Maintain subchondral plate integrity
- Formation of "super clot"

Before Surgery: Overview of Goals, Milestones, and Guidelines[1]

- Must have proper patient selection
  - Patient understands postoperative process.
  - Patient will have to undergo strict rehabilitation program.
- Must have proper alignment
- Must use proper technique
- Must improve joint environment
- Proper rehabilitation

[1]*Prehabilitation, if appropriate, is described in the Nonoperative Rehabilitation section of this chapter.*

Phase I (days 0 to 14): Immediate Postoperative Period

Clinical Pearls

- Patella mobility is the key to the knee.
- A frequent complication of knee surgery is the formation of restrictive scar.
- Mobilization of the patella as well as the quadriceps and patellar tendon helps to maintain the integrity of the anterior interval and the suprapatellar pouch.
- Restrictive scar formation and the subsequent loss of these joint "spaces" increases not only patellofemoral joint contact pressure, but also tibiofemoral contact pressure.

Goals

- Protect the microfracture.
- Begin restoring tibiofemoral and patellofemoral range of motion.
- Reduce postoperative pain, swelling, and inflammation.
- Minimize the effects of immobilization/non–weight-bearing.

Protection

- All trochlear groove microfractures are braced in an immobilizer for 8 weeks. This is done to ensure that the median ridge of the patella does not engage the trochlea. The immobilizer is used at all times, including during sleep, unless in continuous passive motion (CPM).

- No brace is used for femoral condyle/tibial plateau lesions.
- Femoral condyle and tibial plateau microfractures mobilize with touch toe weight bearing for 8 weeks.
- Trochlear groove microfractures mobilize with partial weight bearing for 2 weeks.
- CPM (0° to 50°) is used 8 hours per day for 8 weeks. This improves the quality of the repair tissue, as well as ensuring congruency of the microfracture with the surrounding articular cartilage.[1]

Management of Pain and Swelling

- Femoral nerve block for 24 hours postoperatively
- Oral pain medication
- Continuous cryotherapy for pain and inflammation reduction
- Early range of motion exercises to facilitate resorption of swelling exudate

Techniques for Progressive Increase in Range of Motion

Range of Motion Restrictions

- Typically FROM for femoral condyle/tibial plateau
- May have ROM restrictions for trochlear groove, depending upon the size of the lesion

Manual Therapy Techniques

- Patella mobilization—medial/lateral mobilization of the patella, as well as the patella and quadriceps tendons. Superior/inferior mobilization of the patella. This helps limit scarring of the anterior interval and suprapatellar pouch, and the resultant increase in joint contact pressure.[2]
- Posterior tibial mobilizations in extension to ensure that symmetrical knee extension is attained.
- PROM—seated off the end of the bed with physical therapist assistance for initial flexion ROM. This is a particularly helpful position for trochlear groove microfractures with range of motion restriction or the presence of a femoral nerve block. Progress to independent wall slide as tolerated.
- Anterior-posterior tibial mobilization to ensure symmetrical extension.

Soft Tissue Techniques

- Lymphatic drainage techniques for swelling as required

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Sit and reach stretch with strap around foot. Done to maintain ankle dorsiflexion while patient has a protected weight-bearing status

Other Therapeutic Exercises

- Well-leg biking/rowing and or arm bike for maintenance of cardiovascular fitness

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Quadriceps sets. There are three benefits of teaching an isolated quad set in which the patella glides superiorly and the knee moves into terminal extension.
  - First, it resists muscle atrophy.
  - Second, it reinforces full knee extension, eliminating the possibility of developing a flexion contracture.
  - Finally, a quad set that locks the joint in terminal extension opens the anterior interval by 1 cm, and by doing so reduces the risk of anterior interval scarring.
- Hamstring sets. Usually performed as an isometric straight leg pulldown, or a straight leg bridge on a stable surface
- Gluteal isometrics
- Calf pumps for prevention of blood clots

Milestones for Progression to the Next Phase

- Approximately 115° of knee flexion to allow for a revolution on a stationary bike

Phase II (weeks 2 to 8 postoperative)

Clinical Pearls

- Regaining symmetrical knee extension is essential to the normal functioning of the knee.
- It allows weight-bearing force to be distributed over the entire available chondral surface, decreasing potential point loading.
- Full knee extension also allows the quadriceps to fire in inner range, which is essential for full muscular development.

TIMELINE 31-2: **Postoperative Rehabilitation After Femoral Condyle or Trochlear Groove Microfracture**

PHASE I (weeks 1 to 2 postop)	PHASE II (weeks 3 to 8 postop)
• TTWB x 8 wks for femoral condyle (FC), PWB x 2 wks for trochlear groove (TG) • CPM 0–50, 8 h/day • Immobilizer for TG microfractures • FPROM as tolerated • Patella mobilization • Quadriceps, gluteal and hamstring isometrics • Ice	• TTWB for FC • Immobilizer for TG • CPM 8 h/day • Stationary bike, no resistance • Deep water running • FPROM • Patella mobilization • Quadriceps, gluteal and hamstrings isometric • Ice

Goals

- Protect the microfracture.
- Restore full tibiofemoral and patellofemoral joint range of motion.
- Eliminate swelling and inflammation.
- Minimize the effects of immobilization/non–weight-bearing.

Protection

- Continue touch toe weight-bearing status for femoral condyle microfractures. Trochlear groove microfractures begin to wean off crutches over a period of 10 days after 2 weeks.
- Immobilizer use is continued for trochlear groove cases.
- CPM is continued 8 hours/day through 8 weeks.

Management of Pain and Swelling

- Pain medication use is typically ceased during this time.
- Cryotherapy three to four times daily for 20 minutes duration for pain and inflammation reduction
- Range of motion exercises

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Patella mobilization and posterior tibial mobilization are continued.
- PROM—Patients are encouraged to gently add overpressure to wall slides by placing their well leg on top of the surgical leg. Flexion on a Swiss ball is also added, with the PT gently applying overpressure at the end of range. All overpressure techniques should work into joint stiffness, but never reproduce joint pain.
- Stationary bike is introduced to facilitate ROM gains. Patients begin with 10 minutes duration and increase periodically to achieve 30 minutes duration by 8 weeks. All biking is done with no resistance through 8 weeks.

Soft Tissue Techniques

- Lymphatic drainage techniques for swelling as required.
- Trigger point release of hip flexor/tensor fascia lata is occasionally necessary owing to extended time in CPM and/or ambulating in an immobilizer.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Sit and reach stretch with strap around foot

Other Therapeutic Exercises

- Well-leg biking/rowing and or arm bike for maintenance of cardiovascular fitness
- Deep water aquajogging, ensuring that feet do not touch the bottom of the pool
- Upper body resistance training while ensuring adherence to weight-bearing and ROM precautions

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Quadriceps, hamstrings, and gluteal isometrics are continued and hold times progressed.
- Biofeedback may be used during quadriceps isometrics to facilitate a minimum level of performance during endurance holds for time.
- Straight leg raises are only introduced when the patient is able to demonstrate a quad set that locks the knee in end of range extension. Performing a straight leg raise in the presence of a quadriceps lag places a trochlear groove microfracture under unnecessary stress.

Milestones for Progression to the Next Phase

- 8 weeks post surgery. This ensures sufficient time has passed for the microfracture to tolerate weight-bearing stress.
- Full passive range of motion
- Quad set that locks the knee in terminal extension

Phase III (weeks 9 to 12 postoperative)

Clinical Pearls

- Successfully increasing patients with microfractures weight-bearing tolerance is most safely achieved by controlling total load volume.
- This is most easily done by using cardiovascular equipment, where duration and intensity parameters are easily monitored and progressed.

TIMELINE 31-2: Postoperative Rehabilitation After Femoral Condyle or Trochlear Groove Microfracture (Continued)

PHASE III (weeks 9 to 12 postop)	PHASE IV (weeks 13 to 18 postop)	PHASE V (weeks 19 to 24 postop)
• DC brace for TG • Wean off crutches for FC • Add resistance to stationary bike • Treadmill walking 7% incline • Lap kicking with fins in the pool • Shallow ⅓ knee bends • Double leg bridging • Standing TKE with resistance cord • Joint mobilization as necessary • Ice as necessary	• PROM—maintain full motion • Mobilizations as needed • Foam roller for soft tissue • Progress cardiovascular equipment use • CKC exercises—double leg shallow ROM or single leg static • CKC rhythmic stabilization • Balance and proprioception • Ice as necessary	• PROM—maintain full motion • Mobilizations as needed • Foam roller for soft tissue • Active warm up before strength work • Cardiovascular conditioning • CKC exercises—double leg FROM + single leg controlled ROM • Dynamic stability—introduce unstable surfaces

Goals

- Protect the maturing microfracture.
- Increase unprotected weight-bearing tolerance.
- Initiate muscular endurance base-building activities for the lower extremity.

Protection

- Femoral condyle microfractures begin weaning off crutches after 8 weeks. This is typically achieved though ceasing their use in the home environment. Crutches are still used for outside activity with progressively increased weight bearing. Crutch use is ceased once patients are able to demonstrate that full weight bearing does not increase pain or joint swelling, or lead to a loss of range of motion.
- Immobilizer brace is no longer used for trochlear groove microfractures after 8 weeks.
- CPM is no longer used after 8 weeks.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Techniques for tibiofemoral and patellofemoral mobility are continued only in the presence of joint ROM limitations.

Other Therapeutic Exercises

- Alter-G treadmill (if available)—used to assist weaning off crutches. Patients are typically started at 65% of body, and progressed daily with 5% increments.
- Treadmill walking 7% incline—typically started at 5 to 10 minutes duration with time increased by 10% each session
- Stationary bike—Resistance is progressively added with a goal of achieving 30 minutes of moderate resistance cycling by week 12. Proper technique, including seat height, is critical.
- Pool—lap kicking with fins for non–trochlear groove microfractures. Walking in chest deep water with progression to waist deep water to assist in weaning off crutches.
- Upper extremity resistance program can now incorporate standing positions.
- Deep water aquajogging, UBE, and well-leg rowing can all be used for cardiovascular exercise.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Quadriceps work is predominately in non–weight-bearing positions and focuses on shallow range of motion (0° to 30°).
- Gluteals and hamstrings (posterior chain) can largely be worked through full range in non–weight-bearing positions.

Sensorimotor Exercises

- Toe and heel raises are used to improve foot and ankle balance strategies, as well as improving dorsiflexion and plantarflexion strength.

Open and Closed Kinetic Chain Exercises

- Low-load, high repetition predominates the repetition and set structure for all open kinetic chain (OKC) and closed kinetic chain (CKC) exercises in this phase.
- Double leg bridging and side-lying manual-resisted hip extension are incorporated to develop hip extension.
- Knee extension is developed through low-impact exercises such as prone manual-resisted terminal knee extension and standing sports cord-resisted terminal knee extension.
- Shallow-range double leg squats to promote hip and knee extension. Care is taken to avoid squats deeper than 30° in trochlear groove microfractures, as this significantly increases load on the maturing cartilage surface.

Milestones for Progression to the Next Phase

- 12 weeks from surgery
- Successfully completed progressive loading program without an increase in joint symptoms (pain, swelling or loss of motion)

Phase IV (weeks 13 to 18 postoperative)

Clinical Pearls

- Microfracture cartilage continues to mature over a 12-month period.
- It is normal for patients to have an awareness of their microfracture area during some strengthening exercises and with daily activities such as descending stairs.
- While awareness of the surgical area is normal, pain is not, and therefore it should never be "worked through."

Goals

- Protect maturing microfracture
- Develop a lower extremity muscular endurance base
- Begin thigh girth normalization
- Develop hip and knee stability

Techniques for Progressive Increase in Range of Motion

Soft Tissue Techniques

- Foam roller soft tissue mobilization with emphasis on quadriceps, hamstrings, hip flexors, gluteals, and iliotibial band

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Incorporate active warmup techniques prior to strength work.

Other Therapeutic Exercises

- Unrestricted stationary biking, treadmill 7% incline walking, and pool activity
- May incorporate elliptical trainer as a cardiovascular training option
- Unrestricted upper extremity and core training programs
- Completing a functional movement screen to identify faulty movement patterns may be incorporated as appropriate in this phase.[3] Corrective exercises can be integrated into the treatment plan.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Development of an endurance base of the quadriceps, gluteals, and hamstrings should be the primary focus during this phase.
- Because many patients' operative knee typically displays few symptoms by this phase, careful monitoring of total load volume is necessary to limit the risk of irritating the joint and setting back the rehabilitation timeline.

Sensorimotor Exercises

- Specific exercises for balance are not emphasized at this time. Rather, proprioceptive training is incorporated into existing exercise design (e.g., single leg Romanian deadlift).

Open and Closed Kinetic Chain Exercises

- CKC activities in this phase focus on body weight resistance, double leg through full range exercises, or single leg static positions. OKC exercises are not emphasized.
- Double leg exercises include: squat progression (regular squat, squat to calf raise and squat to weight shift and hold) (Figure 31-19), double leg shuttle/leg press and static holds in reverse lunge position.
- Single leg CKC examples include Romanian deadlift and single leg bridges.

Neuromuscular Dynamic Stability Exercises

- In this phase, it is preferable to focus on the development of static stability before progressing to dynamic stability in the next phase.
- Exercises can focus on medicine ball, tubing, or kettle bell perturbations incorporating push/pull or rotational movements (e.g., static box hold with medicine ball push/pull) (Figure 31-20) and static reverse lunge holds with straight arm rotations.
- Rhythmic stabilization applied through the shoulders or trunk can also be added to these static positions.

Milestones for Progression to the Next Phase

- 18 weeks since surgery
- Demonstrated appropriate levels of stability and form in performing double leg and static single leg activities. Stability is measured by the patient's ability to perform without loss of balance. Form is determined by how the patient performs the activities (i.e., does the patient lower her/himself straight down with equal weight distribution?). The therapist must determine the patient's ability to perform these activities.
- No negative joint reactions (pain, swelling or loss of motion) in response to increase training load.

Phase V (weeks 19 to 24 Postoperative)

Clinical Pearls

- A linear periodized strength plan is the most appropriate structure for rehabilitation.
- It is characterized by an initial high volume of repetitions and sets, and low resistance.
- The following phases involve a gradual decrease in volume and an increase in intensity.
- This gradual increase in intensity corresponds well with the load tolerance of maturing microfracture cartilage.

Goals

- Develop a lower extremity muscular strength base.
- Minimize thigh girth differences.
- Successfully load the microfracture in single leg, full range of motion activities.

Techniques for Progressive Increase in Range of Motion

Soft Tissue Techniques

- Foam roller soft tissue mobilization with emphasis on quadriceps, hamstrings, hip flexors, glutes, and iliotibial band.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Incorporate active warmup techniques prior to strength work. These include sun salutations, hip crossover (Figure 31-21), scorpion (Figure 31-22), hand walks, and elbow to instep.

Other Therapeutic Exercises

- VO_2 Max testing using either a UBE or a stationary bike can be completed.
- Data from this test can be used to develop a cardiovascular base building program relevant to the athletes sport and season start date.

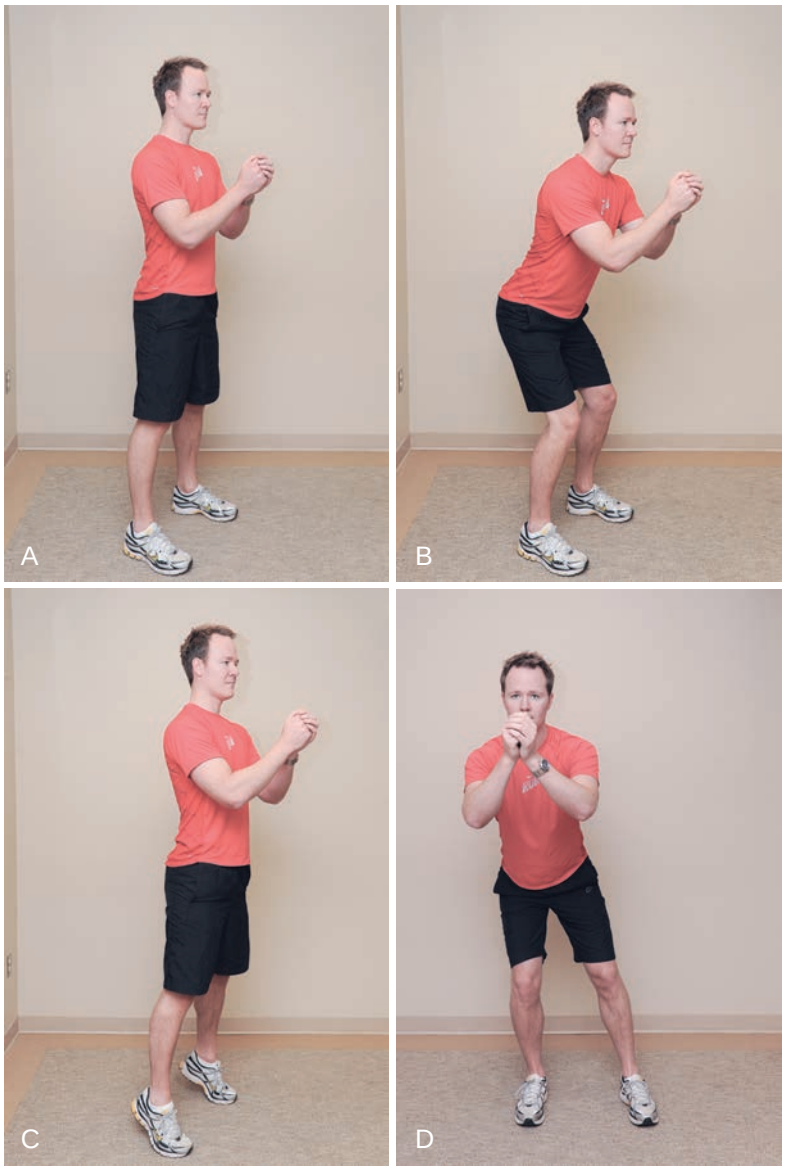

FIGURE 31-19. Squat progression. **A,** Start position. **B,** Regular squat. **C,** Squat to calf raise. **D,** Squat to weight shift.

- Upper extremity and core conditioning can shift from earlier maintenance programs, to periodized strengthening plans specific to the demands of the athlete's sport.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- The emphasis of this phase is on the development of muscular strength of the major muscle groups of the lower extremity (quadriceps, gluteals, and hamstrings). This is initiated through body weight-resisted, single leg activity. Initially exercise range of motion may be controlled, with full range allowed once gains in strength and pelvic stability allow.

Sensorimotor Exercises

- Specific exercises for balance are not emphasized at this time. Rather, proprioceptive training is incorporated into existing exercise design.
- Unstable surfaces (BOSU, half foam rolls, and tilt board) may be introduced to progress double or single leg exercises (e.g., BOSU tuck squats).

Open and Closed Kinetic Chain Exercises

- Single leg CKC exercises are now emphasized. These are predominately compound exercises that incorporate hip and knee flexion and extension (e.g., balance squat; Figure 31-23), single knee bends, and reverse lunges.
- Posterior chain work is continued and progressed: for example, Romanian deadlift with kettle bells, double leg bridges on slider disc—alternating leg flexion/extension.

Neuromuscular Dynamic Stability Exercises

- Incorporating medicine balls (single knee bend with medicine ball chop), elastic tubing (single knee bend

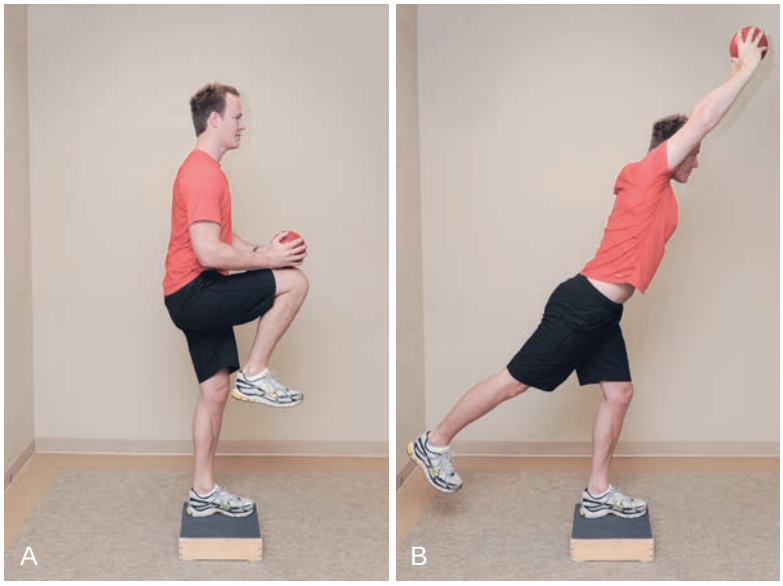

FIGURE 31-20. Static box hold with medicine ball push/pull. **A,** Start position. **B,** Finish position.

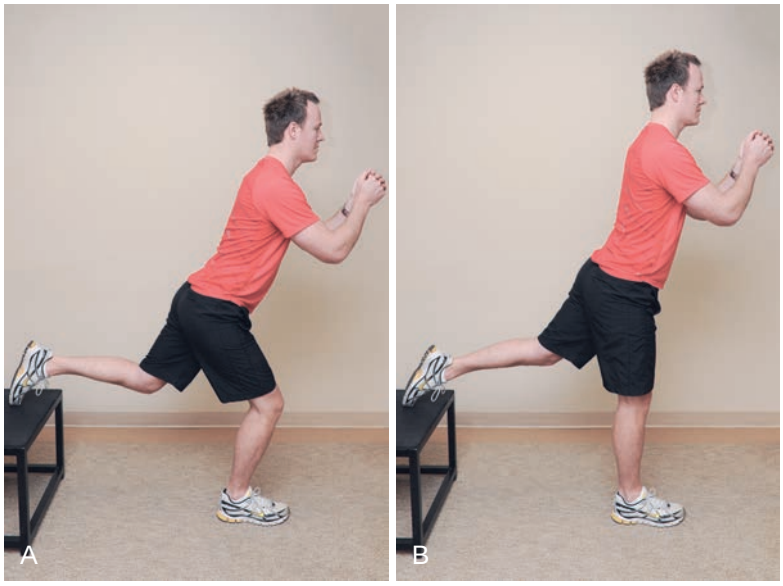

FIGURE 31-21. Hip crossover. **A,** Start position. **B,** Finish position.

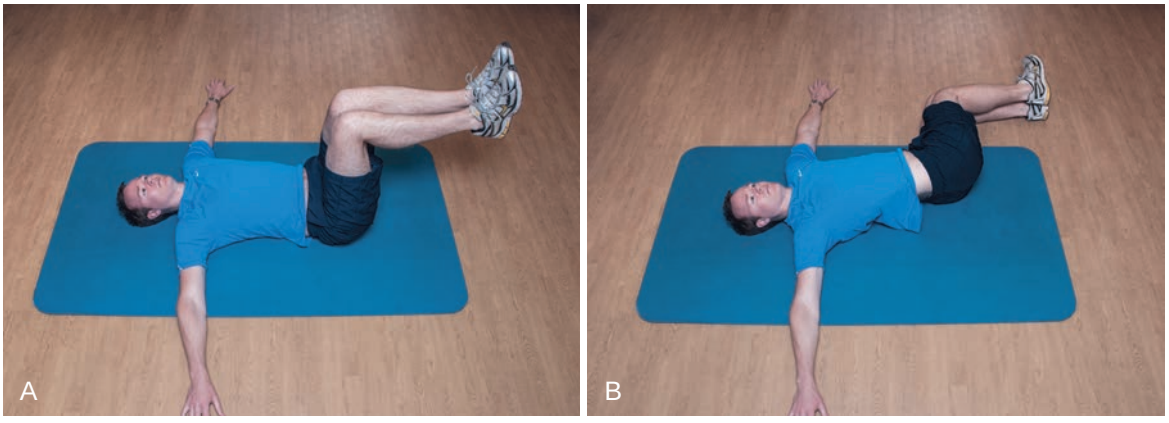

FIGURE 31-22. Scorpion. **A,** Start position. **B,** Finish position.

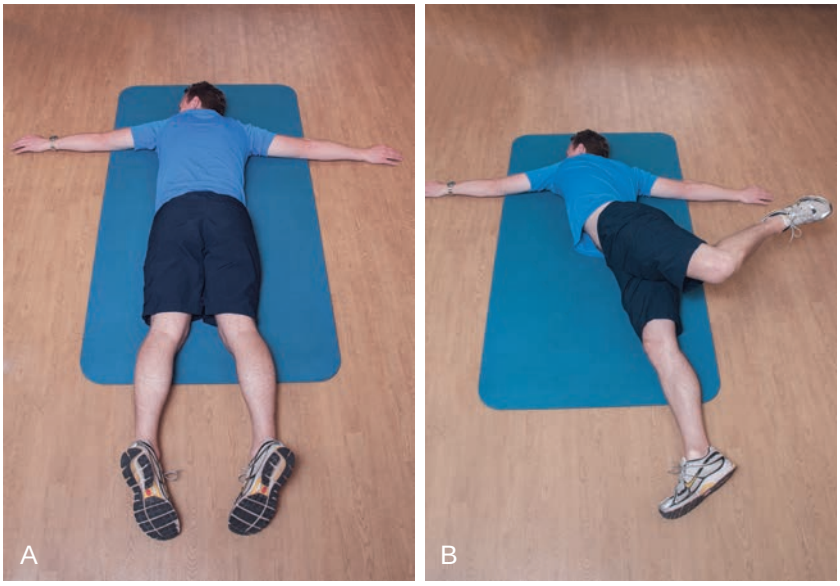

FIGURE 31-23. Balance squat. **A,** Start position. **B,** Finish position.

with single arm row; Figure 31-24) or rhythmic stabilization (single knee bends with rhythmic stabilization at different points in range) can be used to provide dynamic stability challenges to almost any CKC exercise.

Milestones for Progression to the Next Phase

- 24+ weeks post surgery
- Adequate levels of strength and stability in the performance of single leg activities. Strength and stability are measured visually by the therapist. Adequate strength is seen when patients can lower on a single leg and return to upright with little difficulties. Stability is shown by performing the activities without loss of balance or need of support.
- No negative joint symptoms (pain, swelling, or loss of motion) in response to increase training load.

Phase VI (weeks 24 to 36 postoperative)

Clinical Pearls

- Because of high impact stress, delay the start of a running progression for as long as possible.
- Calculate how many weeks will be required to condition the athlete to running. Initial running should take place on a forgiving surface, using 1-minute running followed by 4-minute walking

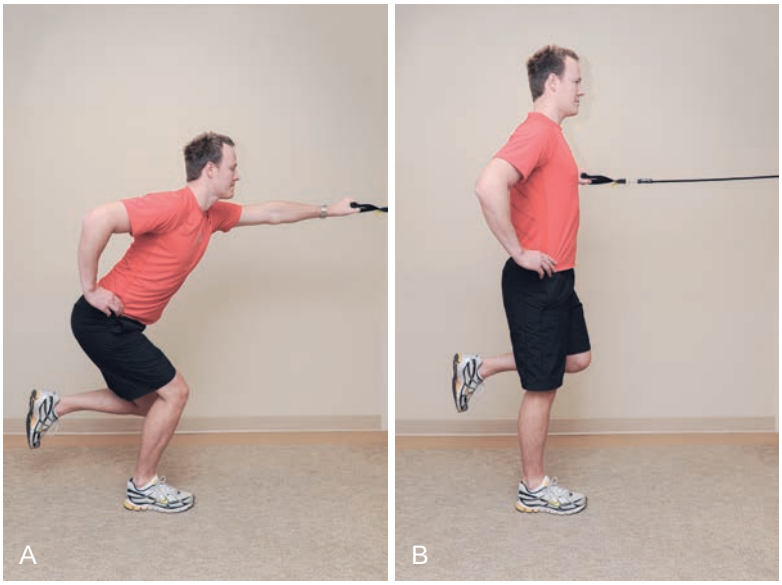

FIGURE 31-24. Single knee bend with single arm row. **A,** Start position. **B,** Finish position.

intervals. Running time is increased by 1 minute per week (associated with a 1-minute decrease in walking time) so that the patient is able to complete 20 minutes of continuous running after 5 weeks. Subtract that from the targeted return to play date to provide a goal date to begin the progression. Working backward like this decreases the risk of overloading the joint and inhibiting the recovery.

Goals

- Thigh girth symmetry
- Successful resumption of running (if required for athlete's sport)
- Return to play

Techniques for Progressive Increase in Range of Motion

Soft Tissue Techniques

- Foam roller soft tissue mobilization with emphasis on quadriceps, hamstrings, hip flexors, glutes, and iliotibial band.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Incorporate active warm up techniques prior to strength/running work.

Other Therapeutic Exercises

- Continue cardiovascular conditioning. Anaerobic threshold training can begin once an aerobic base has been built.
- Upper extremity and core training can begin to integrate sport-specific elements.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Development of muscular strength and power focusing on the posterior chain and the quadriceps predominates this point of rehabilitation.

Open and Closed Kinetic Chain Exercises

- Many of the exercises from phase V are continued now, with the addition of resistance. Resistance can be applied through use of a resistance cord, kettlebells, or dumbbells (e.g., single leg squat with sport cord, reverse lunge with dumbbells, or cowboy squat with kettlebells).
- A lifting program incorporating traditional lifts (e.g., barbell squats and deadlifts), is started once the athlete begins a running progression.
- Low weight is used to begin while appropriate lifting technique is being taught and the knee is adapting to the increased load.
- Weight is increased as technique, muscular performance, and the knee allows.

Neuromuscular Dynamic Stability Exercises

- Dynamic stability activities can be incorporated into daily programs for exercise variety, but are not emphasized in this phase.

Plyometrics

- In attempting to shield the microfracture from unnecessary impact stress, muscular power is developed by emphasizing speed of muscular contraction with the foot remaining in contact with the ground. This is in contrast to traditional plyometrics, which involve the foot leaving the ground. Examples of such modified plyometric exercises include high bench step ups with hip drive (Figure 31-25), prone shuttle press with arm



FIGURE 31-25. High bench step up with hip drive. **A,** Start position. **B,** Finish position.



FIGURE 31-26. Prone shuttle press with arm drive. **A,** Start position. **B,** Finish position.

drive (Figure 31-26), and lateral hip drive with sport cord resistance.

Functional Exercises

- A running progression can begin in this phase as long as thigh girth measurements are within 1 centimeter, and a functional strength test (The Sport Test) is passed. A standard running progression is given in Table 31-1.
- Some sports (baseball, American football) may not require 20 minutes of running.
- The running progression may then be shortened (or lengthened) to match the demands of specific sports or positions.

Sport-Specific Exercises

- Upon successful completion of a running progression, athletes involved in cutting and pivoting sports need to complete speed and agility drills before returning to training.
- Specific drills will vary depending upon the needs of the athlete and the demands of his sport.
- As a general guideline, drills should progress from single plane to multiplane agilities, and from moderate running speed to sprinting. A sample three times per week for 4 weeks progression is outlined in Table 31-2.

Table 31-1 Standard Running Progression

Running Week #	Run Time (minutes)	Walk Time (minutes)	Total Duration (minutes)
1	1	4	20
2	2	3	20
3	3	2	20
4	4	1	20
5	20	0	20

Table 31-2 A Sample Three Times per Week for 4 Weeks Progression

Agility Week #	Sample Agility
1. Linear cone drills	1. Weave run 2. Zig-Zag shuffle 3. Dip and touch 4. Circle around
2. Linear cone drills	1. Jump over—sprint 2. Front/Back shuttle 3. Sprint—shuffle shuttle 4. Figure 8's
3. Zig-zag cone drills	1. Up 2, back 1 2. Shuffle, explode touch 3. Sprint, shuffle touch 4. Run through with hand plants

Criteria for Return to Sport

- Symmetrical patellofemoral and tibiofemoral range of motion
- Thigh girth within 1 cm of unaffected side
- Successful completion of running progression and speed and agility drills without provocation of joint symptoms (pain, swelling or loss of motion)
- Sufficient time must have passed from surgery to allow the microfracture to mature into a durable repair tissue.

After Return to Sport

Exercises and Other Techniques for Prevention of Recurrent Injury

- All future cardiovascular and strength conditioning work should be considered in light of the athlete having an altered chondral surface. Low-load activities should always be preferred over high-load activities when practical.
- Permanently avoid leg extension and forward lunges. Both these place large amounts of unnecessary load on the anterior knee.
- Medical review should be conducted if the athlete experiences persistent pain and/or effusion after activity.

Evidence

Ahmad CS, Kwak SD, Ateshian GA, et al: Effects of patellar tendon adhesion to the anterior tibia on knee mechanics. *Am J Sports Med* 26(5):715–724, 1998.

This cadaveric study examined the effects of patellar tendon adhesion on the knee extensor mechanism and on the kinematics and contact areas for both the patellofemoral and tibiofemoral joint. Adhesion decreased knee extension force, and increased patellofemoral joint reaction force. (Nonclinical Study)

Gill TJ, McCulloch PC, Glasson SS, et al: Chondral defect repair after the microfracture procedure: A nonhuman primate model. *Am J Sports Med* 33(5):680–685, 2005. (Descriptive laboratory study)

Microfracture was performed in primates and repair tissue was evaluated at 6 and 12 weeks. At 6 week, there was limited repair but at 12 weeks the defects were completely filled. This research may indicate that the repair tissue created by microfracture is vulnerable in the first 6 to 12 weeks postoperative and restricting weightbearing may protect the repair.

Hurst JM, Steadman JR, O'Brien L, et al: Rehabilitation following microfracture for chondral injury in the knee. *Clin Sports Med* 29(2):257–265, 2010. (Level 5)

This paper details postoperative care and rehabilitation following microfracture in the knee.

Ramappa AJ, Gill TJ, Bradford CH, et al: Magnetic resonance imaging to assess knee cartilage repair tissue after microfracture of chondral defects. *J Knee Surg* 20(3):228–234, 2007. (Level 4)

This paper reported on a patient who underwent second look arthroscopy and MRI following microfracture. The study showed that the MRI has high sensitivity and specificity for determining fill of the cartilage lesion. In addition, the study demonstrated that most defects had 100% fill following microfracture.

Rodrigo JJ: Improvement of full-thickness chondral defect healing in the human knee after debridement and microfracture using continuous passive motion. *Am J Knee Surg* 7:109–116, 1994. (Level 4)

This study compared grade of cartilage lesion at second look arthroscopy in patients who used CPM following microfracture to those patients who did not use CPM. The paper reported that those patients who used CPM appeared to have superior healing of cartilage defects treated with microfracture.

Steadman JR, Briggs KK, Rodrigo JJ, et al: Outcomes of microfracture for traumatic chondral defects of the knee: average 11-year follow-up. *Arthroscop* 19(5):477–484, 2003. (Level 4)

This paper reported the function outcomes of patients at an average of 11 years following microfracture for traumatic chondral defects of the knee. The results showed significant improvement in Lysholm and Tegner scores at final follow-up. Multivariate analysis revealed age as a predictor of improvement in function.

Yen YM, Cascio B, O'Brien L, et al: Treatment of osteoarthritis of the knee with microfracture and rehabilitation. *Med Sci Sports Exerc* 40(2):200–205, 2008. (Level 5)

This paper details specific postoperative and rehabilitation for patients with osteoarthritis of the knee who have undergone microfracture.

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Multiple-Choice Questions

QUESTION 1. An immobilizer is used for 8 weeks following trochlear groove microfracture for which of the following reasons?

A. To minimize scar tissue formation
B. To prevent the median ridge of the patella from engaging the trochlear in weight-bearing positions
C. To prevent flexion contractures
D. To provide stability to a postsurgical joint

QUESTION 2. Femoral condyle microfractures mobilize TTBW for

A. 2 weeks.
B. 4 weeks.
C. 6 weeks.
D. 8 weeks.

QUESTION 3. A running progression should begin

A. as soon as thigh girth is symmetrical.
B. 20 weeks post surgery.
C. as soon as possible.
D. as late as possible while still allowing the athlete sufficient conditioning time prior to returning to play.

Answer Key

QUESTION 1. Correct answer: **B** (see Phase I)

QUESTION 2. Correct answer: **D** (see Week 2–4)

QUESTION 3. Correct answer: **D** (see Phase VI)

POSTOPERATIVE REHABILITATION AFTER AUTOLOGOUS CHONDROCYTE IMPLANTATION FOR CARTILAGE RESTORATION

Scott D. Gillogly, MD, FACS, and Kate McDonald, BScPT, OCS, COMT

Indications for Surgical Treatment

- Failure of nonoperative treatment
- Persistent activity-related pain
- Significant articular cartilage defect—size, depth, and number of defects; location; and containment all contribute to determining the best treatment option.
- Progression of a localized articular defect to significant joint osteoarthritis
- Symptomatic predominantly full-thickness chondral defects (grade III to grade IV lesions) and osteochondritis dissecans lesions of the femoral condyle and trochlea
- Medium to large focal chondral lesions typically larger than 2.5 cm^2
- Concomitant procedures will often be required in order to correct biomechanical factors that contributed to the injury and to optimize the healing environment.
- Patient age and activity requirements—This surgery is indicated for younger patients (typically less than 50 to 55 years of age) with higher exercise requirements. A hemiarthroplasty or total knee replacement may be indicated for older, more sedentary patients with advanced cartilage damage.

Brief Summary of Surgical Treatment

Major Surgical Steps

- Chondral biopsy is required initially to culture and grow the autologous chondrocytes.
- Autologous chondrocyte implantation (ACI) is an open procedure requiring adequate exposure (Figure 31-27).
- The defect(s) is prepared by sharply demarcating the edge of the defect and removing all degenerated cartilage remnants down thru the calcified cartilage layer without violating the subchondral plate.
- The defects is sized by making a template and transferring the size and shape to the covering membrane of periosteum or an absorbable Type I/III collagen membrane.
- Covering membrane is sutured to the edges of the defect and sealed with fibrin glue to make a water tight seal.
- Defects with uncontained edges may require alternate methods to securely attach the covering membrane such as microsuture anchors or drill holes through bone.
- Autologous cells are then injected under the membrane and the injection site closed and sealed. Any concomitant procedures such as anterior cruciate ligament reconstruction, osteotomy, patellofemoral realignment, or meniscal transplantation are done prior to completing the cell implantation, which should be the last portion of the procedure.

Factors That May Affect Rehabilitation

Anesthetic

- Regional anesthesia may be used. This femoral and/or sciatic nerve block may wear off 8 to 24 hours following surgery. Patient may alternatively be fitted with a continuous nerve block pump—the level of anesthesia can be independently varied—decreased for rehabilitation sessions so that the patient has some quadriceps control, and increased post rehabilitation to afford more pain relief.

Surgical

- Size: Larger lesions require slower rehabilitation.
- Depth: Deeper lesions may require a bone graft which will slow rehabilitation.
- Location: Femoral condyle lesions require protection from weight-bearing forces; patella-trochlea lesions require protection from shear forces.
- Containment: Cleaner boundaries and superior surrounding cartilage is preferable.
- Concomitant procedures: Simultaneous surgeries, such as femoral osteotomy, high tibial osteotomy, or distal tibial realignment (Fulkerson) will each have specific protocol requirements. In general follow the protocol for the technique that is the most conservative. (See Modifications for Concomitant Surgeries section.)

Before Surgery: Overview of Goals, Milestones, and Guidelines[2]

- Prehabilitation is very important prior to cartilage restoration procedures. Postsurgical pain and immobility may be significant and result in fairly significant muscular atrophy. Obviously the stronger the patient is prior to surgery, the easier it will be to maintain and regain muscle.
- One or two prehabilitation sessions of physical therapy should be sufficient to instruct the patient. Focus on the following specific areas:
  - Weight loss
  - Core strengthening (e.g., planks, side planks, abdominal roller, physioball exercises)
  - Hip abductor strengthening (side-lying abduction, single leg balance on wobble board, speedskaters—see Figure 31-39).

[2]*Prehabilitation, if appropriate, is described in the Nonoperative Rehabilitation section of this chapter.*

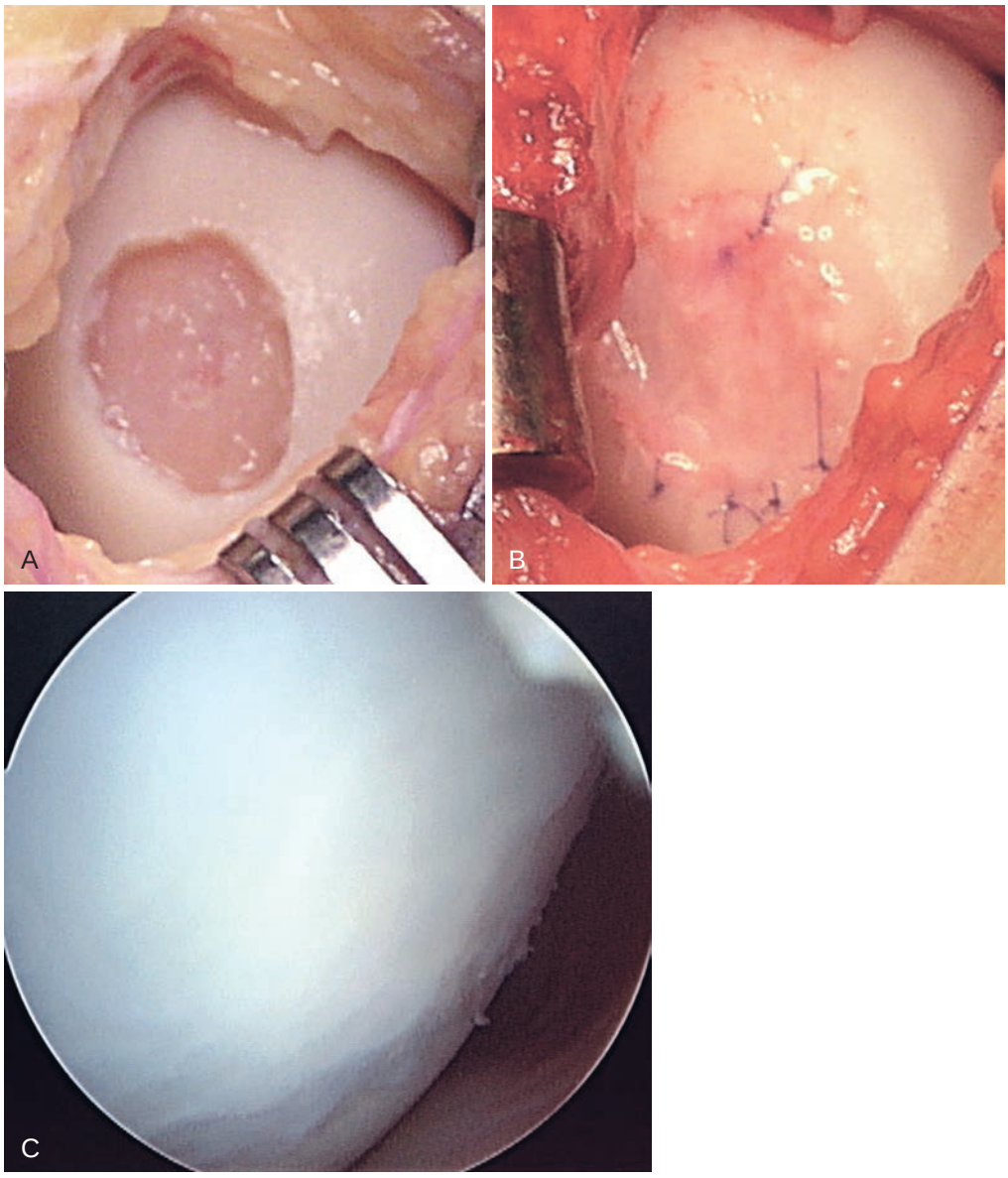

FIGURE 31-27. Autologous chondrocyte Implantation. **A,** Defect has been debrided to a stable edge with surrounding normal articular cartilage. **B,** Periosteum or membrane cover has been sutured into place and sealed with fibrin glue containing the autologous chondrocytes. **C,** The same defect at second look arthroscopy 11 months after implantation showing excellent repair tissue fully filling the defect.

  - Quadriceps strengthening (vastus medialis oblique holds—sit, maintaining good posture on a level surface, with both feet on the ground. Hold the surgical knee in static, active knee extension for 5 minutes. Once finished, slide back onto the bed so that it is not necessary to do open chain knee flexion, sit-to-stands—similar to squats but patient sits down onto a low mat table and then stands again without using arm support, leg presses)
  - General cardiovascular fitness
- In addition, it may be advisable to teach the patient the initial postoperative regime including crutch walking, heel prop, quad sets, ankle pumps, and hamstring and calf stretches during the prehabilitation sessions (refer to Phase I). This is necessary because the patient is often in significant pain and/or on strong analgesia at the initial postsurgery visit.

GUIDING PRINCIPLES OF POSTOPERATIVE REHABILITATION

- Appreciate the anatomic structures involved and their individual rates of healing.
- Appreciate stresses applied in different ranges of motions, with different activities.
- Determine location, size, depth, and number of lesions.
- Determine whether concomitant procedures have been performed. Follow the more conservative protocol.
- Respect ROM requirements and weight-bearing progressions. These will differ for the different surgical techniques and different locations (Table 31-3).

Table 31-3 Comparison of Autologous Chondrocyte Implantation—Femoral Condyle and Patella-Trochlea

	Weight Bearing	PROM Knee Flexion Goals	Return to Sport
ACI-Femoral condyle	Restriction of weight bearing for 8 weeks—10–20 lbs only. 100% weight bearing at weeks 6–8—earlier with permission from MD.	PROM is restricted only by pain; the following are conservative numbers and can be progressed faster. 90° weeks 1–2 105° by week 3 115° by week 4 135° by week 6	6 months Low impact—golf, swimming, skating, rollerblading, cycling 7–8 months Moderate impact—light running, aerobics 12 months High impact —tennis, volleyball, basketball, football, baseball
ACI-Patella-trochlea	Weight bearing can be accelerated more quickly. 25% weight bearing week 2 50% weight bearing week 4 100% weight bearing week 6 (When the knee is in full extension, weight bearing will not load the repair sites.)	Passive ROM knee flexion is progressed slower in the patella-trochlea patient to avoid shear. 90° by weeks 2–3 105° by weeks 3–4 120° by week 7 135° by weeks 8–9	6 months Low impact 7–8 months Moderate impact 12 months High impact

Healing Timeframes: The Four Phases of Chondrocyte Maturation

It is important for the rehabilitation specialist and athlete to be cognizant of the stages of chondrocyte maturation, so that they can fully appreciate the importance of adhering to the protocol timeline.

- Proliferation (early protection) phase
  - Proliferation of chondrocytes occurs during the first 6 postoperative weeks, with cellular activity observed in the first 24 hours. During the hours immediately following surgery, the cells line the base of the defect. They multiply and produce a matrix to fill the lesion. (Patients with ACI-patella surgery will awaken ideally in prone, to take maximum advantage of this early healing process.)
  - Protection is essential during the first 6 weeks. However, gentle weight bearing and range of motion is necessary to stimulate cellular growth.
- Transition phase: This typically occurs during the second 2 months post surgery. During this phase, the cartilage tissue is compressible and spongy and continues to require controlled forces only.
- Remodeling phase: This takes place during the third to sixth postoperative month. Hyaline cartilage is remodeling into a more organized structure, allowing for improved strength and durability. Low to moderate impact activities can be tolerated toward the end of this phase.
- Maturation phase: This can vary from 9 to 18 months in duration. The tissue repair becomes fully mature with stiffness similar to the surrounding tissue.

Phase I (days 0–14): Immediate Postoperative Period

Clinical Pearl

It is imperative to retain full passive knee extension immediately postoperative (e.g., by performing prone hangs or heel props (Figures. 31-28 and 31-29) or using a passive extension device). The patient should additionally be educated against resting with a pillow under the knee. Educating the patient on the importance of this step is invaluable in gaining full compliance.



FIGURE 31-28. Prone hang exercise. The patient should perform this stretch as a low-load, long-duration stretch aimed at regaining full passive knee extension. Moist heat can be applied to the hamstring.



FIGURE 31-29. Heel prop exercise. Maintaining this position for a 20-minute period will provide a low-load, long-duration stretch to regain full passive knee extension.

Goals

- Decrease pain and effusion.
- Protection from load and shear forces
- Immediate restoration of full passive knee extension
- Gradually increase passive knee flexion, limited by patient's pain only.
- Regain quadriceps control.
- Achieve safe crutch walking with full understanding of weightbearing requirements.

Protection

- The patient may present to the clinic in a knee immobilizer. This may be utilized as long as the nerve block continues to be effective, as the patient will have very little active leg control.
- As soon as quadriceps control returns (the patient no longer has a quads lag), a hinged brace should be fitted.
- Lock the brace at the angle achieved in rehabilitation and increase range of knee flexion to mirror the patient's gains in passive knee flexion ROM achieved in rehabilitation.
- Weightbearing must be limited. Two crutches (two-point or three-point gait) should be used and the patient is advised to use heel-toe gait on the affected side while only placing 10% to 20% of body weight on the surgical leg. Complete non–weight-bearing has been shown to negatively affect growing articular cartilage. Conversely, the controlled compression and decompression forces created through weight bearing are believed to nourish the growing articular cartilage and to provide the necessary signals to the tissues to allow matrix production that matches environmental need.
- A compression stocking should be utilized for edema control and to prevent blood clots in the first week. This should be followed by use of a lightweight, shorter compression stocking until edema subsides.

Management of Pain and Swelling

- Pain pump for continuous nerve block may be inserted during surgery
- Oral pain medications
- Cryotherapy for pain and inflammation reduction
- Patient education: The patient should NEVER place a pillow under the knee in an effort to find a position of comfort—this will result in difficulty and pain in attempting to regain passive knee extension.
- The patient should sleep in the hinged knee brace.
- A continuous passive motion (CPM) machine can be used up to 4 hours a day (using ROM gained in PT). This can help with pain management and in regaining motion. Emphasis on full passive knee extension while using CPM should be encouraged from Day 1.
- A compression stocking is worn initially. When control is gained over edema, this can be replaced with a shorter, light compression stocking.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Immediate motion from Day 1
- Maximize passive knee extension immediately. Use a patient-controlled passive knee extension device, heel prop, or prone hangs.
- Perform in 20-minute sessions five times per day.
- Grade 2 to 3 anterior-posterior mobilizations (APs) to the tibiofemoral joint can be used to increase this range.
- Passive patella-femoral joint mobilization, both in the medial-lateral and cephalad-caudad directions, will prevent loss of patella-femoral ROM and resulting potential loss of tibiofemoral ROM. Perform three times a day.
- Passive knee flexion is progressed per patient tolerance. There is no limitation to this increase, except for the pain tolerance levels of the athlete. Perform three times a day.

Clinical Pearl

> Passive knee flexion is limited only by patient tolerance. The increase in ROM is expected to be slower in patella-trochlea ACI patients than in femoral condyle ACI patients. It can be particularly beneficial to aim for an increase in ROM, even if it is just a few degrees, at each treatment session. It is discouraging for a patient to tolerate pain and then not make any gains. This range will always be limited by swelling. Make every effort to reduce swelling, including patient education. If you are not successful, always seek the orthopedic surgeon's opinion, in case knee aspiration is necessary.

Soft Tissue Techniques

- Gentle effleurage to decrease edema in the calf area can be beneficial. Avoid the surgical area during this phase.
- Stretching/flexibility techniques for the musculotendinous unit
- Gentle hamstring and calf stretching will help improve patient comfort and prevent future soft tissue restrictions.

Other Therapeutic Exercises

- As soon as the patient is ready for cardiovascular exercise, an upper body ergometer can be used.
- As soon as patient gains sufficient passive knee flexion, the patient should begin stationary cycling for limited periods (10 to 15 minutes).

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Immediate ankle pumps are advised to aid in edema control and prevent blood clots.
- Quad sets are taught as soon as the patient regains limb control (i.e., once nerve block wears off). Neuromuscular electrical stimulation should be utilized.

- Active assisted straight leg raise (SLR) is added Day 4. Progress to four-way SLR as the patient's tolerance increases.
- Crutch walking should be reviewed. This is difficult initially because the patient has to be completely non–weight-bearing while the nerve block remains effective. Actual gait training should be repeated when leg control returns—10 to 20 lbs heel-toe weight bearing, two crutches, and lace-up shoes. Teach patient how to ascend and descend stairs.
- Week 2—Introduce terminal knee extensions (Figure 31-30)—patient must use crutches for support. Maximum supervision required.

Phase II (weeks 2 to 6 postoperative)

Goals

- Decrease pain and effusion.
- Maintenance of full passive knee extension
- Continued restoration of passive knee flexion.
- Regain quadriceps control.
- Gradually increase strengthening and cardiovascular demand.
- Encourage correct heel-toe gait with crutches (being mindful of the appropriate weightbearing allowances).



FIGURE 31-30. Terminal knee extension exercise. This exercise helps to target the quadriceps muscle and maximize controlled knee extension.

Protection

- Continued use of hinged knee brace. Increase the range of motion in the brace as the patient gains ROM in rehabilitation.
- ACI-Femoral condyle lesion
  - Continued restriction of weight bearing initially—10% to 20% of body weight continues to be the

TIMELINE 31-3: **Postoperative Rehabilitation After Autologous Chondrocyte Implantation of the Femoral Condyle**

PHASE I (weeks 1 to 2 postop)	PHASE II (weeks 2 to 6 postop)	PHASE III (weeks 6 to 10 postop)

• Hinged knee brace—locked at PROM flexion gains in rehab
• PT modalities
• Immediate motion Day 1
• ROM Passive knee extension—full PROM ASAP. Perform in 20 minute sessions 5 times per day.
• ROM Passive knee flexion—progress as per patient tolerance—3 times a day
• ROM Patella-femoral joint mobilization—3 times a day
• Weightbearing—10–20 lbs, heel-toe gait with 2 crutches
• Ankle pumps, quads sets, SLR with NMES
• Stationary bike when ROM allows
• Hamstring, calf, quadriceps stretching
	• Hinged knee brace
	• PT modalities
	• ROM—no precautions, full extension, increase PROM knee flexion as tolerated, PF mobs
	• PROM knee flexion goals:
	  • ACI-Femoral condyle lesion:
	  • 90° weeks 1–2
	  • 105° by week 3
	  • 15° by week 4
	  • 35° by week 6
	  • These are conservative and can be progressed faster.
	  • ACI—Patella-trochlea lesion
	  • 90° by weeks 2–3,
	  • 105° by weeks 3–4,
	  • 120° by week 7.
	• Weight bearing
	  • ACI-Femoral condyle lesion
	  • Continued restriction of weightbearing initially—10 to 20 lbs only
	  • 50% weightbearing at weeks 4–6
	  • ACI—Patella-trochlea lesion
	  • Weightbearing can be accelerated more quickly.
	  • 25% body weight week 2
	  • 50% weightbearing at week 4
	  • Full weightbearing at week 6
	• Ankle pumps, quads sets, SLR with NMES, short arc quads, TKEs
	• Manual rhythmic stabilization of trunk in sitting, nonsurgical leg single leg balance
	• Stationary bike
	• Hamstring, calf, quad (rectus fem) stretching
	• TBS/TAS/TLS activities as recommended and tolerated
	• Week 4—isometric leg press, aquatic treadmill walking
		• DC Brace at week 6
		• Passive Knee ROM
		  • ACI-Femoral condyle
		  • At least 135° PROM knee flexion
		  • ACI-Patella-trochlea
		  • 120° week 7
		  • 135° weeks 8–9
		• Full PROM knee extension, PF mobs, gentle scar tissue mobilization
		• Weightbearing:
		  • ACI-Femoral condyle lesion:
		  • 50% weightbearing with crutches at weeks 4–6.
		  • 100% weightbearing at 6–8 weeks—earlier with permission from MD.
		  • ACI-Patella-trochlea lesion:
		  • 100% weightbearing weeks 6–8
		• Continue previous stretches, add pretzel, Thomas test stretch
		• Continue stationary bike, aquatic TM (lower water level), treadmill wks 8–9
		• TBS/TAS/TLS activities as recommended an tolerated
		• Week 6—isometric leg press, standing weightshifts, rocker board, physioball bridging and walkouts
		• Week 8—Mat squats, double-leg leg press, cup walking, heel raises (double leg), stationary mini-lunge with cable chops
		• Week 9—front step-ups, single leg rockerboard
		• Week 10—elliptical, lateral step ups

restriction that is sufficient to encourage cartilage growth but light enough to protect the growing tissues.
  - 100% weight bearing at weeks 6 to 8 only
- ACI-Patella-trochlea lesion
  - Weight bearing can be accelerated more quickly
  - 25% body weight at week 2
  - 50% weight bearing at week 4
  - Full weight bearing at week 6

Management of Pain and Swelling

- Oral pain medication may remain necessary, particularly at night and for rehabilitation sessions.
- Continued use of cryotherapy (three times per day), elevation of the limb, ankle pumps.
- Continued use of a compression sleeve (lightweight).
- Continued use of CPM, ROM to mirror gains in rehabilitation.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- ROM precautions: None
- PROM: Manual ROM of the patella-femoral joint—medial/lateral and cephalad/caudad.
- PROM: Continue to maintain tibiofemoral extension. Every effort should be made to mirror patients opposite limb extension ROM.
- PROM knee flexion goals
  - ACI-Femoral condyle lesion
    - 105° by week 3
    - 115° by week 4
    - These are conservative and can be progressed faster.
  - ACI-Patella-trochlea lesion
    - 90° by weeks 2 to 3
    - 105° by weeks 3 to 4
    - 120° by week 6
    - ROM progression of passive knee flexion is slower with patella-trochlea than femoral condyle lesions.

Clinical Pearl

At this stage, consider performing passive knee flexion with the hip in extension. This is most easily achieved with the patient in side lying, with the involved leg on the table. This will help to prevent loss of extensibility of the rectus femoris muscle, a two-joint muscle. This position also provides the rehabilitation specialist with excellent leverage (Figure 31-31).

TIMELINE 31-3: Postoperative Rehabilitation After Autologous Chondrocyte Implantation of the Femoral Condyle (Continued)

PHASE IV (weeks 10 to 14 postop)	PHASE V (weeks 14 to 24 postop)	PHASE VI (weeks 24 to 52 postop)

• PROM—maintain full motion, joint mobilizations as needed
• Weightbearing 100%
• Continue lower limb stretches. Add Frog, Pretzel, modified Thomas test stretch
• Stationary bike, treadmill walking, elliptical, StairMaster
• TBS/TAS/TLS activities as recommended an tolerated
• CKC: High step-ups, backward stationary lunges, double leg squats, leg press, heel raises (double and single leg); week 12, single leg leg press
• OKC: speedskaters, open chain knee extension 0°–20°, leg curls
• Single leg balance, walking agility drills
	• PROM—maintain full motion
	• Weightbearing status—aquatic TM run 24 weeks
	• Continue lower limb stretches. Add Frog, Pretzel, modified Thomas test stretch
	• Stationary bike, treadmill/road walking, elliptical, StairMaster
	• PNF lower limb and/or trunk in supine or sitting
	• TBS/TAS/TLS activities as recommended and tolerated
	• CKC: Progress height of high step-up, backward lunge walking, forward lunge walking, single leg squats (vary surface, add perturbations)
	• OKC: speedskaters on proprioceptive equipment, cable kicks in PNF patterns
	• Walking agility—increase complexity
		• Previous levels of functional activities
		• End range sustained stretches
		• Single leg stand/squat on balance device. Increase complexity
		• PNF lower limb patterns in standing and supine
		• PNF upper limb/trunk in tall kneeling, half kneeling, single leg stand on rocker board
		• Physioball ex: bridge back on ball with leg extensions, bridge back on floor, single leg curls
		• CKC: lunges on 2 BOSU, LSU
		• OKC: open chain knee ext 0–20, open chain kicking
		• 6 mo—pool run, 7 mo—treadmill run, increase distance on bike, elliptical, StairMaster
		• Agility drills—fast walk
		• Single leg cone touches, single leg deadlifts
		• 4–7 mo—upper body plyometrics, static stance lower body
		• 7–8 mo—box jump—progress direction, number, single leg
		• 8–9 mo—single leg hop agility drills
		• Sports:
		  • 6 mo—Low impact: golf, swimming, skating, rollerblading, cycling
		  • 7–8 mo—Moderate impact: light running, aerobics
		  • 12 mo—High impact: tennis, volleyball, basketball, football, baseball



FIGURE 31-31. Side-lying knee flexion. Use this position to use to gently gain passive knee flexion range of motion. The rehabilitation specialist is afforded excellent leverage and can maintain the patient in pelvic neutral in this position. Hold-relax can be added.



FIGURE 31-32. Side-lying abduction with the leg maintained in slight hip extension. The patient should keep the abdominal contracted to protect the spine and localize the abduction motion.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Maintain gastroc/soleus ROM—passive stretching in supine, on table.
- Maintain or improve hamstring ROM; angle of stretch can be varied to include the iliotibial band or adductor group.

Other Therapeutic Exercises

- Upper extremity exercises during this phase may include upper body ergometer (UBE) and general weight equipment (such as latt pulldowns, pec deck, tricep pushdowns, biceps curls, scaption). Perform all exercises in a seated position.
- Core exercises may include single leg planks, superman, single leg pushups and reverse planks. In all these exercises, the surgical leg is non–weight-bearing and held off the ground.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Ankle pumps, ankle alphabet exercises
- Quads sets with NMES or biofeedback
- SLR—4 way with NMES or biofeedback

Clinical Pearl

Side-lying abduction is very important. Limited weight bearing may cause muscular atrophy of the gluteal group. Ensure that the patient is in the correct side-lying position with lower limb slightly extended to ensure maximal gluteus medius recruitment. (Figure 31-32)

Sensorimotor Exercises

- Begin active angular replication exercises for motor control. These can be introduced during the SLR exercises.

Techniques to Increase Muscle Strength, Power, and Endurance

- Upper body strengthening
- UBE
- Stationary bike
- Aquatic treadmill at week 4. Remember that chest-high water level is 25% weight bearing, waist-high water level is 50% weight bearing.

Neuromuscular Dynamic Stability Exercises

- Manual rhythmic stabilization of trunk and core, performed in sitting.
- Nonsurgical leg single leg balance retraining.

Phase III (weeks 6 to 10 postoperative)

Goals

- Achieve full PROM of knee flexion.
- Maintain full PROM knee extension.
- Gradually improve quadriceps strength and endurance. Focus on eccentric quadriceps control.
- Progress functional activities during this period.
- Maintain cardiovascular fitness and upper body strength.

Protection

- Brace is discontinued at week 6. Ensure quad lag is eliminated before discontinuing brace.
- ACI-Femoral condyle lesion:
  - 100% weight bearing at weeks 6 to 8—earlier with permission from MD.
- ACI-Patella-trochlea lesion
  - 100% weight bearing at week 6

Management of Pain and Swelling

- Oral analgesic use is continued as needed.
- Cryotherapy is used post therapy to mitigate postexercise inflammation and soreness.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- No knee ROM precautions
- Maximize PROM knee flexion (at least 135°), maintain full PROM of knee extension.
- Continue patella-femoral joint mobilization—cephalad/caudad direction important for assisting in tibiofemoral ROM.
- Maintain hip joint mobility. Consider Hip PAs performed in prone or slight hip extension; add hip ER/IR, being cautious of the possible effects of torque on the knee joint.
- Assess PROM of ankle dorsiflexion. Compare to contralateral limb.

Soft Tissue Techniques

- Gentle scar tissue mobilization can be introduced at this stage.
- Soft tissue techniques may be applied to the quadriceps, hamstrings and calves. Avoid the knee joint.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Continue to focus on gastrocnemius/soleus (now performed in standing), hamstrings, and quadriceps stretches.
- Add Pretzel (piriformis/glutes) stretch, if the knee can tolerate it (see Figure 31-38).
- Thomas test stretch with added PROM knee flexion to improve flexibility of the rectus femoris muscle (Figure 31-33)

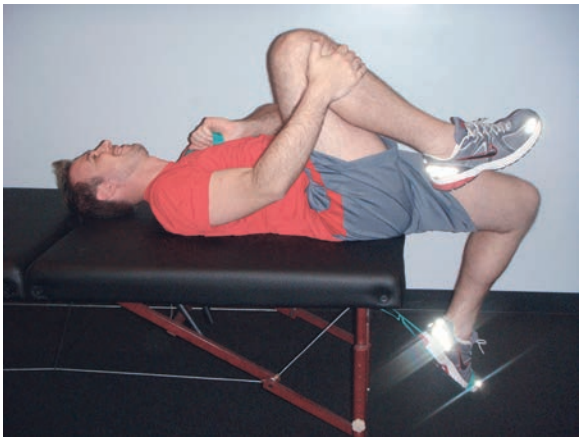

FIGURE 31-33. Thomas test stretch with additional passive knee flexion provided by the stretch band. This allows for simultaneous hip extension and knee flexion, thus targeting the rectus femoris muscle.

Other Therapeutic Exercises

- Cardiovascular—UBE, stationary biking.
- Week 8—Introduce elliptical training and Stairmaster. Gradually build up tolerance.
- Aquatic treadmill walking—Gradually lower water level to tolerance and with respect to the appropriate weight-bearing requirements.
- Week 9 to 10—treadmill walking
- Upper body strengthening can be progressed to preoperative levels.
- Consider combination exercises involving the core and upper body at this stage (e.g., physioball walkouts—roll prone on ball, walk on hands), and consider adding pushups or serratus hunches.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Basic surgical limb strengthening includes four-way straight leg raises with increased resistance. Quad lags should be completely eliminated at this stage. Discontinue use of NMES when quads lag is eliminated.
- Terminal knee extensions in standing—increase resistance
- Week 6—isometric leg press
- Week 8—stationary minilunge with cable chop. The cable chop involves holding a theraband, or attachment to a cable machine and performing a D1 or D2 proprioceptive neuromuscular facilitation (PNF) pattern. All effort is made to maintain core stability.
- Week 8—minisquats 0° to 45° using correct biomechanics. Avoid genu valgum and prevent knee over toes.
- Week 8—Begin double leg leg press through as much ROM as machine will allow.
- Week 8—double leg heel raises
- Week 9—front step-ups.
- Week 10—lateral step-ups. Target eccentric quadriceps and hip abductor control.

Clinical Pearl

The weight shift exercise in standing encourages the patient to weight bear in an equal distribution over the bilateral limbs. It targets hip, knee, and ankle proprioception, which encourages improved joint position awareness, increased joint stability, and decreased patient apprehension.

Begin training with the patient shifting laterally, feet hip distance apart. The patient should avoid side flexion of the trunk and a Trendelenburg at the hip. The patient should shift 90% of weight onto the right leg and then shift 90% of weight onto the left leg (Figure 31-34).

When the patient can achieve this rhythmically and comfortably, progress to stride standing, shifting weight forward onto the front leg (90% weight bearing) and backward onto the back foot (90%



FIGURE 31-34. Lateral weight-shift exercise, performed in standing. Note the maintenance of the vertical trunk while shifting 90% of weight onto the stance leg.



FIGURE 31-35. Anterior-posterior weight shift. Legs are hip distance apart; weight is shifted forward and backward to replicate the weight shifting required form in a nonantalgic gait pattern.

weight bearing) rhythmically (Figure 31-35). Scales can be utilized in order to perform this accurately. In the clinical setting, the rehabilitation specialist can instruct the patient to shift 90% of her/his weight onto the one leg, while keeping the toes of the opposite leg on the floor. This ensures safety when this exercise is first introduced. As weight-bearing tolerance is allowed to progress, this exercise can be further modified in order to allow full single leg weight bearing. It is therefore an excellent tool to use in the clinic.

Again, as patient tolerance allows progress to step-overs—the surgical leg stays fixed on the floor and the patient steps forward and backward with the nonsurgical leg, replicating the stance phase of the gait pattern.

These can be initiated at week 8, and progressed according to weight-bearing tolerance.

Sensorimotor Exercises

- Weightshift exercise in standing
- Rocker board balance retraining. Begin double leg AP direction, progress to lateral. Progress to single leg AP at week 8 to 9.
- Progress to wobble board—circles, right-left, front-back, balance on double leg. Progress to single leg at week 8 to 9.
- Active joint positioning of knee and hip
- Balance equipment (such as the BOSU, Dynadisc) can be incorporated at this stage. Progress patient as appropriate, keeping the exercises challenging.
- Use of physioball—bridging with back on floor, single leg and double leg; bridging with back on ball, add leg extensions and physioball walkouts with single leg extension.

Open and Closed Kinetic Chain Exercises

- Closed chain proprioception activities: rocker board, wobble board, BOSU, etc. utilizing double leg and single leg stance
- Closed chain strengthening exercises: At week 8 introduce leg press, mat squats (double leg), forward step-ups, lateral step-ups—progress resistance.
- Open chain strengthening exercises: short arc quads, VMO holds

Techniques to Increase Muscle Strength, Power, and Endurance

- Progress bike endurance.
- Introduce elliptical training at weeks 7 to 8.
- Aquatic treadmill—Continue walking program.

Neuromuscular Dynamic Stability Exercises

- It is safe, and indeed advisable, to progress proprioceptive challenge on balance equipment as cartilage healing progresses. Consider adding complexity challenges to the exercises (e.g., add perturbations, utilize multijoint exercises such as scaption progressive resistive exercises while balancing single leg on the rocker board).

Plyometrics

- Lower limb plyometrics should be avoided at this stage of critical cartilage repair.

Functional Exercises

- Gait correction is vital at this stage. Consider cup walking (Figure 31-36) at weeks 7 to 8. Cup walking was originally utilized in prosthetic gait training. It encourages a reciprocal gait pattern, full weight bearing



FIGURE 31-36. Cup walking. Cups are laid out and the patient has to step over each cup in a reciprocal pattern. This teaches the patient lower limb dissociation and equal distribution of weightbearing forces. This helps to correct an antalgic gait pattern.

over the surgical side, and forces the patient to pull the foot and knee up in order to clear the cups. Even gait cadence should be emphasized
- Ensure that the patient is walking up stairs reciprocally by weeks 8 to 9. Descending stairs reciprocally will lag behind ascending because of the slower recovery of eccentric quadriceps control.
- Ensure that patient weight bears equally through both lower limbs when transitioning from sit to stand. This can be measured by using scales or by closely observing the lower limb kinetic chain and ensuring that each hip lines up with the respective knee and ankle. Additionally, ensure that the feet are placed in a straight line in the frontal plane, otherwise the foot that is placed further back will be the one bearing most of the weight.
- Throwing athletes may incorporate the Throwers 10 program for the upper limbs.

Sport-Specific Exercises

- This is only appropriate for upper body training during this time period.

Phase IV (weeks 10 to 14 postoperative)

Goals

- Improve muscle strength and endurance.
- Progress functional activities.
- Encourage continued compliance. The patient must respect that overuse of the limb will have a detrimental effect on short-term healing and long-term cartilage integrity.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Maintain full PROM of both the tibiofemoral and patella-femoral joints.
- Hip mobilizations—Maintain or regain full ROM.
- Maintain full ankle dorsiflexion ROM.

Soft Tissue Techniques

- Soft tissue release of the quadriceps, hamstrings, gastroc/soleus complex, and glutes. This is not always necessary. However, occasionally a patient may be aware of significant muscle pain, usually in the quadriceps muscle. The possibility of a deep vein thrombosis (DVT) should always be ruled out. Please consult with the referring physician immediately, if you have any concerns. Effleurage-type massage may be effective in decreasing edema and improving patient comfort.
- Continue gentle scar tissue mobilization.

Stretching/Flexibility Techniques for the Musculotendinous Unit

- Maintain/achieve sufficient flexibility of the lower limb muscles.
- Progress to targeting hip ER and IR ROM—frog stretch (Figure 31-37) and pretzel stretch (Figure 31-38)
- Continue to focus on iliopsoas and rectus femoris length by performing the modified Thomas test stretch.

Other Therapeutic Exercises

- Progress upper body strengthening exercises.
- Progress core recruitment exercises.
- TM walking, elliptical, StairMaster, stationary bike

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- As before with progressive resistance
- Increase leg press through full range; add resistance; aim for equal weight distribution when using both legs.

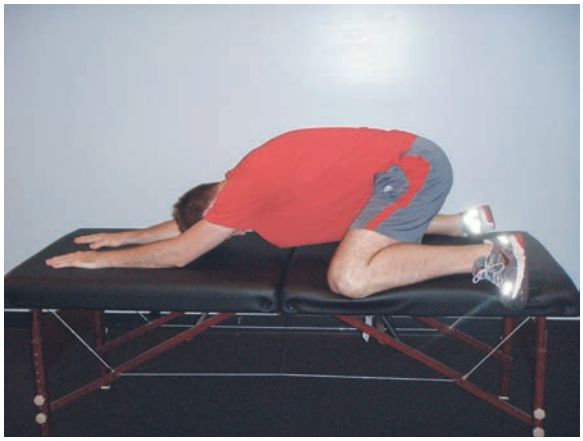

FIGURE 31-37. The frog stretch. The patient must turn out the feet and can vary the position of the pelvis to obtain maximal stretch.



FIGURE 31-38. The pretzel stretch. A low-load, long-duration stretch which aims to restore external rotation of the hip.

Sophisticated digitized leg press machines are able to calculate weight distribution. In the absence of such machines, carefully observe the patient and encourage the patient to avoiding protecting the surgical leg. Ensuring alignment of the feet, ankles, and knees can aid in this goal. As the patient gains strength and confidence, and as pain decreases, he/she should be encouraged to gradually progress to equal weight distribution between both legs.

- Progress to single leg at week 12.
- Add leg curls
  - Single leg heel raises—extended (gastrocnemius) and flexed (soleus) knee

Open and Closed Kinetic Chain Exercises

- CKC
  - High step-ups—Progress to waist height.
  - Backward stationary lunges
  - Double leg squats
  - Athletes are encouraged to avoid locking out the tibiofemoral joint. Stance used should be hip width apart with careful focus on maintaining correct joint mechanics.
- OKC
  - Speedskaters (Figure 31-39)
  - Open chain knee extension 0° to 20°

Techniques to Increase Muscle Strength, Power, and Endurance

- Advance endurance sets to strength exercises (shorter repetitions: 6 to 8)

Neuromuscular Dynamic Stability Exercises

- Progress use of balance equipment. Focus predominantly on single leg exercises and compare sides to judge progress. Time how long patient can stand on a single leg without support on various pieces of balance equipment, such as the rocker board, wobble board, and BOSU. Aim to get the surgical leg to balance for as long as the nonsurgical side. Observe that the patient does not use incorrect hip, knee, or ankle strategies, such as foot pronation or knee genu valgum.



FIGURE 31-39. Speedskaters. The patient must maintain balance over the stance leg, with the weightbearing knee in neutral (avoid genu valgum) and core control. Emphasize the eccentric motion of the nonstance leg.

Functional Exercises

- Lower limb agility drills can be performed utilizing fast walking without sudden changes in direction or pivoting.

Sport-Specific Exercises

- The running athlete must still avoid any lower body impact exercises at this stage.

Milestones for Progression to the Next Phase

- Full range of motion.
- Acceptable strength level
  - Hamstrings within 10% of contralateral leg—isokinetic testing
  - Quadriceps within 10% to 20% of contralateral leg—isokinetic testing
- Balance testing within 30% of contralateral leg. Again, sophisticated balance testing machines are available. However, in the absence of such equipment, measure single leg balance time on the wobble board without allowing the edge of the board to make contact with the ground. Compare sides.
- Able to walk 2 miles or bike for 20 minutes
- 50 lateral step-ups (8-inch height). This is an easily measurable activity, which ensures that sufficient eccentric quad control has been achieved in order to progress to Phase V.

Phase V (weeks 14 to 24 postoperative)

Goals

- Improve muscle strength and endurance.
- Progress functional activities.
- Encourage continued compliance. The patient must respect that overuse of the limb will have a detrimental effect on short-term healing and long-term cartilage integrity.
- Hamstrings and quadriceps strength within 10% of contralateral leg
- Balance testing within 10% of contralateral leg

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Maintain full PROM of both the tibiofemoral and patella-femoral joints.
- Continue hip and ankle mobilizations if necessary

Soft Tissue Techniques

- Assess the need for soft tissue release of the quadriceps, hamstrings, gastroc/soleus complex, and glutes. This is only necessary if the patient continues to complain of specific muscle pain. Trigger points can be assessed and treated. Any edema can be addressed with effleurage massage. Again, always rule out the possibility of DVTs.
- Continue gentle scar tissue mobilization.

Stretching/Flexibility Techniques for the Musculotendinous Unit

- Maintain/achieve sufficient flexibility of the lower limb muscles.
- Continue to focus on iliopsoas and rectus femoris length by performing the modified Thomas test stretch.

Other Therapeutic Exercises

- Progress upper body strengthening exercises.
- Progress core recruitment exercises.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- As before with progressive resistance
- Progress to single leg leg curls and leg extensions at week 14; increase resistance.
- Be cautious with full ROM open chain knee extensions with the patella-trochlea patients. Avoid them completely if they create pain.

Sensorimotor Exercises

- PNF lower limb patterns performed in supine. Be sure to add knee flexion and extension into the patterns to recruit the primary operative muscles. PNF upper limb and trunk patterns in half kneeling and static lunge position.

Open and Closed Kinetic Chain Exercises

- CKC
  - High step-ups—Progress to waist height.
  - Backward lunges—Progress to backward lunge walking; progress to forward lunge walking.
  - Double leg squats—Progress to single leg squats. Vary surface, add perturbations, add upper body/trunk motion.
  - Athletes are encouraged to avoid locking out the tibiofemoral joint. Stance used should be hip width apart, with careful focus on maintaining correct joint mechanics.
- OKC
  - Speedskaters—Increase resistance; the patient can stand on a BOSU or rocker board.
  - Cable kicks in PNF patterns

Techniques to Increase Muscle Strength, Power, and Endurance

- Advance endurance sets to strength exercises (lower repetitions: 6 to 8)
- Alternately focus on endurance (16 to 20) sets and hypertrophy (6 to 8) resistance training

Neuromuscular Dynamic Stability Exercises

- Progress use of balance equipment. Focus predominantly on single leg exercises and compare sides to judge progress. Here again, single leg balance on the wobble board, whereby the edge of the board is not allowed to make contact with the floor, is an effective comparison tool. This same principle can be applied to other balance equipment.
- Add sport-specific drills (e.g., a baseball pitcher can perform trampoline pitching while balancing single leg on a BOSU; a soccer player can replicate kicking with band resistance balancing on a balance board).

Plyometrics

- Plyometrics are still not introduced at this stage, in order to protect the cartilage repair.

Functional Exercises

- Lower limb agility drills can be performed utilizing fast walking. Increase unpredictability of training, by throwing balls and calling direction changes.
- Increase walking distance, speed and inclines as time progresses.

Sport-Specific Exercises

- Gradual reintroduction of impact exercises toward the end of this stage

Phase VI (weeks 24 to 52 postoperative)

Goals

- Prepare patient for return to sport.

Management of Pain and Swelling

- Cryotherapy application post exercise

Techniques for Progressive Increase in Range of Motion

- Full AROM and PROM must be achieved by 4 months.
- Ensure maintenance of patella-femoral ROM.

Soft Tissue Techniques

- Seldom necessary at this stage

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Full, passive knee extension ROM remains critical. Most patients will be easily able to maintain this, especially if their gait pattern is optimal and, as a result, they use knee extension with every step that they take. The occasional patient may continue to struggle. Regular hamstring and gastrocnemius stretching remains useful in these cases. Use of low-load, long-duration passive knee extension may still be required on a daily basis.

Other Therapeutic Exercises

- Continue and progress multijoint exercises.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Aim to return to preinjury levels of function toward the end of this phase.

Sensorimotor Exercises

- Single leg standing on wobble board (or similar device). Increase complexity by adding ball toss, close eyes, add perturbation of board or trunk, and initiate single leg squats.
- PNF lower limb patterns performed in supine and standing. Be sure to add knee flexion and extension into the patterns to recruit the primary operative muscles. PNF upper limb and trunk patterns in half kneeling and static lunge position
- Continued use of physioball—Continue increasing challenge and complexity of exercises (e.g., sitting on physioball with single leg support), perform cable PNF with upper limbs and maintain balance. Perform with eyes closed.

Open and Closed Kinetic Chain Exercises

- Advance the previous exercises in accordance with sport-specific demands.
- CKC progression includes:
  - Single leg squats standing on a wobble board
  - Lunges on two BOSU surfaces, increasing resistance and decreasing support
  - Lateral step-ups with trunk perturbations
- OKC
  - Restrict open chain knee extensions to 0° to 20°.
  - If patient participates in a kicking sport, open chain kicking agility exercises can be incorporated.

Techniques to Increase Muscle Strength, Power, and Endurance

- Pool running can be introduced at the 6-month mark.
- Treadmill running can be introduced at the 7-month mark.
  - Carefully observe the patient's running pattern. Ensure an even rhythm, light grading, equal weight bearing, correct use of upper limbs, and core recruitment.
- Increase endurance on the elliptical, bike and StairMaster. It is usually preferable to increase distance before speed/intensity but individual preference must be respected.

Clinical Pearl

> Use pain and/or swelling to monitor whether you are progressing too quickly. It is an accurate sign of overuse and should be respected accordingly.

Neuromuscular Dynamic Stability Exercises

- Agility drills—cariocas and cone drills can only be performed at a fast walking pace until the 7-month mark, when light running can be added. Speed and complexity can be progressed at that stage.
- Cone touches—Place two cones slightly more than hip distance apart. Stand on one leg in between them. Reach left hand to right cone and reverse, repeat for 20 reps (Figure 31-40).
- Single leg deadlifts (patient holds PVC pipe vertically behind back. Patient performs a single leg deadlift maintaining contact of the PVC pipe against the occiput and tailbone throughout the motion.)
- Deep knee bends (full range, good mechanics) can be introduced to teach efficient eccentric quadriceps release.
- Always challenge the patient.

Plyometrics

- Month 4 to 7—Consider upper body plyometrics while utilizing static stance for lower body (e.g., hold static squat position while throwing ball against wall, physioball bridge with back on ball while performing overhead ball toss and crunches).



FIGURE 31-40. Cone touch exercise. The patient must maintain a neutral knee position on the stance leg. Maintenance of core control is essential.

- Months 7 to 8—Teach box jumping. Monitor patient's level of discomfort during and after the exercise. Ensure patient learns to land with light grading ("light, like a panther") and maintains correct joint positioning (do not allow the knees to go forward over the toes, keep the knees apart and avoid genu valgum) throughout the movement. As time progresses, advance from double leg jumps forward to double leg jumps sideways to double leg jumps over the box. Continue the progression to single leg jumps forward to single leg jumps sideways. For safety, do not allow the patient to become overly fatigued. The patient should be allowed to rest often. The exercises should be discontinued immediately as soon as the patient is no longer able to maintain correct form.
- Month 8 to 9—Progress to single leg hopping agility drills.

Sport-Specific Exercises

- Low-impact sports such as golf, swimming; skating, rollerblading, and cycling are permitted at 6 months.
- Moderate impact sports such as running and aerobics may be performed at 7 to 8 months.
- High-impact sports such as tennis, volleyball, basketball, football, and baseball are allowed at 12 months.

Milestones for Progression to the Next Phase

- Less than 10% side-to-side deficit on isokinetic testing
- Less than 15% side-to-side deficit on hop test
- Patient-reported outcome studies at 52 weeks should be greater than 90% compared with preoperative scores.

Outcome Measures

Patient reported outcome scales should be implemented at the 12-month follow-up appointment. Scales that have been utilized in the literature for cartilage restoration procedures include:

- IKDC—International Knee Documentation Committee Subjective Knee Form
- SF12—Quality of life instrument
- KOOS—Knee injury and Osteoarthritis Outcome Score

Criteria for Return to Sport

General

- Full AROM in tibiofemoral and patella-femoral joint, no apprehension
- Minimum of 80% to 90% side-to-side symmetry on isokinetic testing
- Minimum of 15% side-to-side symmetry on hop test
- Quadriceps-hamstrings ratio that matches nonsurgical limb—isokinetic testing
- Correct hip and knee alignment during jump test and hop test, particularly when fatigued.

Sport-Specific

- Specific sports require specific functional demands of the athlete. The rehabilitation specialist needs to be familiar with sport-specific demands.
- A particular focus should be on working the patient to fatigue, because injury rates have been shown to increase when a patient is fatigued.

After Return to Sport

Continuing Fitness or Rehabilitation Exercises

- Total body fitness regime

Exercises and Other Techniques for Prevention of Recurrent Injury

- Ensure maintenance of lower limb strength, maintain surgical limb at 85% or better when compared to nonsurgical limb. The patient may be encouraged to consult with the rehabilitation specialist every 3 to 6 months in order to undergo repeat isokinetic testing and functional testing, such as the hop test.
- Continue neuromuscular control exercises to maximize core, hip, knee, and ankle stability and proprioception.
- Maintain cardiovascular endurance, balance, and proprioception, flexibility, strength, and endurance. Neglect of any of these areas may place the athlete at risk for reinjury.
- Consider limiting impact and joint loading except when it is necessary for sport-specific demands.

Modifications for Concomitant Surgeries

ACL-Patellar tendon or Hamstring Graft Reconstruction

- Weightbearing progression—Follow ACI protocol.
- Passive ROM follows ACI-patellofemoral guidelines

Meniscus Allograft

- Weight-bearing progression—Follow ACI protocol.
- Passive ROM
  - Week 1: 60 degrees
  - Week 2: 90 degrees
  - Week 5: 100 degrees
  - Week 8: 125 degrees
- No active flexion for 6 weeks (owing to hamstring attachment to the meniscus)
- Resisted hamstring strengthening, week 12

Tibial Tubercle Realignment (Fulkerson)

- Weightbearing progression—Follow ACI protocol.
- Passive ROM
  - Week 1: 60°
  - Week 3: 90°
  - Week 5: full 125°
- No short arc quads until week 8

High Tibial Osteotomy

- Weight-bearing progression—Follow ACI protocol.
- Passive ROM (limited by pain tolerance only)
  - Week 1: 90°
  - Week 3: 115°
  - Week 6: greater than 125°
- Discontinue brace at week 6 to 8 only

Distal Femoral Osteotomy

- Similar to high tibial osteotomy but important to emphasize passive knee flexion early because it can be harder to regain.
- Weightbearing progression—Follow ACI protocol.
- Passive ROM (limited by pain tolerance only)
  - Week 1: 90°
  - Week 3: 115°
  - Week 6: greater than 125°
- Discontinue brace at week 6 to 8 only

Multiple-Lesion ACI

- Slower progression in both weightbearing and ROM than standard ACI protocol

Clinical Pearl

Although protocols are excellent for providing basic timelines, individual patients will differ in their progression. Age, size of lesion, tissue quality, motivational level, and fear avoidance are some examples of factors that will alter the patient's progress. Base the patient's progression in rehabilitation on research findings of articular cartilage healing rates and the patient's ability to fulfill specific criteria before progressing to the next phase.

Evidence

Gillogly S, Myers T, Reinhold M: Treatment of full-thickness chondral defects in the knee with autologous chondrocyte implantation. *J Orthop Sports Phys Ther* 36(10):751–764, 2006.

This article discusses patients' selection for ACI, reviews ACI surgical options and techniques, details postoperative protocols, and summarizes clinical outcomes. (Level 4 evidence)

Kon E, Filardo G, Berruto M, et al: Articular cartilage treatment in high level male soccer players: A prospective comparative study of arthroscopic second-generation autologous chondrocyte implantation versus microfracture. *Am J Sports Med* 39(12):2549–2557, 2011.

This cohort study evaluated prospectively 41 male soccer players at 2 and 7.5 year mean follow-up. Twenty-one patients were treated with ACI, 20 with microfracture. Return to sport was 80% in microfracture, 86% in ACI. Return to playing a soccer game took 8 months (median) for the microfracture group and 12.5 months (median) for ACI. IKDC scores at 2 years were similar, but significantly better at final evaluation for ACI. In fact, microfracture results deteriorated over the long term. The study concluded that ACI patients will take longer to return to competition but ACI offers more durable clinical results. (Level 2 evidence)

Logerstetdt D, Snyder-Mackler L, Ritter R, et al: Knee pain and mobility impairments: Meniscal and articular cartilage lesions. *J Orthop Sports Phys Ther* 40(6):A1–A35, 2010.

Clinical practice guidelines detailing evidence-based recommendations for examination and diagnosis, rehabilitation interventions, and assessment of outcome. (Level of evidence not known)

Mithoefer K, Hambly K, Della Villa S, et al: Return to sports participation after articular cartilage repair in the knee: Scientific evidence. *Am J Sports Med* 37(Suppl 1):167S–176S, 2009.

A systematic review of 20 studies (1363 patients), with average follow up of 42 months. 73% return to sports, with highest rates after OATS. Time to return to sports varied from 7 to 18 months. Initial return to sports at the preinjury level was possible in 68% without significant differences between surgical techniques. Continued sports participation at the preinjury level was possible in 65%; ACI showed best durability. Factors that affected the ability to return to sport included: athlete's age, preoperative duration of symptoms, level of play, lesion size, and repair tissue morphology. (Level 3 evidence)

Peterson L, Vasiliadis HS, Brittberg M, et al: Autologous chondrocyte implantation: A long-term follow-up. *AM J Sports Med* 38(6):1117–1124, 2010.

Twenty years after the implantation (mean, 12.8 years), 74% of the patients reported their status as better or the same as the previous years. There were 92% who were satisfied and would have the ACI again. The average Lysholm score improved from 60.3 preoperatively to 69.5 postoperatively, the Tegner from 7.2 to 8.2, and the Brittberg-Peterson from 59.4 to 40.9. The KOOS score was on average 74.8 for pain, 63 for symptoms, 81 for activities of daily living, 41.5 for sports, and 49.3 for quality of life. The average Noyes score was 5.4. Patients with bipolar lesions had a worse final outcome than patients with multiple unipolar lesions. The presence of meniscal injuries before ACI or history of bone marrow procedures before the implantation did not appear to affect the final outcomes. The age at the time of the operation or the size of lesion did not seem to correlate with the final outcome. (Level IV case series.)

Reinhold M, Wilk K, Marcina L, et al: Current concepts in the rehabilitation following articular cartilage repair procedures in the knee. *J Orthop Sports Phys Ther* 36(10):774–814, 2006.

This paper provides an overview of ACI rehabilitation principles, based on current understanding of the biologic healing response postoperatively. (Level 4 evidence)

Blackburn TA, Gillogly SD, Voight ML: Treatment of articular cartilage defects of the knee with autologous chondrocyte implantation. *J Orthop Sports Phys Ther* 28(4):241–251, 1998.

This paper provides an introduction to ACI surgery. (Level 4 evidence)

Multiple-Choice Questions

QUESTION 1. When should full PROM of tibiofemoral knee extension be established?

A. 0 to 2 weeks
B. 2 to 4 weeks
C. 4 to 6 weeks
D. Never

QUESTION 2. How many months does research indicate, for the surgical cartilage begin to become as durable as the surrounding healthy cartilage?

A. 3 months
B. 6 months
C. 9 months
D. 15 months

QUESTION 3. True/False

An ACI-Femoral condyle lesion will require a slower progression into weightbearing that an ACI-Patella-femoral lesion.

QUESTION 4. When can High impact sports be resumed following an ACI-femoral condyle procedure?

A. 3 months
B. 6 months
C. 9 months
D. 12 months

QUESTION 5. Which surgery allows the fastest return to sports?

A. Allograft OATS
B. Autograft OATS
C. ACI-femoral condyle
D. ACI-patella-trochlea

Answer Key

QUESTION 1. Correct answer: **A** (see Phase I)

QUESTION 2. Correct answer: **C** (see Healing Timeframes section)

QUESTION 3. Correct answer: **True** (see Table 31-3)

QUESTION 4. Correct answer **D** (see Return to sport section)

QUESTION 5. Correct answer **B** (see Table 31-3)

POSTOPERATIVE REHABILITATION AFTER OSTEOCHONDRAL ALLOGRAFT/AUTOGRAFT TRANSFER FOR CARTILAGE RESTORATION

Scott D. Gillogly, MD, FACS, and Kate McDonald, BSc PT, OCS, COMT

Indications for Surgical Treatment

Osteochondral Allograft Transfer

- Symptomatic full-thickness chondral defects (grade III to grade IV lesions) and osteochondritis dissecans (OCD) lesions of the femoral condyle
- Any osteochondral defect or OCD where native subchondral bone loss has occurred, especially bone loss greater than 7 to 8 mm in depth
- Medium to large focal chondral lesions typically larger than 20 mm in diameter and up to the width of the damaged femoral condyle

Osteochondral Autograft Transfer

- Limitations of this technique are related to the amount of tissue that can be safely or easily harvested from the patient's involved knee.
- Typically up to two 10-mm diameter plugs or three 6- to 8-mm diameter plugs can be harvested from the patient's knee.
- Therefore the indications are for smaller lesions that can be filled by this amount of autograft osteochondral tissue. Generally a lesion no bigger than 20 × 10 mm in size.

Brief Summary of Surgical Treatment

Osteochondral Allograft Transfer

- No biopsy is required, although sizing radiographs are obtained to allow size matching of the patients affected defect location with the allograft (cadaver) osteochondral tissue
- Osteochondral allograft transfer (Figure 31-41) is an open procedure requiring adequate exposure.

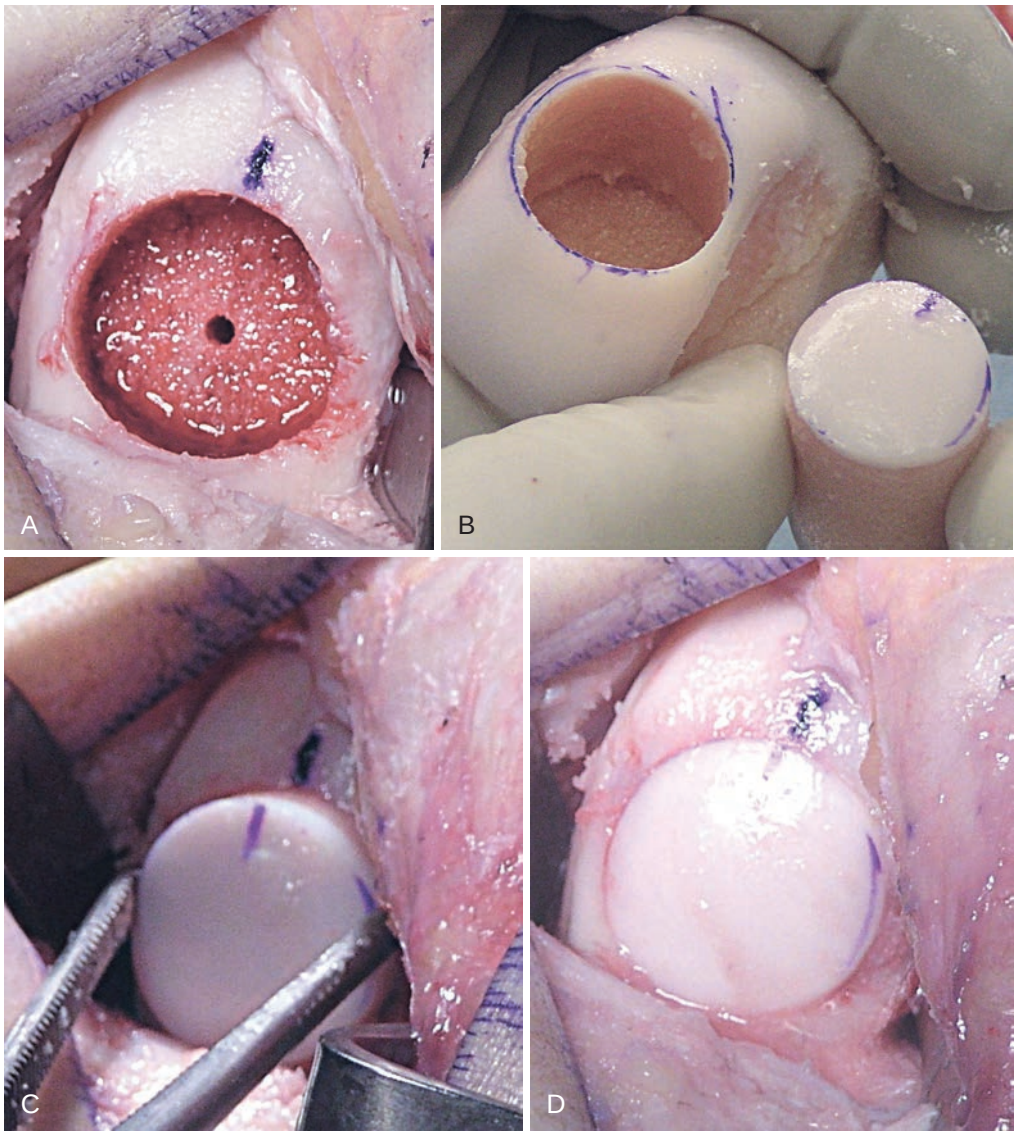

FIGURE 31-41. Osteochondral Allograft Transfer. **A,** The patient's defect has been reamed to remove all damaged cartilage and bone and create a socket for the transfer. **B,** Cylinder osteochondral plug is obtained from a corresponding anatomic site on the allograft condyle. **C,** After shortening the bony portion of the plug to match the depth of the patient socket, the transfer is oriented and inserted by "press fit." **D,** The surface of the transfer is congruous with the patient's surrounding articular cartilage.

- The chondral defect is sized with templates of various size circles, finding the size that will fully cover the defect.
- The defect is then reamed to create a socket for the osteochondral allograft transfer.
- Using the same sized template, the location of the patient defect is matched on the cadaveric donor.
- Using a circular cutting saw of the identical diameter, a cylinder of osteochondral allograft is obtained.
- The depth of the patients defect after preparation is then transferred to the osteochondral allograft, shortening the bony portion to just match the depth of the patient defect.
- The osteochondral cylinder plug is then "press fit" into the patients defect, leaving a surface of donor articular cartilage congruous with the patient's healthy remaining articular cartilage.
- Any concomitant procedures such as anterior cruciate ligament reconstruction, osteotomy, patellofemoral realignment, or meniscal transplantation are done prior to completing the osteochondral allograft transfer, which should be the last portion of the procedure
- The stability of the press fit insertion of the allograft allows for immediate range of motion during the rehabilitation process.

Osteochondral Autograft Transfer

- The procedure at times is performed arthroscopically, although the trend has been to do a mini open technique to insure that the plugs are placed perpendicular to the articular surface.

Table 31-4 Comparison of Osteochondral Allograft and Autograft Transfer Surgery

	Weightbearing	PROM Knee Flexion Goals	Return to Sport
Osteochondral Autograft Transfer	Less protection required for patient's own tissue 25% weight bearing Week1 50% weightbearing Week 2 100% weight bearing Weeks 3–4	Full PROM restored in first 3–6 weeks, restricted by pain only	4 months Low impact 6 months Moderate impact 7–8 months High impact
Osteochondral Allograft Transfer	50% weight bearing Week 2 75% weightbearing Weeks 3–4 100% weightbearing Weeks 6–8	PROM is restricted only by pain; the following are conservative numbers and can be progressed faster. 90° by Weeks 1–2 105° by Week 3 115° by Week 4 135° by Week 6	6 months Low impact 7–8 months Moderate impact 12 months High impact

- The most common harvest site is the superolateral femoral condyle, the non–weight-bearing, and nonarticulating area.
- The recipient site (patient's defect) is prepared for the one to two plugs and the transferred autograft plugs are put in place in a press-fit fashion. The stability of the press-fit insertion of the autograft tissue allows for immediate range of motion during the rehabilitation process.

Before Surgery: Overview of Goals, Milestones, and Guidelines[3]

- Prehabilitation is very important prior to cartilage restoration procedures. Postsurgical pain and immobility may be significant and result in fairly significant muscular atrophy. Obviously, the stronger the patient is prior to surgery, the easier it will be to maintain and regain muscle.
- One or two prehabilitation sessions of physical therapy should be sufficient to instruct the patient. Focus on the following specific areas:
  - Weight loss
  - Core strengthening (e.g., planks, side planks, abdominal roller, physioball exercises)
  - Hip abductor strengthening (side-lying abduction, single leg balance on wobble board, speedskaters [see Figure 31-39])
  - Quadriceps strengthening vastus medialis oblique holds (sit, maintaining good posture on a level surface, with both feet on the ground. Hold the surgical knee in static, active knee extension for five minutes. Once finished, slide back onto the bed so that it is not necessary to do open chain knee flexion). Sit-to-stands (similar to squats but patient sits on the low mat table and then stands again, without using arm support), leg presses.
  - General cardiovascular fitness
- In addition, it may be advisable to teach the patient the initial postoperative regime including crutch walking, heel prop, quad sets, ankle pumps, and hamstring and calf stretches during the prehabilitation sessions (refer to Phase I). This is necessary because the patient is often in significant pain and/or on strong analgesia at the initial postsurgery visit.

[3]*Prehabilitation, if appropriate, is described in the Nonoperative Rehabilitation section of this chapter.*

GUIDING PRINCIPLES OF POSTOPERATIVE REHABILITATION

- Appreciate the anatomic structures involved and their individual rates of healing.
- Appreciate stresses applied in different ranges of motions, with different activities.
- Determine location, size, depth, and number of lesions.
- Determine whether concomitant procedures have been performed. Follow the more conservative protocol.
- Respect ROM requirements and weight-bearing progressions. These will differ for the different surgical techniques and different locations (Table 31-4).
- The osteochondral autograft protocol is considerably less conservative than the osteochondral allograft protocol, due to the fact that a patient's own tissue requires a shorter integration period. The first 14 days of rehabilitation are identical for both procedures, after which the rehabilitation specialist can progress the osteochondral autograft more rapidly.

Phase I (days 0–14): Immediate Postoperative Period

Clinical Pearl

It is imperative to retain full passive knee extension immediately postoperative (e.g., by performing prone hangs or heel props [see Figures. 31-28 and 31-29] or using a passive extension device). The patient should additionally be educated against resting with a pillow under the knee. Educating the patient on the importance of this step is invaluable in gaining full compliance.

Goals

- Decrease pain and effusion.
- Protection from load and shear forces

- Immediate restoration of full passive knee extension
- Gradually increase passive knee flexion, limited by patient's pain only.
- Regain quadriceps control.
- Achieve safe crutch walking with full understanding of weight-bearing requirements.

Protection

- The patient may present to the clinic in a knee immobilizer. This may be utilized as long as the nerve block continues to be effective, because the patient will have very little active leg control.
- As soon as quadriceps control returns (the patient no longer has a quads lag), a hinged brace should be fitted.
- Lock the brace at the angle achieved in rehabilitation and increase range of knee flexion to mirror the patient's gains in passive knee flexion ROM achieved in rehabilitation.
- Weight bearing must be limited. Two crutches (two-point or three-point gait) should be used, and the patient is advised to use heel-toe gait on the affected side while only placing 10% to 20% of body weight on the surgical leg. Complete non–weight-bearing has been shown to negatively affect growing articular cartilage. Conversely, the controlled compression and decompression forces created through weight bearing are believed to nourish the growing articular cartilage and to provide the necessary signals to the tissues to allow matrix production that matches environmental need.
- A compression stocking should be utilized for edema control and to prevent blood clots in the first week. This should be followed by use of a lightweight, shorter compression stocking until edema subsides.

Management of Pain and Swelling

- A pain pump for continuous nerve block may be inserted during surgery.
- Oral pain medications
- Cryotherapy for pain and inflammation reduction
- Patient education: The patient should NEVER place a pillow under the knee in an effort to find a position of comfort—this will result in difficulty and pain in attempting to regain passive knee extension.
- The patient should sleep in the hinged knee brace.

TIMELINE 31-4: **Postoperative Rehabilitation After Osteochondral Autograft/Allograft Transfer**

PHASE I (weeks 1 to 2 postop)	PHASE II (weeks 2 to 6 postop)	PHASE III (weeks 6 to 10 postop)

• Hinged knee brace—locked at PROM flexion gains in rehab
• PT modalities
• Immediate motion Day 1
• ROM Passive knee extension—full PROM ASAP. Perform in 20 minute sessions 5 times per day.
• ROM Passive knee flexion—progress as per patient tolerance—3 times a day
• ROM Patella-femoral joint mobilization—3 times a day
• Weight bearing—10–20 lbs, heel-toe gait with 2 crutches
• Ankle pumps, quads sets, SLR with NMES
• Stationary bike when ROM allows
• Hamstring, calf, quadriceps stretching
	• Hinged knee brace
	• PT modalities
	• ROM—no precautions, full extension, increase PROM knee flexion as tolerated, PF mobs
	• PROM knee flexion goals:
	  • ACI-Femoral condyle lesion:
	  • 90° weeks 1–2,
	  • 105° by week 3,
	  • 15° by week 4
	  • 35° by week 6
	  • These are conservative and can be progressed faster.
	  • ACI-Patella-trochlea lesion
	  • 90° by weeks 2–3
	  • 105° by weeks 3–4
	  • 120°s by week 7
	• Weight bearing
	  • ACI-Femoral condyle lesion
	  • Continued restriction of weight bearing initially—10–20 lbs only
	  • 50% weight bearing at weeks 4–6
	  • ACI-Patella-trochlea lesion
	  • Weight bearing can be accelerated more quickly.
	  • 25% body weight week 2
	  • 50% weight bearing at week 4
	  • Full weight bearing at week 6
	• Ankle pumps, quads sets, SLR with NMES, short arc quads, TKEs
	• Manual rhythmic stabilization of trunk in sitting, nonsurgical leg single leg balance
	• Stationary bike
	• Hamstring, calf, quad (rectus fem) stretching
	• TBS/TAS/TLS activities as recommended and tolerated
	• Week 4—isometric leg press, aquatic treadmill walking
		• DC Brace at week 6
		• Passive Knee ROM
		  • ACI-Femoral condyle
		  • At least 135° PROM knee flexion
		  • ACI-Patella-trochlea
		  • 120° week 7
		  • 135° weeks 8–9
		  • Full PROM knee extension, PF mobs, gentle scar tissue mobilization
		• Weight bearing
		  • ACI-Femoral condyle lesion:
		  • 50% weight bearing with crutches at weeks 4–6
		  • 100% weight bearing at 6–8 weeks—earlier with permission from MD
		  • ACI-Patella-trochlea lesion
		  • 100% weight bearing weeks 6–8
		• Continue previous stretches, add pretzel, Thomas test stretch
		• Continue stationary bike, aquatic TM (lower water level), treadmill wks 8–9
		• TBS/TAS/TLS activities as recommended an tolerated
		• Week 6—isometric leg press, standing weightshifts, rocker board, physioball bridging and walkouts
		• Week 8—Mat squats, double-leg leg press, cup walking, heel raises (double leg), stationary minilunge with cable chops
		• Week 9—front step-ups, single leg rocker board
		• Week 10—elliptical, lateral step ups

- A continuous passive motion (CPM) machine can be used up to 4 hours a day (using ROM gained in PT). This can help with pain management and in regaining motion. Emphasis on full passive knee extension while using CPM should be encouraged from Day 1.
- A compression stocking is worn initially. When control is gained over edema, this can be replaced with a shorter, light compression stocking.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Immediate motion from Day 1
- Maximize passive knee extension immediately. Use a patient-controlled passive knee extension device, heel prop or prone hangs.
- Perform in 20-minute sessions five times per day.
- Grade 2–3 anterior-posterior mobilizations (APs) to the tibiofemoral joint can be used to increase this range.
- Passive patella-femoral joint mobilization, both in the medial-lateral and cephalad-caudad directions, will prevent loss of patella-femoral ROM and resulting potential loss of tibiofemoral ROM three times a day.
- Passive knee flexion is progressed per patient tolerance. There is no limitation to this increase, except for the pain tolerance levels of the athlete. Perform three times a day.

Clinical Pearl

Passive knee flexion is limited only by patient tolerance. The increase in ROM is expected to be slower in patella-trochlea ACI patients than in femoral condyle ACI patients. It can be particularly beneficial to aim for an increase in ROM, even if it is just a few degrees, at each treatment session. It is discouraging for a patient to tolerate pain and then not make any gains. This range will always be limited by swelling. Make every effort to reduce swelling, including patient education. If you are not successful, always seek the orthopaedic surgeon's opinion, in case knee aspiration is necessary.

TIMELINE 31-4: **Postoperative Rehabilitation After Osteochondral Autograft/Allograft Transfer** (Continued)

PHASE IV (weeks 10 to 14 postop)	PHASE V (weeks 14 to 24 postop)	PHASE VI (weeks 24 to 52 postop)

• PROM—maintain full motion, joint mobilizations as needed
• Weight bearing 100%
• Continue lower limb stretches. Add Frog, Pretzel, modified Thomas test stretch
• Stationary bike, treadmill walking, elliptical, StairMaster
• TBS/TAS/TLS activities as recommended an tolerated
• CKC: High step-ups, backward stationary lunges, double leg squats, leg press, heel raises (double and single-leg); week 12, single leg leg press
• OKC: speedskaters, open chain knee extension 0°–20°, leg curls
• Single leg balance, walking agility drills
• *If the osteochondral autograft athlete is demonstrating faster progression, it is reasonable, at this stage, to accelerate the time frames in the upcoming phases.*
	• PROM—maintain full motion
	• Weight-bearing status—aquatic TM run 24 weeks
	• Continue lower limb stretches. Add Frog, Pretzel, modified Thomas test stretch
	• Stationary bike, treadmill/road walking, elliptical, StairMaster
	• PNF lower limb and/or trunk in supine or sitting
	• TBS/TAS/TLS activities as recommended and tolerated
	• CKC: Progress height of high step-up, backward lunge walking, forward lunge walking, single leg squats (vary surface, add perturbations)
	• OKC: speedskaters on proprioceptive equipment, cable kicks in PNF patterns
	• Walking agility drills—increase complexity
		• Previous levels of functional activities
		• End range sustained stretches
		• Single leg stand/squat on balance device. Increase complexity
		• PNF lower limb patterns in standing and supine
		• PNF upper limb/trunk in tall kneeling, half kneeling, single leg stand on rocker board
		• Physioball ex: bridge back on ball with leg extensions, bridge back on floor, single leg curls
		• CKC: lunges on 2 BOSU, LSU
		• OKC: open chain knee ext 0°–20°, open chain kicking
		• 6 mo—pool run, 7 mo—treadmill run, increase distance on bike, elliptical, StairMaster
		• Agility drills—fast walk
		• Single leg cone touches, single leg deadlifts
		• 4–7 mo—upper body plyometrics, static stance lower body
		• 7–8 mo—box jump—progress direction, number, single leg
		• 8–9 mo—single leg hop agility drills
		• Sports—Osteochondral autograft
		  • 4 mo—Low impact: golf, swimming, skating, rollerblading, cycling
		  • 6 mo—Moderate impact: light running, aerobics
		  • 7–8 mo—High impact: tennis, volleyball, basketball, football, baseball
		• Sports—Osteochondral allograft
		  • 6 mo—Low impact: golf, swimming, skating, rollerblading, cycling
		  • 7–8 mo—Moderate impact: light running, aerobics
		  • 12 mo—High impact: tennis, volleyball, basketball, football, baseball

Soft Tissue Techniques

- Gentle effleurage to decrease edema in the calf area can be beneficial. Avoid the surgical area during this phase.
- Stretching/flexibility techniques for the musculotendinous unit
- Gentle hamstring and calf stretching will help improve patient comfort and prevent future soft tissue restrictions.

Other Therapeutic Exercises

- As soon as the patient is ready for cardiovascular exercise, an upper body ergometer can be used.
- As soon as patient gains sufficient passive knee flexion, the patient should begin stationary cycling for limited periods (10 to 15 minutes).

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Immediate ankle pumps are advised to aid in edema control and prevent blood clots.
- Quad sets are taught as soon as the patient regains limb control (i.e., once nerve block wears off). Neuromuscular electrical stimulation (NMES) should be utilized.
- Active assisted straight leg raise is added Day 4. Progress to 4-way SLR as the patient's tolerance increases.
- Crutch walking should be reviewed. This is difficult initially because the patient has to be completely non–weight-bearing while the nerve block remains effective. Actual gait training should be repeated when leg control returns—10% to 20% of body weight heel-toe weight bearing, two crutches, and lace-up shoes. Teach the patient how to ascend and descend stairs.
- Week 2—Introduce terminal knee extensions (see Figure 31-30); patient must use crutches for support. Maximum supervision required.

Phase II (weeks 2 to 6 postoperative)

Goals

- Decrease pain and effusion.
- Maintenance of full passive knee extension
- Continued restoration of passive knee flexion
- Regain quadriceps control.
- Gradually increase strengthening and cardiovascular demand.
- Encourage correct heel-toe gait with crutches (being mindful of the appropriate weight-bearing allowances).

Protection

- Continued use of hinged knee brace. Increase the range of motion in the brace as the patient gains ROM in rehabilitation.
- Osteochondral allograft
  - 25% weightbearing week 2
  - 50% weightbearing week 4
- Osteochondral autograft
  - Less protection required for patient's own tissue
  - 50% weightbearing week 2
  - 100% weightbearing weeks 3 to 4

Management of Pain and Swelling

- Oral pain medication may remain necessary, particularly at night and for rehabilitation sessions.
- Continued use of cryotherapy (three times per day), elevation of the limb, ankle pumps
- Continued use of a compression sleeve (lightweight)
- Continued use of CPM, ROM to mirror gains in rehabilitation

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- ROM precautions: None
- PROM: Manual ROM of the patella-femoral joint—medial/lateral and cephalad/caudad.
- PROM: Continue to maintain tibiofemoral extension. Every effort should be made to mirror the patient's opposite limb extension ROM.
- PROM knee flexion goals
  - OATS Autograft
    - Full ROM restored in first 3 to 6 weeks, restricted by pain only
  - OATS Allograft
    - PROM is restricted only by pain; the following are conservative numbers and can be progressed faster.
    - 105° by week 3
    - 115° by week 4
    - 135° by week 6

Clinical Pearl

At this stage, consider performing passive knee flexion with the hip in extension. This is most easily achieved with the patient in side-lying, with the involved leg on the table. This will help to prevent loss of extensibility of the rectus femoris muscle—a two joint muscle. This position also provides the rehabilitation specialist with excellent leverage (see Figure 31-31).

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Maintain gastroc/soleus ROM—passive stretching in supine, on table
- Maintain or improve hamstring ROM; angle of stretch can be varied to include the iliotibial band or adductor group.

Other Therapeutic Exercises

- Upper extremity exercises during this phase may include upper-body ergometer (UBE) and general weight equipment (such as lat pulldowns, pec deck, tricep pushdowns, biceps curls, scaption). Perform all exercises in a seated position.

- Core exercises may include single leg planks, single leg pushups, and reverse planks. Reverse planks are similar to regular planks, except that the patient performs them belly-up (supine), instead of belly-down (prone) like a regular plank. As in regular planks, the patient can weight bear on the hands or on the forearms. In all these exercises, the surgical leg is non–weight-bearing and held off the ground.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Ankle pumps, ankle alphabet exercises
- Quads sets with NMES or biofeedback
- SLR—4-way with NMES or biofeedback
- Short arc quads with NMES or biofeedback
- Stationary bike
- Isometric leg press at week 4
- Aquatic treadmill walking at week 4
- Nonsurgical leg exercises are begun
- No open chain knee extension for 4 months. This precaution may be necessary because patients often complain of patella-femoral joint symptoms following the surgery. This temporary complaint is suspected to be a result of quad weakness and remedies itself as the patient's quad control returns.

Clinical Pearl

Side-lying abduction is very important. Limited weight bearing may cause muscular atrophy of the gluteal group. Ensure that the patient is in the correct side-lying position with lower limb slightly extended to ensure maximal gluteus medius recruitment (see Figure 31-32).

Sensorimotor Exercises

- Begin active angular replication exercises, for motor control. These can be introduced during the SLR exercises.

Techniques to Increase Muscle Strength, Power, and Endurance

- Upper body strengthening
- UBE
- Stationary bike
- Aquatic treadmill at week 4. Remember that chest-high water level is 25% weight bearing, waist-high water level is 50% weight bearing.

Neuromuscular Dynamic Stability Exercises

- Manual rhythmic stabilization of trunk and core, performed in sitting
- Nonsurgical leg single leg balance retraining

Functional Exercises

- Gait training
- Single leg bridging to increase ease of transitioning
- Ensure that the patient is lifting the surgical leg independently when getting on and off table.

Phase III (weeks 6 to 10 postoperative)

Goals

- Achieve full PROM of knee flexion.
- Maintain full PROM knee extension.
- Gradually improve quadriceps strength and endurance. Focus on eccentric quadriceps control.
- Progress functional activities during this period.
- Maintain cardiovascular fitness and upper body strength.

Protection

- Brace is discontinued at week 6—Ensure quad lag is eliminated before discontinuing brace.
- Osteochondral autograft: Full weightbearing, no restrictions
- Osteochondral allograft: 100% weightbearing by weeks 6 to 8

Management of Pain and Swelling

- Oral analgesic use is continued as needed.
- NSAID use may be prescribed for persistent pain.
- Cryotherapy is used post therapy to mitigate postexercise inflammation and soreness.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- No knee ROM precautions
- Maximize PROM knee flexion (at least 135°), maintain full PROM of knee extension.
- Continue patella-femoral joint mobilization—cephalad/caudad direction important for assisting in tibiofemoral ROM
- Maintain hip joint mobility—Consider Hip PAs performed in prone or slight hip extension, add hip ER/IR, being cautious of the possible effects of torque on the knee joint.
- Assess PROM of ankle dorsiflexion—Compare to contralateral limb.

Soft Tissue Techniques

- Gentle scar tissue mobilization can be introduced at this stage.
- Soft tissue techniques may be applied to the quadriceps, hamstrings, and calves—Avoid the knee joint.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Continue to focus on gastrocnemius/soleus (now performed in standing), hamstrings, and quadriceps stretches.

- Add Pretzel (piriformis/glutes) stretch, if knee can tolerate (see Figure 31-38).
- Thomas test stretch with added PROM knee flexion to improve flexibility of the rectus femoris muscle (see Figure 31-33).

Other Therapeutic Exercises

- Cardiovascular—UBE, stationary biking
- Week 8—Introduce elliptical training and Stairmaster. Gradually build up tolerance.
- Aquatic treadmill walking—Gradually lower water level to tolerance and with respect to the appropriate weight-bearing requirements.
- Weeks 9 to 10—Treadmill walking
- Upper body strengthening can be progressed to preoperative levels.
- Consider combination exercises involving the core and upper body at this stage (e.g., physioball walkouts: roll prone on ball, walk on hands), and consider adding push-ups or serratus hunches.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Basic surgical limb strengthening includes four-way straight leg raises with increased resistance. Quad lags should be completely eliminated at this stage. Discontinue use of NMES when quads lag is eliminated.
- Terminal knee extensions in standing; increase resistance
- Week—isometric leg press
- Week 8—stationary minilunge with cable chop. The cable chop involves holding a Thera-Band or attachment to a cable machine and performing a D1 or D2 PNF pattern. All effort is made to maintain core stability.
- Week 8—mini-squats 0° to 45° using correct biomechanics. Avoid genu valgum and prevent knee over toes.
- Week 8—Begin double leg leg press through as much ROM as machine will allow
- Week 8—double leg heel raises
- Week 9 front step ups.
- Week 10 lateral step up—Target eccentric quadriceps and hip abductor control.

Clinical Pearl

The weightshift exercise in standing encourages the patient to weight bear in an equal distribution over the bilateral limbs. It targets hip, knee, and ankle proprioception, which encourages improved joint position awareness, increased joint stability, and decreased patient apprehension.

Begin training with the patient shifting laterally, feet hip distance apart. The patient should avoid sideflexion of the trunk and a Trendelenburg at the hip. The patient should shift 90% of weight onto the right leg and then shift 90% of weight onto the left. Scales can be utilized in order to perform this accurately. In the clinical setting, the rehabilitation specialist can instruct the patient to shift 90% of weight onto the one leg, while keeping the toes of the opposite leg on the floor. This ensures safety when this exercise is first introduced. As weight-bearing tolerance is allowed to progress, this exercise can be further modified in order to allow full single-leg weightbearing. It is therefore an excellent tool to use in the clinic (see Figure 31-34)

When the patient can achieve this rhythmically and comfortably, progress to stride standing, shifting weight forward onto the front leg (90% weight bearing) and backward onto the back foot (90% weight bearing) rhythmically (see Figure 31-35).

Again, as patient tolerance allows progress to stepovers—the surgical leg stays fixed on the floor and the patient steps forward and backward with the nonsurgical leg, replicating the stance phase of the gait pattern.

These can be initiated at week 8, and progressed according to weight-bearing tolerance.

Sensorimotor Exercises

- Weightshift exercise in standing
- Rocker board balance retraining. Begin doubleleg AP direction, progress to lateral. Progress to single leg AP at weeks 8 to 9.
- Progress to wobble board—circles, right-left, front-back, balance on double leg. Progress to single leg at weeks 8 to 9.
- Active joint positioning of knee and hip
- Balance equipment (such as the BOSU, Dynadisc) can be incorporated at this stage. Progress patient as appropriate, keeping the exercises challenging.
- Use of physioball—bridging with back on floor, single leg and double leg; bridging with back on ball, add leg extensions and physioball walkouts with single leg extension.

Open and Closed Kinetic Chain Exercises

- Closed chain proprioception activities: rocker board, wobble board, BOSU, etc. utilizing double leg and single leg stance
- Closed chain strengthening exercises: At week 8 introduce leg press, mat squats (double leg), forward step-ups, lateral step-ups—progress resistance.
- Open chain strengthening exercises: short arc quads, VMO holds

Techniques to Increase Muscle Strength, Power, and Endurance

- Progress bike endurance.
- Introduce elliptical training at weeks 7 to 8.
- Aquatic treadmill—Continue walking program

Neuromuscular Dynamic Stability Exercises

- It is safe, and indeed advisable, to progress proprioceptive challenge on balance equipment as cartilage healing

progresses. Consider adding complexity challenges to the exercises (e.g., add perturbations, utilize multijoint exercises such as scaption PREs while balancing single leg on the rocker board).

Plyometrics

- Lower limb plyometrics should be avoided at this stage of critical cartilage repair.

Functional Exercises

- Gait correction is vital at this stage. Consider cup walking (see Figure 31-36) at week 7 to 8. Cup walking was originally utilized in prosthetic gait training. It encourages a reciprocal gait pattern, full weight bearing over the surgical side, and forces the patient to pull the foot and knee up in order to clear the cups. Even gait cadence should be emphasized.
- Ensure that the patient is walking up stairs reciprocally by weeks 8 to 9. Descending stairs reciprocally will lag behind ascending because of the slower recovery of eccentric quadriceps control.
- Ensure that patient weight bears equally through both lower limbs when transitioning from sit to stand. This can be measured by using scales or by closely observing the lower limb kinetic chain and ensuring that each hip lines up with the respective knee and ankle. Additionally, ensure that the feet are placed in a straight line in the frontal plane, otherwise the foot that is placed further back will be the one bearing most weight.
- Throwing athletes may incorporate the Throwers 10 program for the upper limbs.

Sport-Specific Exercises

- This is only appropriate for upper body training during this time period.

Phase IV (weeks 10 to 14 postoperative)

If the osteochondral autograft athlete is demonstrating faster progression, it is reasonable, at this stage, to accelerate the time frames in the upcoming phases.

Goals

- Improve muscle strength and endurance.
- Progress functional activities.
- Encourage continued compliance. The patient must respect that overuse of the limb will have a detrimental effect on short-term healing and long-term cartilage integrity.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Maintain full PROM of both the tibiofemoral and patella-femoral joints.
- Hip mobilizations—maintain or regain full ROM.
- Maintain full ankle dorsiflexion ROM.

Soft Tissue Techniques

- Soft tissue release of the quadriceps, hamstrings, gastroc/soleus complex and glutes. This is not always necessary. However, occasionally, a patient may be aware of significant muscle pain, usually in the quadriceps muscle. The possibility of a DVT should always be ruled out. Please consult with the referring physician immediately, if you have any concerns. Effleurage-type massage may be effective in decreasing edema and improving patient comfort.
- Continue gentle scar tissue mobilization.

Stretching/Flexibility Techniques for the Musculotendinous Unit

- Maintain/achieve sufficient flexibility of the lower limb muscles.
- Progress to targeting hip ER and IR ROM—frog stretch (see Figure 31-37) and pretzel stretch (see Figure 31-38)
- Continue to focus on iliopsoas and rectus femoris length by performing the modified Thomas test stretch.

Other Therapeutic Exercises

- Progress upper body strengthening exercises.
- Progress core recruitment exercises.
- Treadmill walking, elliptical, Stairmaster, stationary bike

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- As before with progressive resistance
- Increase leg press through full range; add resistance; aim for equal weight distribution when using both legs. Sophisticated digitized leg press machines are able to calculate weight distribution. In the absence of such machines, carefully observe the patient and encourage the patient to avoiding protecting the surgical leg. Ensuring alignment of the feet, ankles, and knees can aid in this goal. As the patient gains strength and confidence, and as pain decreases, she/he should be encouraged to gradually progress to equal weight distribution between both legs.
- Progress to single leg at week 12.
- Add leg curls.
- Single leg heel raises—extended (gastrocnemius) and flexed (soleus) knee

Open and Closed Kinetic Chain Exercises

- CKC
  - High step-ups—Progress to waist height.
  - Backward stationary lunges
  - Double leg squats
  - Athletes are encouraged to avoid locking out the tibiofemoral joint. Stance used should be hip width apart with careful focus on maintaining correct joint mechanics.

- OKC
  - Speedskaters (see Figure 31-39)
  - Open chain knee extension 0° to 20°

Techniques to Increase Muscle Strength, Power, and Endurance

- Advance endurance sets to strength exercises (fewer repetitions 6 to 8).

Neuromuscular Dynamic Stability Exercises

- Progress use of balance equipment. Focus predominantly on single leg exercises and compare sides to judge progress. Time how long patient can stand on a single leg without support on various pieces of balance equipment, such as the rocker board, wobble board, and BOSU. Aim to get the surgical leg to balance for as long as the nonsurgical side. Observe that the patient does not use incorrect hip, knee, or ankle strategies, such as foot pronation or knee genu valgum.

Functional Exercises

- Lower limb agility drills can be performed utilizing fast walking without sudden changes in directions or pivoting.

Sport-Specific Exercises

- The running athlete must still avoid any lower body impact exercises at this stage.

Milestones for Progression to the Next Phase

- Full range of motion
- Acceptable strength level
  - Hamstrings within 10% of contralateral leg—isokinetic testing
  - Quadriceps within 10% to 20% of contralateral leg—isokinetic testing
- Balance testing within 30% of contralateral leg—Again, sophisticated balance testing machines are available. However, in the absence of such equipment, measure single leg balance time on the wobble board without allowing the edge of the board to make contact with the ground. Compare sides.
- Able to walk 2 miles or bike for 20 minutes
- 50 lateral step-ups (8 inch height). This is an easily measurable activity, which ensures that sufficient eccentric quad control has been achieved in order to progress to Phase V.

Phase V (weeks 14 to 24 postoperative)

Goals

- Improve muscle strength and endurance.
- Progress functional activities.
- Encourage continued compliance. The patient must respect that overuse of the limb will have a detrimental effect on short-term healing and long-term cartilage integrity.
- Hamstrings and quadriceps strength within 10% of contralateral leg
- Balance testing within 10% of contralateral leg

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Maintain full PROM of both the tibiofemoral and patella-femoral joints.
- Continue hip and ankle mobilizations if necessary.

Soft Tissue Techniques

- Assess the need for soft tissue release of the quadriceps, hamstrings, gastroc/soleus complex, and glutes. This is only necessary if the patient continues to complain of specific muscle pain. Trigger points can be assessed and treated. Any edema can be addressed with effleurage massage. Again, always rule out the possibility of DVTs.
- Continue gentle scar tissue mobilization.

Stretching/Flexibility Techniques for the Musculotendinous Unit

- Maintain/ achieve sufficient flexibility of the lower limb muscles.
- Continue to focus on iliopsoas and rectus femoris length by performing the modified Thomas test stretch.

Other Therapeutic Exercises

- Progress upper body strengthening exercises.
- Progress core recruitment exercises.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- As before with progressive resistance
- Progress to single leg leg curls and leg extensions at week 14; increase resistance.
- Avoid open chain knee extensions if they increase patient discomfort.

Sensorimotor Exercises

- PNF lower limb patterns performed in supine. Be sure to add knee flexion and extension into the patterns to recruit the primary operative muscles. PNF upper limb and trunk patterns in half kneeling and static lunge position

Open and Closed Kinetic Chain Exercises

- CKC
  - High step ups—Progress to waist height.
  - Backward lunges—Progress to backward lunge walking; progress to forward lunge walking.
  - Double leg squats—Progress to single leg squats. Vary surface, add perturbations, add upper body/ trunk motion.

  - Athletes are encouraged to avoid locking out the tibiofemoral joint. Stance used should be hip width apart, with careful focus on maintaining correct joint mechanics.
- OKC
  - Speedskaters—Increase resistance; the patient can stand on a BOSU or rocker board
  - Cable kicks in PNF patterns

Techniques to Increase Muscle Strength, Power, and Endurance

- Advance endurance sets to strength exercises (fewer repetitions 6 to 8).
- Alternately focus on endurance (16 to 20) sets and hypertrophy (6 to 8) resistance training.

Neuromuscular Dynamic Stability Exercises

- Progress use of balance equipment. Focus predominantly on single leg exercises and compare sides to judge progress. Here again, single leg balance on the wobble board, whereby the edge of the board is not allowed to make contact with the floor, is an effective comparison tool. This same principle can be applied to other balance equipment.
- Add sport-specific drills (e.g., a baseball pitcher can perform trampoline pitching while balancing single leg on a BOSU; a soccer player can replicate kicking with band resistance balancing on a balance board).

Plyometrics

- Plyometrics are still not introduced at this stage, in order to protect the cartilage repair.

Functional Exercises

- Lower limb agility drills can be performed utilizing fast walking. Increase unpredictability of training by throwing balls and calling direction changes.
- Increase walking distance, speed, and inclines as time progresses.

Sport-Specific Exercises

- Gradual reintroduction of impact exercises toward the end of this stage

Phase VI (weeks 24 to 52 postoperative)

Goals

- Prepare patient for return to sport.

Management of Pain and Swelling

- Cryotherapy application post exercise

Techniques for Progressive Increase in Range of Motion

- Full AROM and PROM must be achieved by 4 months.
- Ensure maintenance of patella-femoral ROM.

Soft Tissue Techniques

- Seldom necessary at this stage.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Full, passive knee extension ROM remains critical. Most patients will be easily able to maintain this, especially if their gait pattern is optimal and, as a result, they use knee extension with every step that they take. The occasional patient may continue to struggle. Regular hamstring and gastrocnemius stretching remains useful in these cases. Use of low-load, long-duration passive knee extension may still be required on a daily basis.

Other Therapeutic Exercises

- Continue and progress multijoint exercises.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Aim to return to preinjury levels of function toward the end of this phase.

Sensorimotor Exercises

- Single leg standing on wobble board (or similar device). Increase complexity by adding ball toss, close eyes, add perturbation of board or trunk, and initiate single leg squats.
- PNF lower limb patterns performed in supine and standing. Be sure to add knee flexion and extension into the patterns to recruit the primary operative muscles. PNF upper limb and trunk patterns in half kneeling and static lunge position
- Continued use of physioball—continue increasing challenge and complexity of exercises (e.g., sitting on physioball with single leg support), perform cable PNF with upper limbs and maintain balance. Perform with eyes closed.

Open and Closed Kinetic Chain Exercises

- Advance the previous exercises in accordance with sport-specific demands.
- CKC progression includes:
  - Single leg squats standing on a wobble board
  - Lunges on two BOSU surfaces, increasing resistance and decreasing support
  - Lateral step-ups with trunk perturbations.
- OKC
  - Restrict open chain knee extensions to 0° to 20°.
  - If patient participates in a kicking sport, open chain kicking agility exercises can be incorporated.

Techniques to Increase Muscle Strength, Power, and Endurance

- Pool running can be introduced at the 6-month mark.
- Treadmill running can be introduced at the 7-month mark.
  - Carefully observe the patient's running pattern. Ensure an even rhythm, light grading, equal weight bearing, correct use of upper limbs, and core recruitment.
- Increase endurance on the elliptical, bike, and StairMaster. It is usually preferable to increase distance before speed/intensity but individual preference must be respected.

Clinical Pearl

Use pain and/or swelling to monitor whether you are progressing too quickly. It is an accurate sign of overuse and should be respected accordingly.

Neuromuscular Dynamic Stability Exercises

- Agility drills—cariocas and cone drills can only be performed at a fast walking pace until the 7-month mark, when light running can be added. Speed and complexity can be progressed at that stage.
- Cone touches—Place two cones slightly more than hip distance apart. Stand on one leg in between them. Reach left hand to right cone and reverse, repeat for 20 reps (Figure 31-40).
- Single leg deadlifts (patient holds PVC pipe vertically behind back. Patient performs a single leg deadlift maintaining contact of the PVC pipe against the occiput and tailbone throughout the motion.)
- Deep knee bends (full range, good mechanics) can be introduced to teach efficient eccentric quadriceps release.
- Always challenge the patient.

Plyometrics

- Month 4 to 7—Consider upper body plyometrics while utilizing static stance for lower body (e.g., hold static squat position while throwing ball against wall, physioball bridge with back on ball while performing overhead ball toss and crunches).
- Months 7 to 8—Teach box jumping. Monitor patient's level of discomfort during and after the exercise. Ensure patient learns to land with light grading ("light, like a panther") and maintains correct joint positioning (do not allow the knees to go forward over the toes, keep the knees apart and avoid genu valgum) throughout the movement. As time progresses, advance from double leg jumps forward to double leg jumps sideways to double leg jumps over the box. Continue the progression to single leg jumps forward to single leg jumps sideways. For safety, do not allow the patient to become overly fatigued. The patient should be allowed to rest often. The exercises should be discontinued immediately as soon as the patient is no longer able to maintain correct form.
- Month 8 to 9—Progress to single leg hopping agility drills.

Sport-Specific Exercises

Osteochondral Autograft

- Low impact sports such as golf, swimming, skating, rollerblading, and cycling are permitted at 4 months.
- Moderate impact sports such as running and aerobics may be performed at 6 months.
- High impact sports such as tennis, volleyball, basketball, football, and baseball are allowed at 7 months.

Osteochondral Allograft

- Low-impact sports such as golf, swimming; skating, rollerblading, and cycling are permitted at 6 months.
- Moderate impact sports such as running and aerobics may be performed at 7 to 8 months.
- High-impact sports such as tennis, volleyball, basketball, football, and baseball are allowed at 12 months.

Milestones for Progression to the Next Phase

- Less than 10% side-to-side deficit on isokinetic testing
- Less than 15% side-to-side deficit on hop test
- Patient reported Outcome Studies at 52 weeks should be greater than 90% compared with preoperative scores.

Outcome Measures

Patient reported outcome scales should be implemented at the 12-month follow-up appointment. Scales that have been utilized in the literature for Cartilage Restoration Procedures include:

- IKDC—International Knee Documentation Committee Subjective Knee Form
- SF12—Quality of life instrument
- KOOS—Knee injury and Osteoarthritis Outcome Score

Criteria for Return to Sport

General

- Full AROM in tibiofemoral and patella-femoral joint, no apprehension
- Minimum of 80-90% side-to-side symmetry on isokinetic testing.
- Minimum of 15% side-to-side symmetry on hop test.
- Quadriceps-hamstrings ratio that matches non-surgical limb, based on isokinetic testing results.
- Correct hip and knee alignment during jump test and hop test—particularly when fatigued.

Sport-Specific

- Specific sports require specific functional demands of the athlete. The rehabilitation specialist needs to be familiar with sport-specific demands.
- A particular focus should be on working the patient to fatigue, because injury rates have been shown to increase when a patient is fatigued.

After Return to Sport

Continuing Fitness or Rehabilitation Exercises

- Total body fitness regime

Exercises and Other Techniques for Prevention of Recurrent Injury

- Ensure maintenance of lower limb strength, maintain surgical limb at 85% or better when compared with nonsurgical limb. The patient may be encouraged to consult with the rehabilitation specialist every 3 to 6 months in order to undergo repeat isokinetic testing and functional testing, such as the hop test.
- Continue neuromuscular control exercises to maximize core, hip, knee, and ankle stability and proprioception.
- Maintain cardiovascular endurance, balance and proprioception, flexibility, strength, and endurance. Neglect of any of these areas may place the athlete at risk for reinjury.
- Consider limiting impact and joint loading except when it is necessary for sport-specific demands.

Evidence

Gudas R, Kalesinskas RJ, Kimtys V, et al: A prospective randomized clinical study of mosaic osteochondral autologous transplantation versus microfracture for the treatment of osteochondral defects in the knee joint in young athletes. *Arthroscopy* 21(9):1066–1075, 2005.

A prospective, randomized clinical study compared 60 athletes. At an average of 37.1 months (range, 36 to 38 months) follow-up, the OATS procedure demonstrated significant superiority over microfracture. Only 52% of microfracture athletes could return to sports at the preinjury level, as compared with 93% of the OATS athletes. (Level 2 evidence)

Logerstetdt D, Snyder-Macker L, Ritter R, et al: Knee pain and mobility impairments: Meniscal and articular cartilage lesions. *J Orthop Sports Phys Ther* 40(6):A1–A35, 2010.

Clinical practice guidelines detailing evidence-based recommendations for examination and diagnosis, rehabilitation interventions, and assessment of outcome. (Level of evidence not known)

Mithoefer K, Hambly K, Della Villa S, et al: Return to sports participation after articular cartilage repair in the knee: Scientific evidence. *Am J Sports Med* 37(Suppl 1):167S–176S, 2009.

A systematic review of 20 studies (1363 patients), average follow-up of 42 months. 73% return to sports, with highest rates after OATS. Time to return to sports varied from 7 to 18 months. Initial return to sports at the preinjury level was possible in 68% without significant differences between surgical techniques. Continued sports participation at the preinjury level was possible in 65%; ACI showed best durability. Factors that affected the ability to return to sport included: athlete's age, preoperative duration of symptoms, level of play, lesion size, and repair tissue morphology. (Level 3-x evidence)

Multiple-Choice Questions

QUESTION 1. When should full PROM of tibiofemoral knee extension be established?

A. 0 to 2 weeks
B. 2 to 4 weeks
C. 4 to 6 weeks
D. Never

QUESTION 2. Why is it preferable to stretch the knee into passive flexion in prone or side lying rather than supine, with the hip in flexion?

A. It is more comfortable for the patient.
B. It allows the patient to gain passive ROM more quickly.
C. It addresses all four quadriceps muscles, including the all-important rectus femoris—the flexibility of which needs to be addressed post surgery.
D. It allows the patient to return to high impact sports more quickly.

QUESTION 3. Which surgery allows a faster return to sports?

A. Osteochondral allograft transfer
B. Osteochondral autograft transfer

QUESTION 4. Which criterion does not apply when evaluating whether a patient is ready to progress to Phase V of the rehabilitation process?

A. Full range of motion
B. Balance testing within 30% of contralateral leg
C. Ability to hop 50 paces
D. Ability to walk 2 miles or bike for 20 minutes

Answer Key

QUESTION 1. Correct answer: **A** (see Phase I)

QUESTION 2. Correct answer: **C** (see the Clinical Pearl in Phase II)

QUESTION 3. Correct answer: **B** (see Table 31-3)

QUESTION 4. Correct answer: **C** (see Milestones for Progression to the Next Phase [Phase V])

BEYOND BASIC REHABILITATION: RETURN TO BASKETBALL AFTER OSTEOCHONDRAL ALLOGRAFT TRANSPLANTATION

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ASPECTS OF BASKETBALL THAT REQUIRE SPECIAL ATTENTION IN REHABILITATION

- Hennig[1] summarized four categories for consideration regarding decisions to return an athlete to her or his chosen sport: medical, socioeconomic, political, and legal.
- Most athletes pursue surgery for a medical condition with the full intention of returning to his or her chosen sport.
  - The goal of the sports medicine healthcare provider is to return the athlete to the particular sport.
  - The provider hopes to allow the athlete to maximize his or her abilities, without compromising their safety and the safety of others, and prevent reinjury.
- With recent advances in the recognition and surgical treatment of chondral defects in the knee,[1,2] there is a similar lack of proven standards for returning an athlete to sport and in particular, to basketball, following an osteochondral allograft transplantation (OA graft) procedure.

Introduction

- Cartilage repair procedures yield less predictable outcomes in this population given the inherent demands placed upon their reconstructed joints and the inability to completely reduce or eliminate pain to the point where athletic performance is not compromised.
  - Added to this complexity is the concern that once a patient achieves his or her desired degree of pain relief and functional return, there is the inherent risk of sport and athletic injury similar to the risk that may have contributed to the initial joint failure.
- Postoperative return to sports presents the most significant measure of a successful outcome for the injured athlete and the healthcare provider.
  - Because of the multifactorial nature of this decision, guidelines are best employed to encompass each individual athlete's needs and goals at appropriate intervals.
- Decision making is both based upon evidence-based medicine reporting outcomes as well as an "economic" argument that considers risk versus benefit. Ultimately, it becomes the patient's decision as to whether he or she will knowingly expose themselves to these risks, assuming they achieve their desired outcome.
- It is always best to correct extraarticular aspects contributing to their pathology and symptoms.
  - In a setting of clinically relevant malalignment, performing an osteotomy even without an intraarticular cartilage repair procedure may yield an acceptable clinical result without the additional risk of future injury to transplanted cartilage repair tissue, assuming that an acceptable amount of symptom relief and associated functional return are achieved.
- Some factors identified that can delay the return to sport participation following chondral repair of the knee:
  - Age of the athlete
  - Preoperative duration of symptoms, size of lesion
  - Recreational versus professional playing level
  - Morphology of the tissue repair and the nature of the concomitant co-morbidities addressed at the time of the cartilage repair procedure[3–7]

Literature

- Many factors have been identified to affect full return to sport following any chondral repair in the knee; overall results for those who choose to return to sport are promising.[8,9]
- Flanigan et al.[10] report the prevalence of full-thickness chondral injuries in the athletic population to be 36% and significantly higher than those found in the general population.
- Chondral injuries of the knee are also noted to occur in association with other knee injuries, and in particular anterior cruciate ligament tears.[11–13]
- It is estimated that up to 50% of athletes undergoing anterior cruciate ligament (ACL) reconstructions will have an associated chondral injury.
  - The current reported incidence of ACL injuries each year is approximately 200,000, which may indicate that there are 100,000 associated chondral injuries as well.[14,15]

Advanced Rehabilitation Program

- A key component of this return to sport program is the addition of functional testing to determine the athlete's readiness to return to basketball safely. This far exceeds the relevance of any rehabilitation program and is also significantly overlooked in the current literature, especially when considering this condition.

Measurement of Skills and Movement

- The most important aspect for the final return to sport is the functional progression and transition of the

athlete to proficient performance of high-demand sporting activities. In contrast, one of the greatest limitations for professional determination of an athlete's ability to return to sport is the lack of objective criteria and physical performance measures that coincide with the functional demands of the sport in question.

- Without specific functional performance measures, the rehabilitation provider may be left with only subjective input from the athlete as to readiness and therefore, miss crucial impairments that could expose the athlete to further risk of injury, and allow the athlete to return without adequate preparation. This may also force the clinician to justify delay in returning to sport with little objective criteria.
- Standardized approaches for functional movement testing are not necessarily established for determining an athlete's ability to return to basketball following an OA graft procedure. However, based on previous literature concerning successful rehabilitation of ACL reconstruction, there are appropriate criteria that address the relevant needs of the basketball athlete and support decisions made by physicians and therapists in allowing the athlete to return to basketball.
- As well, these criteria are also appropriate to guide further strengthening and conditioning for the athlete beyond basic rehabilitation to allow for successful return to sport.

Functional Testing

- Identifying specific functional testing and establishing baseline values for the athlete can be particularly helpful by not only identifying functional deficits but also establishing goals for the athlete to prepare for a full return to sport.
- However, the return to sport phase in many rehabilitation programs for athletes is not well established and this is particularly evident when looking for protocols to return the basketball athlete to sport following an OA graft procedure.
- Common testing that may be utilized to assess functional movement typically involves cutting and pivoting drills that include bilateral functional movements.
- One of the limitations of these activities is that unilateral strength deficits can be missed during these tests. Deficits during actual sporting activities can also be missed for the same reason, as most sport demands are bilateral in nature.
- As an example, studies have documented continued asymmetrical strength deficits in quadriceps strength in those athletes who have received ACL reconstructions.[16]
- More importantly, athletes have returned to sport even when deficits were still present in the surgical extremity compared with the nonsurgical extremity via unilateral functional activities such as single leg hop for distance testing.[16]
- Several studies have also documented continued functional deficits and asymmetries in performance-based testing as well as decreased quadriceps strength in athletes who have undergone ACL reconstruction, even after athletes have been returned to sport for 18 to 24 months.[17]
- It is likely that this same presentation would be evident in the athlete who had undergone a chondral repair, especially when combined with the previous knowledge of the incidence of chondral injuries associated with ACL tears in the athletic population.
- Myer and colleagues provide some guidance to fulfill this deficit in the literature regarding unilateral functional lower extremity testing.[17] In a 2011 study the investigators utilize modified NFL combine testing methodology to test functional deficits in athletes following ACL reconstruction after release to sport against a group of controls who had not undergone ACL reconstruction. The tests compare single leg functional tasks with double leg tasks to distinguish deficits between the two groups.
- Functional testing includes the broad jump, vertical jump, modified long shuttle, modified pro shuttle, modified agility t-test, timed hop, triple hop, single hop, and crossover hop tests. The results of this study confirm that athletes who had undergone ACL reconstruction and who had been returned to sport continue to demonstrate unilateral functional testing deficits that were not evident when double-limb performance activities were utilized.[17]
- The authors also state that isolated single-limb performance tasks such as the single leg hop for distance, triple hop for distance, and crossover hop for distance are able to demonstrate functional deficits in athletes who had undergone ACL reconstruction when compared with controls.
- Although this chapter is concerned with those athletes who have undergone an OA graft procedure, it is highly likely that owing to the nature of the length of symptoms and postoperative restrictions following a chondral repair, many of the same functional deficits will be evident in this patient population, therefore making these functional tests appropriate for use with the athlete who has undergone surgical chondral repair.
- Second, these activities are consistent with sport demands and therefore it is recommended that athletes should be able to complete these tests before returning to sport.
- The authors recommend that the surgically repaired leg should perform at 90% of the uninjured leg before return to sport is considered. Measuring this difference in limbs is referred to as the limb symmetry index (LSI), which is calculated by dividing the distance hopped on the involved lower extremity by the distance hopped on the uninvolved lower extremity and then multiplying this number by 100% (involved side performance/uninvolved side performance × 100%) (Figure 31-42).[16] These tests will be reviewed to guide the sports medicine professional in specific unilateral functional testing of the lower extremity.
- Single-leg hop for distance
  - The athlete begins this test standing on the involved extremity in a prejump stance with the knee partially bent. The athlete is then instructed to initiate the hop by swinging the arms forward and then hopping forward as far as possible while being able to land safely and controlled on the same limb. The athlete also maintains the landing stance for one second to

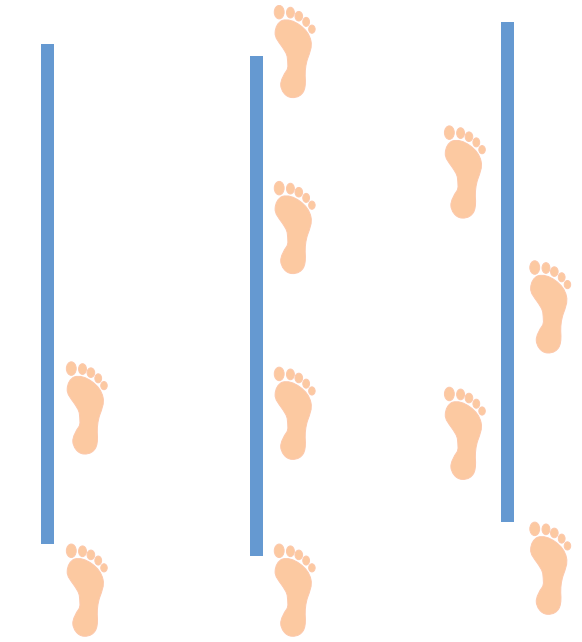

FIGURE 31-42. Lower limb symmetry index test.

have a successful trial. The distance hopped is measured in centimeters. Each leg will perform two trials with the best trial of each lower extremity chosen for calculation.

- Crossover hop for distance
  - The starting position for this test begins with the athlete standing on the involved lower extremity in a prehop position with a line that is placed medial to the standing foot. The athlete is then instructed to hop forward as far as possible and land on the same leg while crossing over the line with each subsequent hop. The athlete is allowed to use the arms as previously described in the single leg hop for distance test. The athlete maintains the last jump for one second for a successful trial. The distance hopped is measured in centimeters. Each leg will perform two trials with the best trial of each lower extremity chosen for calculation.
- Triple hop for distance
  - The starting position for this test begins with the athlete standing on the involved lower extremity in a prehop position with the knee slightly bent. The athlete is then instructed to hop forward as far as possible on the same leg and to then immediately complete two more hops as far as possible and holding the third hop for one second to complete the trial. The distance hopped is measured in centimeters. Each leg will perform two trials with the best trial for each lower extremity chosen for calculation.

Analysis of Testing

- Each of these tests takes into consideration the athlete's ability to generate functional power, attenuate force, and control postural stability as it relates specifically to demands that may occur during sport. The ability of the athlete to maintain and generate single-limb power and control the redirection of motion may be significant in reducing further injury. Once each of these tests is completed, the provider will have objective measures of potential unilateral limb asymmetries that can guide the decision to return the athlete to sport. The sports medicine provider will also be able to apply the appropriate intervention regarding strengthening, coordination, and flexibility training, which may all influence an athlete's ability to return to sport and participate safely without risking further injury. It should be noted that these three functional tests might not be the only tests that can or will be utilized with an athlete to determine sport readiness and also do not take into account the ability to evaluate the overall quality of movement while performing the tests.

Phase I (weeks 16 to 24 postoperative): Advanced Strength and Conditioning Programs

- Establish baseline measurements prior to beginning phased rehabilitation for return to sport.
- Baseline testing is conducted at the conclusion of the 12- to 16-week initial post-rehabilitation program following surgical procedure. Recommendations for full return to impact activities are imposed at 8 months postoperative.
  - Cardiovascular: Establish baseline cardiovascular endurance via cycle ergometry.
  - 1 to 3 RM power clean: Evaluates the athlete's total body explosiveness. The technique for performing should be standardized and athlete instructed.
  - 1 to 3 RM bench press and back squat: Evaluates upper and lower body maximum strength
  - 1 to 3 RM leg press: performed at regular knee angles
  - 1-minute crunch and situp test: legs held down
  - Flexibility testing: hamstrings via sit-and-reach test
  - Specific functional performance measures as described: Single leg hop for distance, cross-over hop for distance, and triple hop for distance testing. Determine limb symmetry index (see previous).

Periodization

- Linear: preseason, in-season and postseason training

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- Recommend this approach begin no sooner than 12 to 16 weeks post rehabilitation program (Table 31-5)
- Proprioception training via single leg balance and non-impact agility drills. Include sport-specific basketball coordination drills.
- Emphasis on return of cardiovascular function via cycling and initial strength training phases for endurance of lower extremity and trunk musculature performed in straight planes of movement

Table 31-5 Four-Month Plan (following completion of Acute Rehab Phase) for Return to Basketball After Osteochondral Allograft Transplantation

Month 1	Month 2	Month 3	Month 4 (approx. 8 months post surgical date)
Proprioception training via single leg balance and nonimpact agility drills. Include sport-specific basketball coordination drills. Emphasis on return of cardiovascular function via cycling and initial strength training phases for endurance of lower extremity and trunk musculature performed in straight planes of movement. Recommended strength training occurring 3 days per week. Monitor response at the knee for any adverse effects.	Retest all variables as conducted during baseline testing. Establish goals with athlete. Emphasis on core strengthening. Incorporate diagonal patterns of movement during single leg stance activities. Continue LE strengthening and progress resistance as appropriate. If available, introduce swimming for cardiovascular endurance. Increase cycle intensity to address endurance.	Retest all variables conducted during baseline testing. Establish new goals based on results. Based on results, modify strengthening or power emphasis as needed. Introduce snatch pulls and pressing snatch for balance and core stability/power training. Monitor knee response. Begin nonimpact pivot drills with basketball. Continue to progress lateral strengthening of the lower extremities.	Retest all variables conducted during baseline testing. Establish new goals based on results. Modify strengthening or power emphasis as needed and continue to increase resistance. Retest all variables with special emphasis on LSI index. If all criteria are met, consider return to full sport following the introduction of running, sprinting, cutting, and pivoting drills.

- Recommended strength training occurring 3 days per week. Monitor response at the knee for any adverse effects.

Training Principles Used in the Design of the Program

- Principle of progression
- Principle of individualization
- Principles of specificity—specific adaptation to imposed demands (SAID)

Application of Acute Training Variables

- Repetitions: used in this phase to increase endurance and therefore range in the higher numbers per set, as 10 to 12 repetitions
- Sets: used in this phase to increase endurance so greater number of sets at 3 per exercise
- Rest interval: Allow full recovery before beginning next set or exercise.
- Intensity: Lower intensity to allow return of endurance.
- Repetition tempo: slow
- Training frequency: recommend strengthening at 3 times per week in this phase with cardiovascular conditioning
- Training duration: based on athlete's individual ability
- Specific exercises used in the training: upper body strengthening, core strengthening, and lower extremity to include squats and general exercises.

Phase II (weeks 24 to 28 postoperative): Performance Enhancement Training Techniques

Periodization

- This phase begins at month 2 following the 12 to 16 week initial rehabilitation program and to continue with progression through month 3.
- Retest all variables as conducted during baseline testing. Establish new goals with the athlete and physician. Emphasize core strengthening and lower extremity strengthening.
- Linear

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- Month 2: Begin diagonal patterns of movement during single leg stance activities. Continue LE strengthening and progress resistance as appropriate. If available, introduce swimming for cardiovascular endurance. Increase cycle intensity to address emphasis on power.
- Month 3: Based on results, modify strengthening or power emphasis as needed. Introduce snatch pulls and pressing snatch for balance and core stability/power training. Monitor knee response. Begin nonimpact pivot drills with basketball. Continue to progress lateral strengthening of the lower extremities.

Training Principles Used in the Design of the Program

- Principle of progression
- Principle of variation
- Principle of individualization
- Principles of specificity—(SAID)

Application of Acute Training Variables

- Repetitions: At month 3 begin decreasing repetitions as weight resistance is increased with strengthening to begin improving overall strength and power.
- Sets: Decrease sets by beginning to bring the muscles to fatigue with increased resistance.
- Rest interval: At month 3 begin decreasing rest intervals with cycle ergometry to introduce anaerobic training.
- Repetition tempo: quicker but controlled
- Training frequency: At month 3 increase to 4 days per week with strengthening remaining at three times per week.

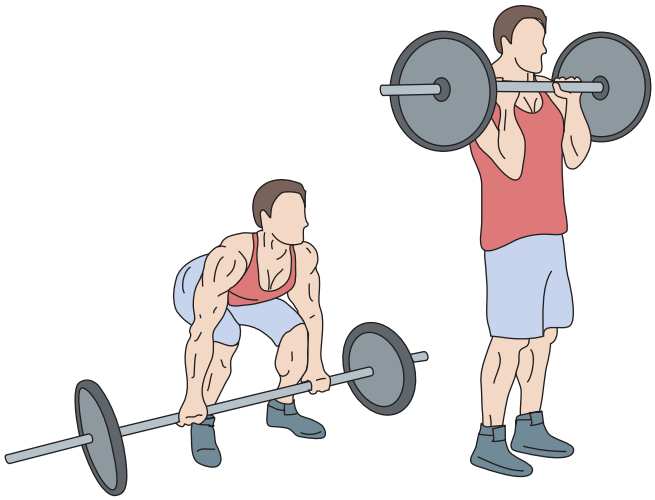

FIGURE 31-43. Power clean.

- Training duration: 60 minutes per session with intervals beginning at month 3
- Training volume
- Specific exercises used in the training: squats, single leg press, hamstring curls, bicep curls, tricep extensions; at month 3 begin power cleans (Figure 31-43), clean and jerks.

Phase III (weeks 28 to 32 postoperative): Sport-Specific Training

- Retest all variables conducted during baseline testing. Establish new goals based on results. Modify strengthening or power emphasis as needed and continue to increase resistance.
- Retest all variables with special emphasis on LSI. If all criteria are met, consider return to full sport following the introduction of running, sprinting, cutting, and pivoting drills.

Periodization

- Linear

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- Neuromuscular dynamic stability exercises
- Training for speed, agility, quickness
- Plyometric training
- Functional training
- Sport-specific training

Olympic Lifts Used in the Training Program

- Snatch
- Clean and jerk
- Power clean

Training Principles Used in the Design of the Program

- Principle of overload
- Principle of individualization
- Principles of specificity—(SAID)

Application of Acute Training Variables

- Repetitions: to fatigue; lower reps 6 to 8 per set
- Sets: one to two sets per exercise to fatigue

TIMELINE 31-5: **Return to Basketball After Osteochondral Allograft Transplantation**

Phase I Initial Postrehabilitation Program (weeks 0 to 16 postoperative)			
Weeks 0 to 6	**Weeks 6 to 8**	**Weeks 8 to 12**	**Weeks 12 to 16**

• Non–weight-bearing
• Bracing
  • Week 0–1: Locked in full extension (remove only for CPM and exercises)
  • Week 2–4: Gradually open brace in 20 degree increments as quadriceps control is gained; discontinue when no quad lag is present with a straight leg raise
• ROM: CPM use for 6–8 hours per day; begin at 0–40°, increasing by 5–10° daily per patient comfort; gain 100° by week 6
• PROM/AAROM to tolerance
• Manual therapy: patellar and tibiofibular joint mobilizations (grades I/II)
• Strengthening: hamstring and gluteal sets, SLR
• Flexibility: hamstrings
	• Partial weight bearing (25%)
	• No brace
	• ROM: Gradually increase flexion; patient to have 130° of flexion
	• Active exercise: stationary bike for ROM, advance LE strengthening with WB precautions
	• Manual therapy: scar and patellar mobilizations
		• Gradually return to full weight bearing
		• ROM: progress to full and pain free AROM and PROM
		• Proprioception: Begin gait training.
		• Exercise: Begin closed chain activities (wall sits, shuttle leg press, mini-squats, calf raises, begin unilateral stance activities).
			• Weight bearing normal with normal gait pattern
			• ROM: full and pain free
			• Strengthening: Advance strengthening and exercise as tolerated.
			• Begin consideration of return to sport training as appropriate.

- Rest interval: no more than 30 seconds between exercises/drills
- Intensity: high
- Training frequency: 4 to 5 days per week with plyometrics introduced one day per week
- Training duration: 2 hours
- Specific exercises used in the training: Olympic style lifts, sprints, cutting and pivoting drills, specific basketball agility drills

Sports Performance Testing

General Information

- General history
- Subjective questionnaires
- Medical history
- Sports injury history
- Surgical history
- Chronic conditions/medication

Specific Tests

- Specific lower extremity functional testing that specifically includes single leg activities should be included once the athlete is cleared to begin single leg plyometric activity

Objective Tests

- Physiological assessments
- Body composition tests
- Static/dynamic postural assessments
- Dynamic muscle performance testing
- Movement performance testing
- Sport-specific testing: single leg hop for distance, triple hop for distance, crossover hop for distance

Specific Criteria for Progression to the Next Stage to Determine Readiness for Basketball

- Weekly evidence of improvement across all variables of strength, endurance and flexibility

Specific Criteria for Release to Unsupervised Complete Participation in Basketball

- The surgically repaired leg should perform at 90% of the uninjured leg on three tests before return to sport is considered: the single leg hop for distance, the triple hop for distance, and crossover hop for distance. Measuring this difference in limbs is referred to as the limb symmetry index.

Recommended Ongoing Exercises

- Strengthening of the lower extremities with periodized plyometric activity

Evidence

Blazevich AJ, Jenkins D: Physical performance differences between weight-trained sprinters and weight trainers. *J Sci Med Sport* 1(1):12–21, 1998.

Tests of strength and power are also included in most basketball conditioning programs, as resistance training has an important role in improving athletic power production. The use of Olympic style lifts is consistent with existing literature

TIMELINE 31-5: **Return to Basketball After Osteochondral Allograft Transplantation** (Continued)

PHASE I (16 to 24 weeks postoperative)		PHASE II (weeks 24 to 28 postoperative)	PHASE III (weeks 28 to 32 postoperative)
Weeks 16 to 20	**Weeks 20 to 24**		
• Initiate specific baseline testing with emphasis on functional strength testing of the lower extremities. • Proprioception training with unilateral stance • Nonimpact agility drills including sport specific basketball coordination drills • Cycle ergometry to improve endurance • Double leg and single leg strengthening, upper body and core strengthening in straight planes of movement	• Retest all baseline variables. • Core strengthening, incorporate diagonal patterns of movement during single leg stance activities, progress LE strengthening, increase cardio intensity, and begin anaerobic intervals with cycling	• Retest all baseline variables; LE strength improving to 70% of noninvolved LE with single leg hop tests. • Begin emphasis on power; introduce Olympic style lifts for LE strength. • Power cleans, clean and jerk, snatch pulls • Emphasis on balance and core strength with power • Begin nonimpact pivot drills with basketball. • Progress lateral strengthening with cutting and pivoting. • Begin double leg/single leg jump drills.	• Retest all variables; LE strength at or approaching 90% of noninvolved LE with single leg hop tests • Emphasize any specific areas that require further training in strength, power, or proprioception. • Begin full running, pivoting, and sprinting drills.

relating to the large anaerobic and power components needed for basketball performance. (Level 3 evidence)

Ebben WP, Blackard DO: Strength and conditioning practices of National Football League strength and conditioning coaches. *J Strength Cond Res* 15(1):48–58, 2001.

Variations of Olympic lifts and squats remain the most commonly used strengthening exercises, consistent with what has been previously reported in surveys of professional athletes. (Level 5 evidence)

Fleck S: Periodized strength training: A critical review. *J Strength Cond Res* 13(1):82–89, 1999.

Periodization of conditioning programs is also employed to allow progressive cycling of various aspects of training in regard to intensity and frequency of training. The main aim of periodization is to allow peak training effects to occur at a critical time in the sport season. (Level 4 evidence)

McInnes SE, Carlson JS, Jones CJ, et al: The physiological load imposed on basketball players during competition. *J Sports Sci* 13(5):387–397, 1995.

McInnes and colleagues demonstrate that basketball is comprised of approximately 1000 changes of movement patterns occurring on average every 2 seconds. As well, 30% of these total movements occur in a lateral fashion with another 10% being short, direct sprints. The specific position of the player should be taken into consideration as forwards or centers may jump slightly more than those in the position of guard who typically may not spend as much time under the basket retrieving rebounds. (Level 4 evidence)

Mithoefer K: High-impact athletics after knee articular cartilage repair: A prospective evaluation of the microfracture technique. *Am J Sports Med* 34(9):1413–1418, 2006.

Mithoefer et al. completed a systematic analysis of the literature for athletes who had undergone articular cartilage repair, with results stating a return to sport was possible in 73% of the athletes who were reviewed with a 65% preinjury participation level. The overall time to return to sport varied from 7 to18 months and was dependent on the type of chondral repair performed. (Level 4 evidence)

Mithoefer K, Hambly K, Della Villa S, et al: Return to sports participation after articular cartilage repair in the knee: Scientific evidence. *Am J Sports Med* 37:167–175, 2009.

Mithoefer et al. conducted a systematic review of twenty studies describing 1363 patients with the time for return to sport between 7 and 18 months. However, it should be noted that this review included techniques such as microfracture, autologous chondrocyte transplantation, and osteochondral autograft transfer. The average length of time for return following osteochondral autograft transfer was 7 ± 2 months in this study. The longest amount of time before full return to sport for the osteochondral autograft transfer was found to be 18 ± 4 months. It should also be noted that of the factors, age demonstrated the greatest effect on full return to preinjury level sport participation, with 90% of athletes younger than 30 years of age returning to full participation, whereas only 23% of older athletes were able to return to preinjury levels. (Level 2 evidence)

Myer GD, Schmitt LC, Brent JL, et al: Utilization of modified NFL combine testing to identify functional deficits in athletes following ACL reconstruction. *J Orthop Sports Phys Ther* 41(6):377–387, 2011.

Myer and colleagues provide some guidance to fulfill this deficit in the literature regarding unilateral functional lower extremity testing. In a 2011 study the investigators utilized modified NFL combine testing methodology to test functional deficits in athletes following ACL reconstruction after release to sport against a group of controls who had not undergone ACL reconstruction. The tests compared single leg functional tasks with double leg tasks to distinguish deficits between the two groups. Functional testing included the broad jump, vertical jump, modified long shuttle, modified pro shuttle, modified agility t-test, timed hop, triple hop, single hop, and crossover hop tests. The results of this study confirmed that athletes who had undergone ACL reconstruction and who had been returned to sport continued to demonstrate unilateral functional testing deficits that were not evident when double-limb performance activities were utilized. (Level 3 evidence)

Noyes FR, Barber SD, Mangine RE: Abnormal lower limb symmetry determined by function hop tests after anterior cruciate ligament rupture. *Am J Sports Med* 19:513–518, 1991.

Noyes recommends that the surgically repaired leg should perform at 90% of the uninjured leg before return to sport is considered. Measuring this difference in limbs is referred to as the limb symmetry index (LSI), which is calculated by dividing the distance hopped on the involved lower extremity by the distance hopped on the uninvolved lower extremity and then multiplying this number by 100% (involved side performance/uninvolved side performance × 100%). (Level 3 evidence)

Simenz CJ, Dugan CA, Ebben WP: Strength and conditioning practices of National Basketball Association strength and conditioning coaches. *J Strength Cond Res* 19(3):495–504, 2005.

In an article published by Simenz in 2005, the basic practices of strength and conditioning coaches were investigated in the National Basketball Association. Twenty-nine strength and conditioning coaches were surveyed with a return rate of 68.9%. This study demonstrates that strength and conditioning coaches assess an average of 7.3 parameters of fitness, with body composition being one of the most common. All coaches used a variety of flexibility development strategies. 95% of coaches in this study indicated that their athletes used Olympic-style lifts, whereas all coaches used plyometric exercises with their athletes. Seventeen of 20 coaches used a periodization model to train their athletes across all parameters necessary for top conditioning. (Level 5 evidence)

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Multiple-Choice Questions

QUESTION 1. What are the limitations of bilateral functional testing for athletes?

A. Length of time to complete tests
B. Strength deficits are not evident
C. Too many tests to consider
D. Tests are too hard for athletes to perform.

QUESTION 2. One of the most important considerations for returning an athlete to basketball following an OA procedure is:

A. The athlete's motivation to return to sport
B. The demands of the coach
C. The athlete's ability to perform sport specific demands safely
D. The current status of the repair

QUESTION 3. A recommended level of performance of the involved extremity with single leg hop functional tests is

A. 65% of the distance of the non-involved lower extremity.
B. 85% of the distance of the non-involved lower extremity.
C. a one-second hold being maintained on the involved lower extremity.
D. 90% of the distance of the noninvolved lower extremity.

QUESTION 4. The most significant measure of outcome for an OATs procedure in the basketball athlete is:

A. No knee pain when using stairs
B. Being able to run pain free
C. Jumping without knee pain or swelling
D. Full return to basketball

QUESTION 5. The limb symmetry index is a measure of what?

A. Girth of the quadriceps musculature
B. A measurement of strength
C. Measure of one leg to hop the same distance as the other
D. An index of limitations in leg balance

Answer Key

QUESTION 1. Correct answer: B (Review section on functional testing)

QUESTION 2. Correct answer: D (Review section on postoperative recommendations)

QUESTION 3. Correct answer: D (Review section on functional testing)

QUESTION 4. Correct answer: D (Review section on measurement of skills and movement)

QUESTION 5. Correct answer: C (Review section on functional testing)

Chapter 32



Anterior Cruciate Ligament Injuries

INTRODUCTION

J. Martin Leland, MD

Epidemiology

- Anterior cruciate ligament (ACL) ruptures are common athletic injuries with over 100,000 reconstruction surgeries performed annually in the United States
- ACL ruptures most commonly occur in cutting/pivoting sports, such as soccer, basketball, volleyball, and football
- The most common mechanism for ACL ruptures is a noncontact valgus rotational injury to the knee
- Women, especially those participating in soccer and basketball, are three times more likely to rupture their ACL than their male counterparts
- Athletes of any age can rupture their ACL. While ACL ruptures are most commonly seen in the second and third decades of life, this is most likely as a result of the more aggressive nature of athletic participation in younger athletes.

Pathophysiology

Intrinsic Factors

- Numerous intrinsic factors have been postulated for increasing the risk of ACL rupture including:
  - Deconditioned athletes
    - Do not have proper muscular co-contraction (normally aides in stabilization of the knee)
  - Athletes with poor jumping mechanics
    - Those who land with knees in a valgus position—most often encountered in female athletes
    - Risk may be decreased by participating in programs focused on neuromuscular training and ACL injury prevention, such as Cincinnati sportsmetrics and PEP (prevent injury enhance performance)
  - Knees with:
    - Intercondylar notch stenosis
    - Increased posterior tibial slope
    - Increased quadriceps (Q) angle
  - Estrogen's effect on increasing soft tissue laxity in female athletes

Extrinsic Factors

- Any sporting equipment that does not allow the foot to slide out when an athlete begins to fall and instead, transmits the forces through the knee
  - First generation AstroTurf (high coefficient of friction)
  - More cleats, larger cleats, and dry climates
  - Ski bindings that do not release properly
- "Chop blocking" (blocking below the knees) in football

Traumatic Factors

- Noncontact injuries (approximately 70%)
  - Deceleration combined with a sudden change in direction over a planted foot
  - Valgus rotational injury to the knee
  - Knee hyperextension
- Contact injuries (approximately 30%)
  - Direct blow to the knee

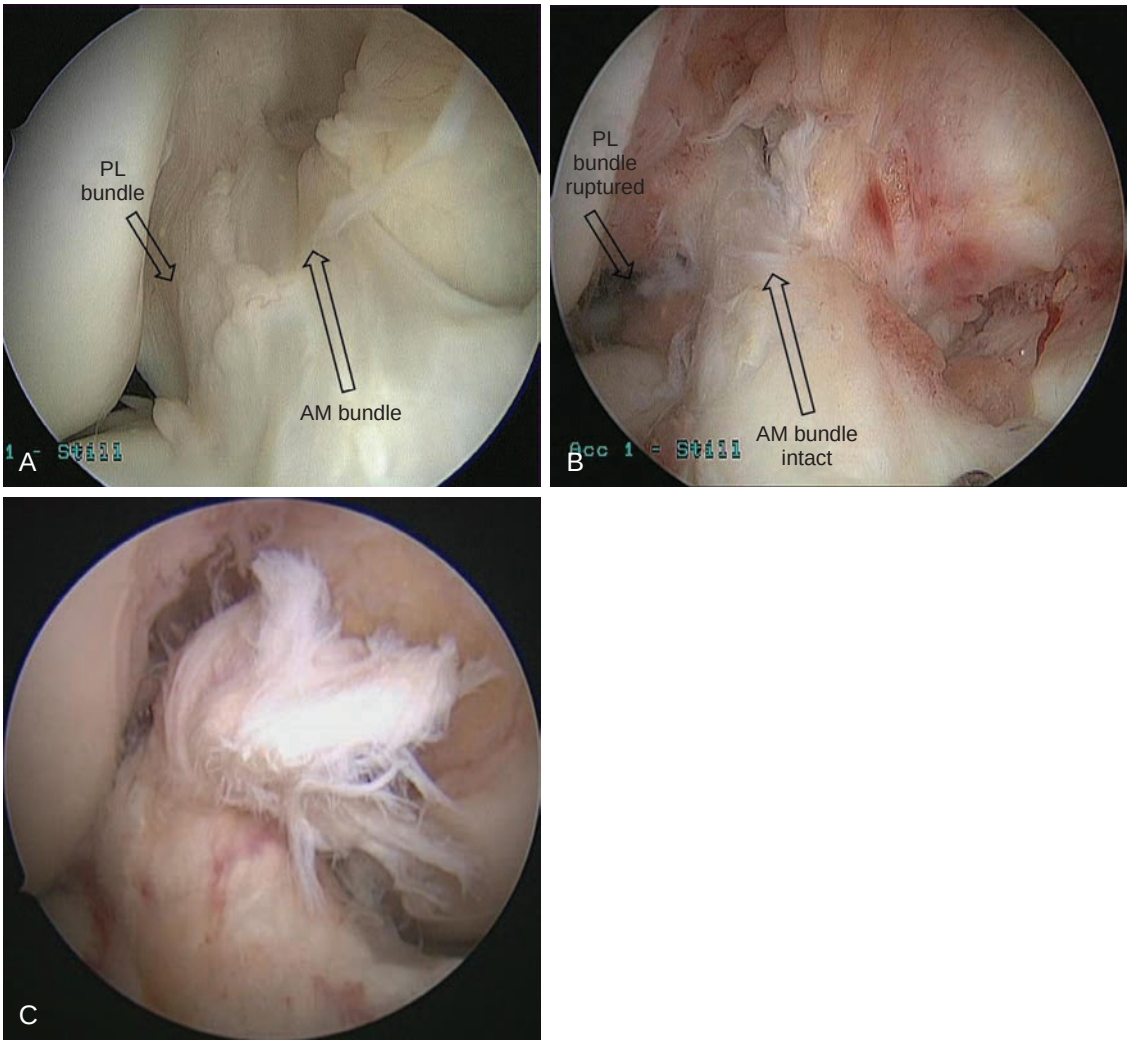

FIGURE 32-1. Arthroscopic images of an intact anterior cruciate ligament (ACL), single-bundle rupture, and complete rupture. (**A**) Intact, native ACL. The anteromedial (AM) and posterolateral (PL) bundles are labeled and have arrows running in the direction of the fibers of the individual bundles. (**B**) Posterolateral single-bundle ACL rupture. The anteromedial bundle is intact. (**C**) Complete rupture of the ACL (both bundles are ruptured). In this case, the ACL was ruptured at its femoral insertion.

Classic Pathological Findings

- The pathological findings of this injury include a partial or complete rupture of one bundle (anteromedial or posterolateral) or both bundles of the anterior cruciate ligament (Figure 32-1).
- Lateral-sided, direct injuries may lead to a Terrible Triad of the knee: ACL rupture, MCL rupture, and lateral meniscal tear
  - Lateral meniscal tears are more common in acutely-torn ACL injuries
  - Medial meniscal tears are more common in chronically-torn ACL injuries
- Other concomitantly-torn ligaments in the knee, in order of decreasing frequency:
  - Medial collateral ligament (MCL)
  - Posterior cruciate ligament (PCL)
  - Lateral collateral ligament (LCL)
- Other concomitant injuries can include:
  - Meniscal injuries (as mentioned above)
  - Cartilage injuries
  - Capsular injuries
  - Patellar dislocations

Clinical Presentation

History

- While there is a wide variety of presentations following ACL injury, typical complaints include:
  - Recollection of a specific contact or noncontact injury to the knee, frequently associated with pivoting on the knee or landing from a jump
  - Report of having heard a pop or felt the knee buckle
  - Immediate difficulty bearing weight on the injured knee and inability to continue athletic participation
  - Development of a large effusion of the knee 2 to 12 hours after injury
  - Knee stiffness for 1 to 2 weeks following injury (a result of the effusion)

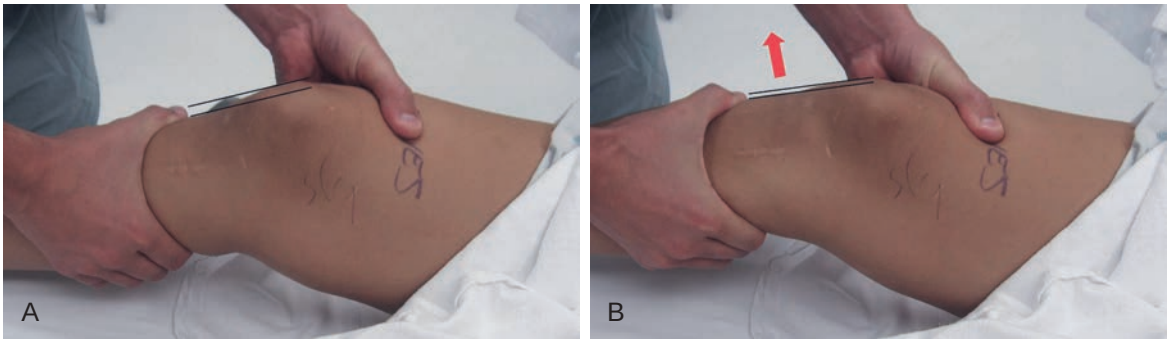

FIGURE 32-2. Positive Lachman test. (**A**) No forces are being applied. (**B**) The tibia is being pulled anteriorly. The black lines represent the relationship between the anterior aspect of the tibia and the anterior aspect of the patella (used as a consistent landmark between the two images). Note how the black lines show the tibia moves anteriorly in relation to the patella (and, therefore, the femur).

- After primary injury, recurrent instability or swelling with pivoting activities

Physical Examination

Abnormal findings

- Present if examined within a week of injury
  - Large knee hemarthrosis
  - Stiffness of the knee, lacking terminal flexion and extension
- Present if a relaxed examination of the knee is possible
  - Positive Lachman test (Figure 32-2)
  - Positive anterior drawer
  - Positive pivot shift

Pertinent normal findings

- Negative valgus and varus stress tests
- Negative posterior drawer
- Negative patellar apprehension
- Painless arc of motion (normally from approximately 25° to 75° of flexion)
- Ability to hold leg extended against gravity
- No palpable defects or crepitus

Imaging

- Radiographs
  - Should be negative
    - No subluxations/dislocations evident
    - No fractures
  - Positive findings
    - Effusion
    - Segond fracture: Anterolateral tibial capsular avulsion highly associated with ACL injuries (Figure 32-3)
    - Anterior tibial spine avulsion: ACL tibial avulsion (Figure 32-3)
- Magnetic resonance imaging (MRI)
  - Confirm ACL rupture
    - Disruption of ACL fibers (Figure 32-4) or tibial avulsion
    - Bone bruises (subcortical microfractures) commonly present in central aspect of lateral femoral

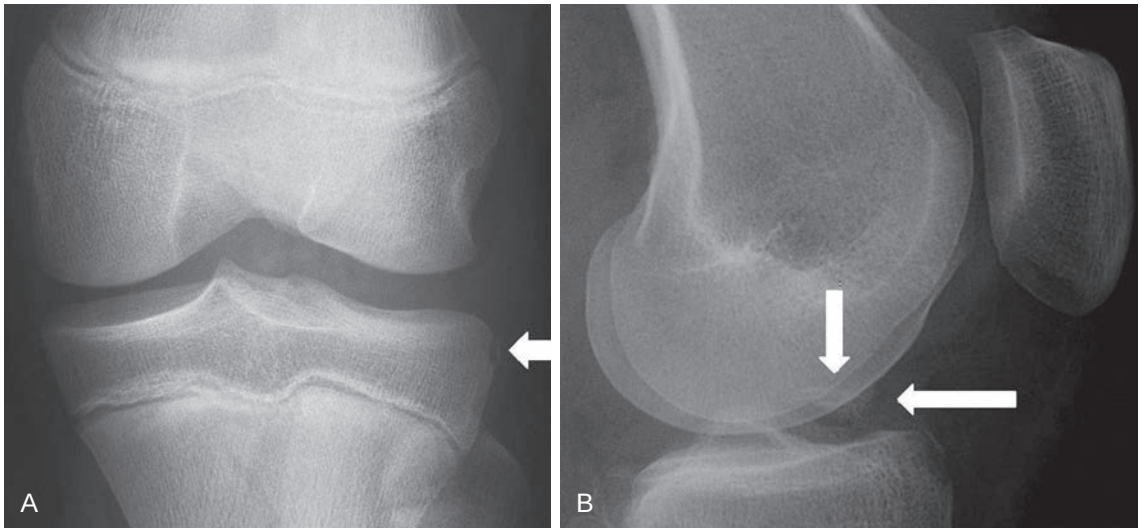

FIGURE 32-3. Radiographs of a Segond fracture and an anterior tibial spine avulsion. (**A**) Anteroposterior radiograph of a skeletally immature knee showing an anterolateral tibial capsular avulsion marked with a white arrow (Segond fracture). These avulsions are highly associated with anterior cruciate ligament (ACL) injuries. (**B**) Lateral radiograph of a skeletally mature knee showing an anterior tibial spine avulsion marked with white arrows. These avulsions occur when the ACL avulses a tibial fragment instead of rupturing midsubstance.



FIGURE 32-4. MRI of an ACL rupture. Sagittal, nonfat suppressed T2-weighted MRI showing a ruptured ACL marked with white arrows.

condyle and posterior aspect of lateral tibial plateau
- Diagnose other concomitant injuries (as listed above)

Differential Diagnosis

- Isolated meniscal tear: small effusion; negative Lachman/anterior drawer/pivot shift; tenderness over medial or lateral joint line; positive McMurray test
- Patellar dislocations: report of having observed patella dislocated laterally and subsequent reduction; increased lateral patellar translation; positive patellar apprehension
- Medial collateral ligament injuries: medial-sided pain and swelling; pain or instability with valgus stress test at 30°
- Posterior cruciate ligament injuries: positive posterior drawer; positive tibial sag sign
- Posterolateral corner injuries: lateral-sided pain and swelling; pain or instability with varus stress test at 30°; positive dial test at 30°; possible fibular head avulsion seen on radiographs
- Fractures of the patella, distal femur, or proximal tibia (including osteochondral injuries): positive crepitus or palpable deformity; pain with any range of motion of knee; fracture seen on radiographs
- Patellar tendon/Quadriceps tendon rupture: inability to hold leg extended against gravity; palpable defect in tendon

Treatment

Nonoperative Management

- Rest/ice/compression/elevation (RICE) and NSAIDs to help with acute pain and effusion
- Range of motion exercises to regain motion
- Quadriceps and hamstring strengthening exercises (focus on hamstrings to pull tibia posteriorly)
- ACL-deficient bracing may be helpful in stabilizing the knee during moderate- or low-intensity activities

Guidelines for Choosing among Nonoperative Treatments

- All patients should be initially treated with nonsurgical options to decrease pain and swelling and increase range of motion
  - Patients who undergo ACL reconstruction while their knee has an effusion and limited range of motion generally have more difficulty regaining motion postoperatively
- Patients unwilling or unable to undergo ACL reconstruction should proceed with nonsurgical treatment

Surgical Indications

- There are no absolute indications for ACL reconstruction
- Relative indications:
  - High activity level athletes
  - Recurrent instability
  - Concomitant ligament injury
  - Concomitant unstable, vertical meniscal tears
- Contraindications:
  - Infection
  - Fracture (other than tibial spine avulsion or osteochondral fragment)
  - Neurovascular compromised extremity
  - Unstable medical comorbidities
  - Open wounds around the knee
  - Unwilling/unable to follow postoperative rehabilitation protocols

Aspects of History, Demographics, or Exam Findings that Affect Choice of Treatment

- Age and activity level
  - Younger, higher-demand athletes, and those who tear their ACL during sport participation usually require ACL reconstruction in order to return to high-level activities
  - Older, lower-demand individuals usually do not require ACL reconstruction to return to low-demand activities. ACL is required for rotational stability of the knee and is not necessary for walking, stair-climbing, and low-demand in-line activities
- Willingness to modify activities
  - Individuals willing to modify their level of activity to moderate or lower levels may successfully be treated with nonoperative therapy
- Degree of instability of the knee
  - Recurrent instability with lower levels of activity, such as light dancing, may require ACL reconstruction in order to continue such activities
- Concomitant injuries
  - Large, unstable vertical meniscal tears
    - Meniscal repairs performed in ACL-deficient knees have a high incidence of reinjury. Options include meniscal repair in association with ACL reconstruction or meniscectomy.

- Multiligament injured knee
  - Knees with multiple injured ligaments are often more unstable and frequently require multiligament reconstruction

Aspects of Clinical Decision-Making When Surgery is Indicated

- Graft use
  - Autograft options: patellar tendon, hamstrings, quadriceps tendon
    - Increased pain postoperatively from donor site
  - Allograft options: patellar tendon, hamstrings, Achilles, anterior tibialis, posterior tibialis
    - Risk of disease transmission

    HIV: approximately 1 in 1.5 million

    Hepatitis C: approximately 1 in 150,000
    - Recent literature has shown higher re-rupture rates following allograft ACL reconstruction in patients under 25 years old
- Tunnel placement
  - Anatomic versus nonanatomic
    - Current literature supports anatomic tunnel drilling to increase rotational stability of the knee and improve functional results
- Single bundle versus double bundle reconstruction
- Method of graft fixation
  - Cortical: suspensory button; cross-pin; screw and washer; staple
  - Aperture: interference screw

Evidence

Ferretti M, Ekdahl M, Shen W, et al: Osseous landmarks of the femoral attachment of the anterior cruciate ligament: an anatomic study. *Arthroscopy* 23:1218–1225, 2007.

The femoral attachment of the ACL was studied histologically in seven human fetuses, arthroscopically in 60 ACL surgeries, and grossly in 16 cadaveric knees. Two different osseous landmarks were detected: the lateral intercondylar ridge (present in 100%) and the lateral bifurcate ridge (present in 80%).

Hewett TE, Myer GD, Ford KR, et al: Biomechanical measures of neuromuscular control and valgus loading of the knee predict anterior cruciate ligament injury risk in female athletes: A prospective study. *Am J Sports Med* 33:492–501, 2005.

Female soccer, basketball, and volleyball athletes were prospectively measured for neuromuscular control during a jump-landing task. Of the female athletes who subsequently sustained ACL ruptures, greater knee abduction angles at landing and higher ground reaction forces were observed. (Level II evidence)

Hussein M, van Eck CF, Cretnik A, et al: Prospective randomized clinical evaluation of conventional single-bundle, anatomic single-bundle, and anatomic double-bundle anterior cruciate ligament reconstruction: 281 cases with 3- to 5-year followup. *Am J Sports Med* 40:512–520, 2012.

ACL reconstruction patients were prospectively randomized into three groups: anatomic double bundle (ADB), anatomic single bundle (ASB), and conventional (transtibial) single bundle (CSB). ADB and ASB reconstructions were significantly superior to CSB reconstructions in terms of AP and rotational stability. ADB was also more stable than ASB, but these differences were small and may not be clinically relevant. (Level I evidence)

Hwang MD, Piefer JW, Lubowitz JH: Anterior cruciate ligament tibial footprint anatomy: Systematic review of the 21st century literature. *Arthroscopy* 28:728–734, 2012.

This systematic review examined 17 original articles published between 2000 and 2010 which described the ACL tibial footprint. They concluded that the anatomic center of the ACL tibial footprint was 15 mm anterior to the PCL (the most consistent arthroscopic landmark) and two-fifths the medial-lateral width of the interspinous distance.

Kopf S, Musahl V, Tashman S, et al: A systematic review of the femoral origin and tibial insertion morphology of the ACL. *Knee Surg Sports Traumatol Arthrosc* 17:213–219, 2009.

This systematic review examined 20 studies published before 2009 which described the anatomy of the ACL. They found a high diversity in size, shape, origin, and insertion of the ACL. They concluded that the use of anatomical landmarks and remnant tissue were the most reliable means of assessing anatomic origins.

Mandelbaum BR, Silvers HJ, Watanabe DS, et al: Effectiveness of a neuromuscular and proprioceptive training program in preventing anterior cruciate ligament injuries in female athletes: 2-year follow-up. *Am J Sports Med* 33:1003–1010, 2005.

Female soccer players between 14 and 18 years old underwent a neuromuscular and proprioceptive sport-specific training program and were compared to a control group. The intervention group had a 74% to 88% reduction in anterior cruciate ligament injuries compared to the control group. (Level II evidence)

Prodromos CC, Han Y, Rogowski J, et al: A metaanalysis of the incidence of anterior cruciate ligament tears as a function of gender, sport, and a knee injury-reduction regimen. *Arthroscopy* 23:1320–1325, 2007.

This metaanalysis examined ACL injury rates as a function of gender, sport, and prior injury-reduction training. Female/male ACL tear incidence ratios were as follows: basketball, 3:5; soccer, 2:67; lacrosse, 1:18; and Alpine skiing, 1:0. Injury-reduction programs were shown to be effective for soccer but not basketball. (Level IV evidence)

Multiple-Choice Questions

QUESTION 1. What is the most common mechanism for an ACL rupture?

A. Noncontact hyper-extension injury
B. Direct, lateral-sided injury
C. Noncontact valgus rotational injury
D. Direct anterior injury

QUESTION 2. In patients with ACL injuries, which other ligament of the knee has the highest rate of concomitant injury?

A. Medial patellofemoral ligament
B. Posterior cruciate ligament
C. Lateral collateral ligament
D. Medial collateral ligament

QUESTION 3. Which of the following increases an athlete's risk of rupturing their ACL?

A. Being a 37-year-old basketball player
B. Being a male ice hockey player
C. Returning to play after a high ankle sprain
D. Playing sports on modern artificial turf (infill surfaces)

QUESTION 4. Which of the following is commonly found in patients with acute ACL ruptures?

A. Inability to hold the leg extended against gravity
B. Painless arc of motion
C. Lack of effusion
D. Inability to recall a specific injury

QUESTION 5. Which of the following is LEAST helpful in making the diagnosis of an ACL rupture?

A. Magnetic resonance imaging
B. Radiographs
C. Physical examination
D. Computed tomography

Answer Key

QUESTION 1. Correct answer: **C** (see Epidemiology)

QUESTION 2. Correct answer: **D** (see Pathophysiology)

QUESTION 3. Correct answer: **C** (see Epidemiology and Pathophysiology)

QUESTION 4. Correct answer: **B** (see Clinical Presentation)

QUESTION 5. Correct answer: **D** (see Clinical Presentation)

NONOPERATIVE AND PREOPERATIVE REHABILITATION OF ANTERIOR CRUCIATE LIGAMENT INJURIES

David Logerstedt, PT, PhD, MPT, MA, SCS, Kathleen White, PT, PhD, DPT, Michael J. Axe, MD, and Lynn Snyder-Mackler, PT, ScD, SCS, ATC, FAPTA

GUIDING PRINCIPLES OF NONOPERATIVE REHABILITATION

- Rehabilitation should be progressed based on clinical milestones (time frames are included to guide progression)
- Rehabilitation strives to restore clinical and functional limb-to-limb symmetry
- Patients can return to previous levels of activity for short periods of time upon completion of rehabilitation that includes perturbation training

Phase I (weeks 0 to 3)

Protection

- Isolated ACL injuries do not require bracing for performance of ADLs and acute traditional isolated treatment.
- Execution of dynamic weight-bearing tasks, such as hopping tasks and agility drills, are often completed with a brace. Variations with this are often surgeon preference.

TIMELINE 32-1: Nonoperative and Preoperative Rehabilitation of Anterior Cruciate Ligament Injuries

PHASE I (weeks 0 to 3)	PHASE II (weeks 4 to 8)	PHASE III (weeks 9 to 12)
• Crutches: DC when ambulating with normal gait pattern • Brace • ROM through full range equal to contralateral knee • Manual therapy techniques • Stretching • ROM exercises • Quadriceps muscle activation • NMES if QI < 80% • OKC/CKC exercises • Functional exercises • TLS activities as recommended and tolerated	• Brace • Stretching • Quadriceps muscle activation • NMES if QI < 80% • OKC/CKC exercises • Perturbation training • Functional exercises • Agility training • TLS activities as recommended and tolerated	• Brace • Stretching • OKC/CKC exercises • Functional exercises • Walk/jog running progression • Sport-specific exercises

- Crutches may be used initially to assist with a normalized gait patterns after initial injury as well as to control knee-joint effusion.
- In patients with multiligamentous injuries and/or chondral deficiencies, bracing may be indicated.
- Individuals with potential repairable meniscal injuries are not recommended to participate in hopping activities as this puts them at higher risk for an extension of their initial injury.

Management of Pain and Swelling

- Effusion management is critical for these patients in the acute stage of rehabilitation. The modified stroke technique is used to objectively measures effusion.[1] This technique has substantial agreement between raters (interrater reliability).
- Effusion should be evaluated at every session, and treatment programs should be modified accordingly. For example, if a patient has an increase in effusion grades after a rigorous therapy session, then the treatment should not be progressed until the effusion has decreased.
- The modified stroke technique measures effusion on a 5-point scale (Table 32-1). Fluid must be pushed out of the medial sulcus of the knee superiorly followed by an inferior sweep of the lateral knee. The amount of fluid that refills the medial sulcus is used to determine the grade of effusion; 3+ effusion is the inability to move the fluid out of the medial sulcus. If fluid is moved out of the medial sulcus and then spontaneously refills the space, this is graded 2+ effusion. If the lateral stroke is completed and a large amount of fluid refills the medial sulcus, this is graded 1+ effusion. If only a small amount of fluid refills the medial sulcus, this is graded trace effusion. If the lateral sweep is completed and no fluid refills the medial sulcus, this is graded a zero-grade effusion.
- Increased effusion is a limiting factor for progression through rehabilitation. It is essential for patients to take steps on their own, as well as in the clinic, to manage knee-joint effusion.
- Patients should be instructed to ice the knee while the leg is elevated above the level of the heart with increased compression around the joint. Patients should be instructed to ice and elevate after activities and at the end of the day.

Table 32-1 Effusion Grades

Grade	Description
3+	Unable to move the fluid out of the medial sulcus
2+	Fluid is pushed out of the medial sulcus but immediately refills without the lateral stroke
1+	Large amount of fluid refills the medial sulcus with the lateral stroke
Trace	Small amount of fluid refills the medial sulcus with the lateral stroke
Zero	No fluid is present with the lateral stroke

(From Sturgill LP, Snyder-Mackler L, Manal T, Axe MJ: Interrater reliability of a clinical scale to assess knee joint effusion. J Orthop Sports Phys Ther 39, 846, 2009.)

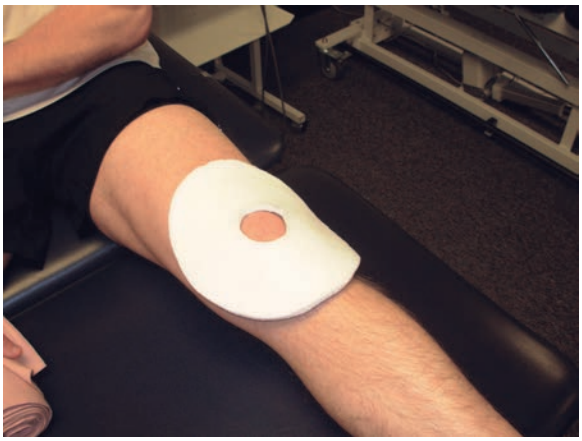

FIGURE 32-5. Donut for controlling knee effusion.

- If the patient continues to have persistent effusion, an additional donut is used to provide additional compression while the patient is completing daily tasks throughout the day in a dependent position. The donut is an oval shape with the inner most part removed as this space is made for the patella (Figure 32-5). This should be applied to the knee and then an additional wrap or bandage is used to hold it in place.
- This additional compression around the knee will assist in limiting increases in knee-joint effusion throughout the day. If patients are compliant with this method, it is effective in reducing the knee-joint effusion.
- Complaints of pain are most prominent in Phase I of rehabilitation. Pain can be resolved with the use of medications and modalities, such as ice, TENS, and noxious stimulation.
- Noxious stimulation (50 pulses per second, 12 seconds on, 8 seconds off, 2 seconds ramp) should be used for isolated areas of irritation to noncontractile tissues, such as fat pad irritation, patellar tendon inflammation, and joint line pain.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- To assist with knee-joint effusion management, retrograde massage can be performed by providing effleurage massage techniques from distal to proximal to move to fluid out of the affected area. This should be performed in addition to effusion management techniques listed above.
- For deficits with range of motion, manual techniques should be used.
- Overpressure to the tibiofemoral joint at end ranges of motion in both flexion and extension can be performed to increase knee range of motion.
- Mobility of the patella should also be evaluated to assist with a proper superior and inferior glides of the patella. Good mobility of the patella in the superior direction will allow for improved quadriceps contraction, while good patellar mobility in the inferior direction is essential for achieving full knee flexion range of motion.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Often, limitations in range of motion are caused by soft tissue musculotendinous restrictions.
- Flexibility of muscles that cross the knee joint should be evaluated and stretching should be completed where limitations exist.
- Flexibility limitations often occur in to the hamstrings, quadriceps, and triceps surae muscles. Stretching of these muscles should be done daily to improve and maintain flexibility after injury. Stretches can be held for 30 seconds and repeated at least 3 times. Additional stretching may be needed for some patients, and patient's tolerance should be considered.

Other Therapeutic Exercises

- Stationary cycling
- Classification screening
- Within 6 months of initial injury, classification of the patients with ACL deficiency should be performed using objective measures.
- A screening classification system has been developed to determine which active individuals with an ACL injury have a good probability of returning to high level of functioning without operative management for short periods of time, such as to complete a sports season.[2]
- Athletes classified as potential copers who received perturbation training are more likely to return to high-level activities in the short term than those who received standard training.[3]
- Noncopers have the potential to return to their previous activity level but only after undergoing lengthy rehabilitation.[4]
- The screening examination[2] consists of 6-meter timed hop[5]; patient reported outcome measures with the knee outcome survey, activities of daily living scale (KOS-ADLS)[6] and global rating scale of perceived function[2] and the number of episodes of giving way.
- For patients to be eligible to complete the screening exam, they must demonstrate less than 1+ knee-joint effusion, normalized knee range of motion, quadriceps strength measure 70% or greater compared to the contralateral limb with maximal voluntary isometric contraction with a central activation ratio of 95% or more with burst superimposition test[7] and no complaints of pain with single-legged hopping. The burst superimposition test[8] is completed with an electromechanical dynamometer with patients seated in an upright position and their hip and knee flexed to 90°. A supramaximal burst of electrical stimulation is given to the patient while they are actively contracting their quadriceps. If the patient is able to give a true maximal contraction, then no increase in force from the stimulation will be produced. This is reported as the central activation ratio and should be 95% or greater.[7]
- Potential copers are classified based on the following criteria: one or less episode of giving way, 80% or more on 6-meter timed hop test compared to the contralateral limb, 80% or more on KOS-ADLS, and 60% or more on global rating score (Table 32-2). Failure to meet any of these criteria will classify the patient as a noncoper.[2]

Table 32-2 Screening Classification[2]

	Potential Coper	Noncoper
Episodes of giving way	≤ 1	Failure to meet any of these criteria
6-m hop test	≥ 80% timed	
KOS-ADLS score	≥ 80%	
Global rating score	≥ 60%	

Activation of Primary Muscles Involved

- Quadriceps activation deficits are most prominent in Phase I of rehabilitation. Neuromuscular electrical stimulation may be used as an effective tool to improve quadriceps activation. High intensity setting (2500 Hz, alternating current at 75 burst per second, 10 to 15 seconds on with 50 second rest period) should be performed isometrically, with the knee flexed to 90° for 10 repetitions, 3 to 5 times per week.[9,10]
- This can also be used with active quadriceps contraction during a quadriceps setting exercise[11] or straight leg raise.
- Isotonic exercises, such as open chain knee extension exercises, may be used to increase quadriceps muscle activation.
- Additionally, isokinetic strength training has been found to increase quadriceps strength.[12]

Range of Motion Exercises

- Range of motion limitations are addressed using several techniques. Along with manual techniques, additional exercises can be completed by the patient to improve range of motion deficits.
- Knee extension:
  - Prone passive hangs with weight around ankle
  - Seated knee extension hangs with weight on knee joint
- Knee flexion:
  - Supine heel slides with heel on the table or the wall
  - Prone knee flexion stretching
  - Seated knee flexion stretching in closed chain

Open and Closed Kinetic Chain Exercises[13]

- Open Kinetic Chain (OKC)
  - Quadriceps setting: Quadriceps setting should be initiated with the patient in long sitting. Verbal and tactile cueing can be given from the rehabilitation specialist to isolate the quadriceps muscle and limit cocontraction of the hamstrings, quadriceps, and gastrocnemius. Patients should be instructed to perform 50 repetitions of quadriceps sets up to 5 to 10 times a day. This exercise can be progressed to standing to provide an additional weight-bearing component.
  - Straight leg raise (SLR): The SLR exercise can be completed with the quadriceps setting exercise. Patients should complete a quadriceps set first and then complete the SLR. A sign of quadriceps weakness is a quadriceps lag while the patient is completing the SLR exercise. Patients can complete 3 sets of

10 repetitions. This can be progressed with the addition of ankle weights as well as sets and repetitions.
  - Seated knee extension (long arc quadriceps (LAQ)): Unilateral LAQs can be completed with the patient seated at 90° of hip and knee flexion. Patients should be encouraged to complete the exercise through the entire range of motion since at this phase of rehabilitation, no range of motion restrictions are present. Patients can complete 3 sets of 10 repetitions and progression of resistance and volume should be done to challenge the patient. If patients complain of anterior knee pain with this exercise, knee extension can be initiated at 60° of flexion or a pain-free range. This exercise should be discontinued if patients report a worsening of knee symptoms, and the rehabilitation specialist should reassess for additional impairments.
- Closed Kinetic Chain (CKC)
  - Sit-to-stand activities: Sit-to-stand activities should be performed in front of a mirror for visual feedback. If one is not available, verbal and tactile feedback can be given by the rehabilitation specialist. Patients should be able to complete this task with symmetrical weight through the lower extremities and minimal trunk shifting. Patients can begin with 1 set of 10 repetitions and progress to 3 sets of 10 to 15 repetitions. The height of the sit-to-stand surface can also be lowered to provide an additional challenge to the patient.
  - Leg press: The leg press should be completed with the involved limb only if tolerated by the patient. Assist from the uninvolved limb may be needed if the patient is affected shortly after injury. Patients can complete this exercises with 3 sets of 10 to 15 repetitions. Resistance and volume can be increased to progress the exercise.
  - Isometric wall sits: Wall slides should be completed with the patient's back against the wall and feet shoulder-width apart. The patient should begin by sliding down the wall until their knees are flexed to 90°. This exercise can be held for 10 seconds for 5 repetitions and can progress to be held for 30 to 60 seconds for 10 repetitions.

Techniques to Increase Muscle Strength, Power, and Endurance

- After initial injury, quadriceps strength and activation deficits exist.
- Open chain exercises, such as quadriceps setting, straight leg raises (SLR), and unweighted, seated knee extension long arc quadriceps (LAQ), can be performed to strengthen the quadriceps muscles.
- Progression towards weight-bearing (closed kinetic chain) exercises should be initiated once the patient demonstrates improved quadriceps strength with open chain exercises, such as the absence of a quadriceps lag with a straight leg raise (SLR).

Functional Exercises

- Altered movement patterns during gait are present in noncopers with ACL deficiency and differ based on gender.[14-17]
- After ACL injury, noncopers demonstrate increased cocontraction of quadriceps and hamstrings musculature throughout gait.[15,18]
- Limitations in knee-joint range of motion, quadriceps strength measures, and patient's complaints of pain may contribute to gait deviations.
- In addition to resolving these impairments, gait training should be performed in the clinic with verbal, tactile, and visual cuing. Emphasis should be placed on heel strike at initial contact with quadriceps muscle contraction as well as symmetrical stance time between limbs.
- Interventions in the later phases of rehabilitation (perturbation training) have been suggested to abate these asymmetrical movement patterns in male and female noncopers.[14,15]

Milestones for Progression to the Next Phase

- 1+ effusion or less using the modified stoke technique[1]
- Symmetrical passive knee extension and flexion to the contralateral limb should be measured with a goniometer. Knee extension should be symmetrical to the uninvolved limb. If the uninvolved limb demonstrates hyperextension, the involved limb should demonstrate at least 0° of extension. Knee flexion range of motion should be within 5° to the contralateral side.
- No complaints of additional pathology (e.g., patellar tendon irritation, joint line pain, tibial tuberosity pain)

Phase II (weeks 4 to 8)

Protection

- Patients are required to wear a functional knee brace during the agility component of this phase.

Management of Pain and Swelling

- Soreness rules and effusion are used to determine progression through this phase.[1,19]
- The criteria for progression using the soreness rules are found in Figure 32-6.
- Knee-joint effusion is assessed using the modified stroke test (Table 32-1).[1] If effusion is 2+ or greater, the patient does not advance in the rehabilitation program.
- Effusion and pain in the knee joint are treated using cryotherapy, compression, elevation, and antiinflammatory medications as needed. In addition, retrograde massage of the knee is used for effusion management.

Techniques for Progressive Increase in Range of Motion

- To progress into this phase, full passive knee extension and flexion range of motion equal to the contralateral side must be present.[2,20]

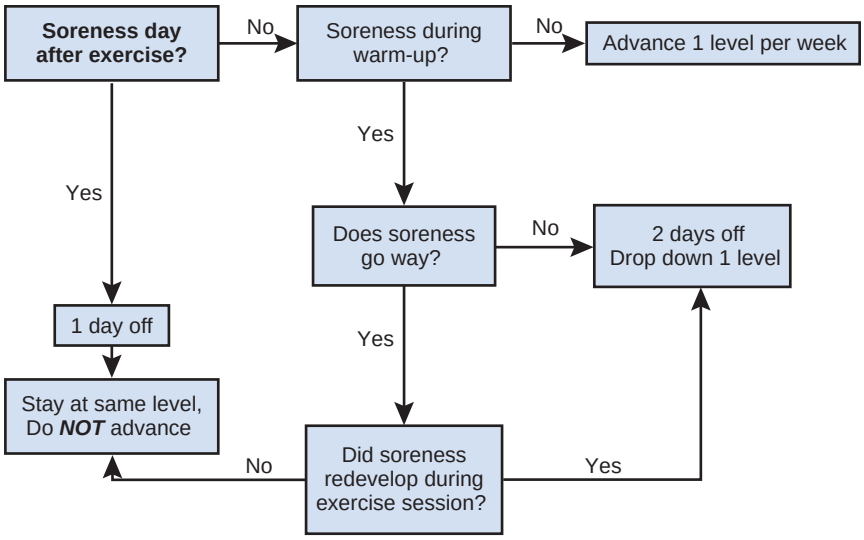

FIGURE 32-6. Soreness rules.[19]

Manual Therapy Techniques

- Tibiofemoral mobilization with rotation are used to regain full passive knee flexion.

Stretching and Flexibility Techniques for the Musculotendinous Unit

Stretching should be done to improve and maintain flexibility. The following stretches below are recommended after ACL injury. Stretches should be held for 30 seconds and repeated at a minimum of 3 times. Additional repetitions may be needed for some patients.

- Quadriceps stretch
- Hamstring stretch
- Iliotibial band (ITB) stretch
- Gastrocnemius/soleus stretch

Other Therapeutic Exercises

The type of cardiovascular training should be related to the patient's sport or occupational activity. A graded program should be initiated for 5 to 10 minutes using the soreness rules and effusion grades to determine progression.[1,19] When patients can perform the activity for 15 to 20 minutes without pain or swelling, they can progress to road or track-related activities.[20]

Stationary cycling: Should be used to improve endurance. Resistance and time can be increased as per patient's response.

- Elliptical machine: Reduces body weight to approximately 75%, so this should be initiated until patients can tolerate full weight bearing, pain-free. Progressive resistance should be added to improve endurance.
- Stair climber can be used as an additional form of cardiovascular training. Only when full, pain-free weight bearing can be tolerated should patients complete this form of cardiovascular exercise.

Activation of Primary Muscles Involved

- If quadriceps index is less than 80%, neuromuscular electrical stimulation to the quadriceps muscles is used to augment quadriceps strengthening exercises.
- Neuromuscular stimulation may improve quadriceps strength if applied in a high-intensity setting.[9-11,21]

Open and Closed Kinetic Chain Exercises

- The implementation of nonweightbearing (open kinetic chain) and weightbearing (closed kinetic chain) quadriceps strengthening exercises has been demonstrated to improve muscle strength and functional outcomes in patients with ACL injury.[3,21-23] Quadriceps muscles strength training involves the use of high-intensity, low-repetition, nonweightbearing and weightbearing quadriceps strengthening exercises to the involved limb (60% to 70% of 1-repetition maximum for 8 to 12 repetitions for 1 to 3 sets, with progression to 80% to 100% of 1-repetition maximum to maximize strength).[24]
- Nonweightbearing quadriceps strengthening exercises include knee extension exercises and isokinetic exercises on an electromechanical dynamometer.[13,15]
- Weightbearing exercises included resisted leg press and lateral and forward step-downs. Step-downs were performed initially on a 10.16 cm (4 inches) step and subjects were progressed in step height when they demonstrated adequate performance and proper technique.[13,15]

Techniques to Increase Muscle Strength, Power, and Endurance

- Open Kinetic Chain (OKC):
  - Resisted knee-extension exercises: seated knee extension should be completed with progressive weights. Unilateral strengthening and eccentric strengthening will improve quadriceps strength deficits of the involved limb. Low repetitions with high intensity are recommended for making improvements in strength deficits. To determine initial resistance, a resistance of approximately 75% of the patients' 1-repetition maximum should be used. It is recommended that 3 to 5 sets of 6 to 8 repetitions at this resistance is completed.[13]

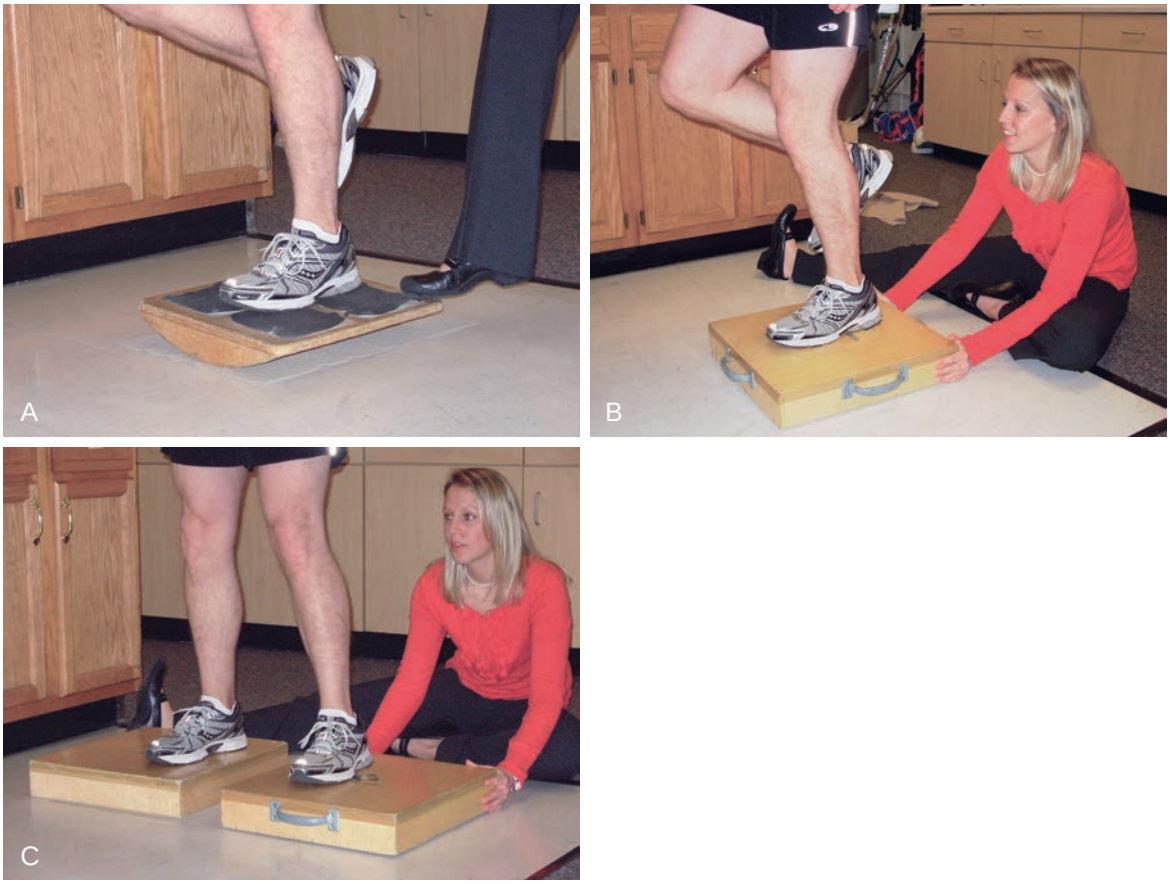

FIGURE 32-7. A, Perturbation training on rocker board. **B,** Perturbation training on roller board. **C,** Perturbation training on roller board and platform.

  - Isokinetic exercises on electromechanical dynamometer at various speeds: This strengthening protocol includes concentric and eccentric resistance of the knee extensors during active knee flexion and extension. Isokinetic strengthening can be completed using an isokinetic dynamometer at speeds beginning at 60°/s and progress to 180°/s at 30°/s increments.[13]
- Closed Kinetic Chain (CKC):
  - Resisted leg press: Both unilateral and eccentric leg press exercises are recommended to improve strength deficits. Similar to knee-extension exercises, low repetitions at 75% of the patient's 1-repetition maximum are recommended; 3 to 5 sets of 6 to 8 repetitions are suggested.[13]
  - Lateral and forward step-downs: These exercises are recommended for functional benefits and must be completed with proper form. The rehabilitation specialist should monitor the patient's mechanics, observing a level pelvis and that the patient keeps the knee alignment correctly over the foot. The height of the step should be chosen based on the highest height that the patient can properly maintain their form; 3 sets of 10 repetitions are recommended, and the height of the box is progressed as per patient's tolerance.[13]

Neuromuscular Dynamic Stability Exercises

- Perturbation training is a specialized neuromuscular training technique designed to encourage compensatory muscle strategies in patients with ACL deficiency[3,20,25]
- The proposed mechanisms for increasing dynamic knee stability with perturbation training is based on increasing the heightened sensitivity of muscle spindles to facilitate antagonist muscle activation to respond to perturbations (length feedback) and reciprocal inhibition of agonist muscles mediated by Golgi tendon organs (force feedback).[3,26-28]
- Perturbation training involves the destabilization of the lower extremity in a systematic progressive manner with translatory and rotary perturbations on support surfaces to elicit selective muscle activation without gross muscle cocontraction.[3,20,25]
- Perturbation training consists of 3 specific techniques to facilitate joint stability (Figure 32-7) (A) rocker board perturbations, (B) multiplanar roller board perturbations, and (C) multiplanar roller board perturbations with a stationary platform.
- For the rocker-board and roller-board techniques, initially all patients begin the first session in a double limb support stance. If the patient exhibits good balance reaction without loss of balance, they progress to single limb support stance for the remainder of the sessions.

- For the roller board/stationary platform condition, the subject placed the involved limb on either the roller board or the stationary platform and after the completion of 3 sets, the limbs were alternated and the treatment was repeated.
- The goal for this condition was to have the subject resist the speed and magnitude of the perturbation force applied by the therapist without anticipatory muscle contraction or rigid cocontraction. Subjects were given verbal commands: "Meet my force, don't beat my force," "Don't overpower me," "Soften your knees," and "Relax between perturbations".
- The objective was to either resist the force or to reestablish a balanced posture after the perturbation was applied by the therapist.
- For the first 2 to 5 sessions, the patient is informed with verbal cues of the direction and timing of perturbation movement. Verbal and tactile cues are used to inform the patient to avoid cocontractions at the knee.
- Subsequent sessions progressed from expected to random directions and timing of the perturbation, increasing intensity and magnitude of the force, and decreasing verbal cues.
- Progression of perturbations is individualized depending on the subject's ability to apply appropriate directional and counter-resistive force, selective muscle activation patterns, and reduction in loss of balance.
- During the last 5 sessions, a sports- or activity-specific task was introduced to distract the subject's attention to increase difficulty of the task.
- The progression of perturbation training is detailed in Table 32-3.

Functional Exercises

- Agility training is designed to expose the lower extremities to rapid body movement and directional changes of the limbs.[20]
- Clinicians should observe the patient's willingness to use and rely on the operated lower limb. We recommend the use of functional knee braces during agility training.
- Side shuffles and carioca drills are used to expose the involved limb to quick changes of direction in the lateral direction.
- Shuttle runs are used to promote rapid acceleration and deceleration.

Table 32-3 Perturbation Exercises and Progression Guidelines[20]

	Early (Estimated Treatment 1–3)	Middle (Estimated Treatment 4–7)	Late (Estimated Treatment 8–10)
Roller Board	Position: Patient on board (bilateral 1st treatment, progress to unilateral) Application: Slow application of force, low magnitude, Straight plane of movement (do all A/P reps before you begin M/L) Observe: Cue patient to avoid massive cocontraction at knee. Do not overstress beyond limit of stability (do not induce fall)	Position: Unilateral Application: Unexpected forces with rapid increasing magnitude force application with added rotatory and diagonal motions Distraction: Add distraction (ball toss, stick work) Observe: Observe difficulty with recovery but few to no falls	Position: Unilateral Application: Increased magnitude of force application with random direction movements Distraction: Increase speed and magnitude of distraction in sport specific positions Observe: Look for disassociation of hip, knee, and ankle
Rocker Board	Position: Begin bilateral, progress to unilateral Application: Slow application of force, low magnitude with less force medial than lateral Observe: Cue patient to maintain equal weight bearing bilaterally and avoid massive cocontraction at the knee	Position: Unilateral Application: Unexpected forces with rapid increasing magnitude force application Distraction: Add distraction (ball toss, stick work) Observe: Look for a rapid return to a stable base after perturbation	Position: Unilateral with foot on a diagonal Application: Increased magnitude force application with random direction movements Distraction: Increase speed and magnitude of distraction in sport specific positions Observe: Look for minimal sway from stable stance at rest or following any perturbation
Roller-board and Stationary Platform	Position: One foot on the roller board, one on the platform with equal weightbearing on both lower extremities Application: Slow application of force, low magnitude in all directions Observe: Cue patient to maintain equal weightbearing bilaterally (watch for unweighting of the involved limb as level of difficulty increases). Do not overpower the patient. Patient should match therapist's forces without excessive movement of roller board	Position: One foot on the roller board, one on the platform with equal weight bearing on both lower extremities Application: Unexpected forces with rapid increasing magnitude force application with added combined movements Distraction: Add distraction (ball toss, stick work) Observe: Cue patient to maintain equal weightbearing bilaterally. Cue patient to react as you remove force (avoid rebound board movement)	Position: One foot on the roller board, one on the platform with equal weightbearing on both lower extremities Application: Increased magnitude force application with random direction movements Distraction: Increase speed and magnitude of distraction with added diagonal/sport specific stance (forward split, backward split) Observe: Cue patient to maintain equal weight bearing bilaterally. Cue patient to react as you remove force (avoid rebound board movement)
Time: 3 sets of 1 minute of each with 30 to 60 seconds rest periods Phases: 10 treatments total			

Courtesy of Tara Jo Manal, University of Delaware Physical Therapy Clinic.

- Cutting and pivoting drills are incorporated to expose the patient to more sport-specific movements. The drills are initiated at half-speed and progress to full speed based on the knee's response to the training by using the soreness and effusion criteria for progression.
- Progression of the distance and the incorporation of unexpected direction changes and sports equipment into the drill is based on the patient's apprehension, pain, and swelling.

Sport-Specific Exercises

- Sport-specific skills and movements are gradually incorporated into the perturbation and agility training programs.[20]
- Patients must be able to perform the agility training without pain, swelling, or apprehension.

Milestones for Progression to the Next Phase

- This phase of the rehabilitation program is a minimum of 10 training sessions.
- The perturbation training is 10 sessions.
- To progress to the next phase, patients must pass a battery of tests to determine readiness for return to sports (RTS criteria).[2]
  - No pain using a visual analog scale (VAS) or numeric pain rating scale (NPRS)
  - No effusion measured with the modified stroke test[1]
  - Full passive knee extension and flexion ROM
  - Quadriceps index of 90% or greater measured with a maximal voluntary contraction (MVIC with the burst superimposition test or peak torque with isokinetic testing)
  - Single-leg hop symmetry index of 90% or greater
    - Single hop for distance
    - Triple crossover hop for distance
    - Triple hop for distance
    - 6-m timed hop
  - Knee Outcome Survey, Activities of Daily Living Scale (KOS-ADLS) of 90% or more
  - Global rating scale (GRS) of perceived knee function question of 90% or more

Phase III (weeks 9 to 12)

Protection

- Patients are required to wear a functional knee brace during the sport-specific drills and return to sports.

Management of Pain and Swelling

- Soreness rules and effusion grades are used to determine progression through this phase with the same criteria for progression as stated in Phase I and Phase II.[1,19]
- Effusion and pain in the knee joint are treated using cryotherapy, compression, elevation, and antiinflammatory medications as needed. Additionally, retrograde massage of the knee is used for effusion management.

Techniques for Progressive Increase in Range of Motion

- Patients must have full passive knee extension and flexion ROM before initiation of this phase.

Stretching and Flexibility Techniques for the Musculotendinous Unit

Stretching should be maintained as part of a home exercises program in this phase of rehabilitation. If flexibility restrictions remain in this phase, manual stretching by the therapist may be required. The stretches below are recommended, holding for 30 seconds for 3 repetitions.

- Quadriceps stretch
- Hamstring stretch
- Iliotibial band (ITB) stretch
- Gastrocnemius/soleus stretch

Other Therapeutic Exercises

All exercises should be completed as per patient's response to activity. An increase in knee-joint effusion or knee symptoms may occur, therefore, these exercises should not be progressed and symptoms should be treated and monitored.[1,19]

- Stationary cycling: Recommended at this phase to continue to improve endurance. Progressive resistance with interval training will increase endurance and strength, with progression to 20 to 30 minutes.
- Elliptical machine: Progressive resistance and increased incline can be added at this phase to improve endurance and strength with progression to 20 to 30 minutes. This can be completed both forward and backward as well as in a squat position to increase strengthening.
- Stair climber: Should be increased in resistance to improve endurance and increase strength with progression to 20 to 30 minutes.

Activation of Primary Muscles Involved

- The burst superimposition test should be used to determine muscle activation.[7,8] Patients should demonstrate less than 5% quadriceps inhibition.[7] This is measured as the force exerted by the patient volitionally divided by the force exerted with the burst super imposition multiplied by 100. This should be performed bilaterally.

Open and Closed Kinetic Chain Exercises

Muscle strength training involves the use of high-intensity, low-repetition, nonweightbearing and weightbearing muscle-strengthening exercises to the involved limb as recommended by the American College of Sports Medicine position on progression models in resistance training for healthy adults (60% to 70% of 1-repetition maximum, for 8 to 12 repetitions, for 1 to 3 sets; with progression to 80% to 100% of 1-repetition maximum to maximize strength).[24]

- Open Kinetic Chain (OKC):
  - Resisted knee-extension exercises: Similar to exercises in Phase II, these exercises can be competed with increased resistance. Unilateral and eccentric exercises can be used to increase strength of the involved limb knee extensors.

- Resisted knee flexion exercises: Hamstring weakness relative to quadriceps strength is linked to a higher rate of injury.[29] A hamstring to quadriceps ratio of at least 55% is recommended.[30]
- Isokinetic exercises on electromechanical dynamometer at various speeds: Concentric and eccentric resistance of the knee extensors can be completed with an isokinetic dynamometer. Similar to recommendations in Phase II, increased resistance can be added to challenge the patient.

- Closed Kinetic Chain (CKC):
  - Resisted leg press: Unilateral and eccentric exercises will improve quadriceps strength. Progressive resistance should be increased from the recommendations in Phase II.
  - Lateral and forward step-downs: Repetitions and height of the box should be progressed from Phase II without resulting in poor mechanics. Proper mechanics should be maintained with this exercise.
  - Squats: Can be completed both bilaterally and unilaterally with proper mechanics. Similar to step-downs, patients should maintain a level pelvis and correct knee alignment over the foot. This can be progressed to unstable surfaces, such as foam or a BOSU ball.
  - Lunges: Should be completed as long as patients are free of pain. Lunges can be repeated or alternating to improve quadriceps and hip extensor muscle strength. This can be progressed to holding weights or lunging on unstable surfaces, such as foam.
  - Heel raises: Can be completed bilateral or unilateral and can be progressed with the addition of weights.

Techniques to Increase Muscle Strength, Power, and Endurance

- See OKC and CKC exercises

Functional Exercises

- Walk/jog running progression for the benefit of unilateral lower limb strengthening and increased force generation and attenuation during a dynamic running task (Table 32-4).

Sport-Specific Exercises

- The demands and performance characteristics of the athlete's sport will dictate the necessary performance enhancement techniques.[31,32]

Milestones for Progression to Advanced Sport-Specific Training and Conditioning

All activities in this progression should be pain-free, measured with soreness rules, and no knee-joint effusion, measured with effusion grades via the modified stroke test.[1,19]

Before beginning agilities, patients should be able to hop without pain, effusion, or apprehension/hesitation

- Full-speed agilities without pain, effusion, or apprehension/hesitation.[1,19,20]
- Unopposed practice of sport-specific skills without pain, effusion, or apprehension/hesitation.[1,19,20]

Table 32-4 Walk/Jog Running Progression

	Running Progression	
	Treadmill	*Track*
Level 1	0.1-mile walk/0.1-mile jog repeat 10 times	Jog straights/walk curves (2 miles)
Level 2	Alternate 0.1-mile walk/0.2-mile jog (2 miles)	Jog straights/Jog 1 curve every other lap (2 miles)
Level 3	Alternate 0.1-mile walk/0.3-mile jog (2 miles)	Jog straights/Jog 1 curve every lap (2 miles)
Level 4	Alternate 0.1-mile walk/0.4-mile jog (2 miles)	Jog 1¾ lap/Walk curve (2 miles)
Level 5	Jog full 2 miles	Jog all laps (2 miles)
Level 6	Increase workout to 2.5 miles	Increase workout to 2.5 miles
Level 7	Increase workout to 3 miles	Increase workout to 3 miles
Level 8	Alternate between running/jogging every 0.25 miles	Increase speed on straights/jog curves

Courtesy of Tara Jo Manal, University of Delaware Physical Therapy Clinic.

Criteria for Abandoning Nonoperative Treatment and Proceeding to Surgery or More Intensive Intervention

- Any giving way episode with pain and swelling during or after the completion of Phase II
- Patient unable to return to preferred level of activity

Tips and Guidelines for Transitioning to Performance Enhancement

- The transition from rehabilitation program to performance enhancement progresses from recovery of the sports injury in which the physical impairments and functional limitations are largely resolved to allow return to sports participation.
- A balance between the ability of the healing tissue to handle the progressive loading while increasing the intensity and volume of the training program to meet the high physical demands of returning to sports.[33]
- It is at this time period when the athlete can incorporate strategies and techniques to enhance performance. General guidelines to transition to this stage include:
  - No signs of joint inflammation.
    - No pain using a visual analog scale (VAS) or numeric pain rating scale (NPRS).
    - No effusion measured with the modified stroke test[1].
  - Normal limb-to-limb symmetry in:[20]
    - Full passive knee extension and flexion ROM
    - Quadriceps index of 90% or more measured with a maximal voluntary contraction (MVIC with the burst superimposition test or peak torque with isokinetic testing)

  - Single-legged hop symmetry index of 90% or greater
  - Single hop for distance
  - Triple crossover hop for distance
  - Triple hop for distance
  - 6-meter timed hop
- Knee outcome survey, activities of daily living scale (KOS-ADLS) of 90% or more
- Global rating of perceived knee function (GRS) question of 90% or more

Performance Enhancement and Beyond Rehabilitation: Training/Trainer and Optimization of Athletic Performance

- Athlete is transitioned back to sports with the assistance of athletic trainers and strength and conditioning specialists/coaches.
- The demands and performance characteristics of the athlete's sport will dictate the necessary performance enhancement techniques.[31]
- Components of performance training will include enhancement of strength, power, speed, agility, endurance, and metabolic system specificity.

Specific Criteria for Return to Sports Participation: Tests and Measurements

- Patients must pass a battery of tests to determine readiness for return to sports (RTS criteria).[2,20]
  - No signs of joint inflammation
    - No pain using a visual analog scale (VAS) or numeric pain rating scale (NPRS).
    - No effusion measured with the modified stroke test[1].
  - Normal limb-to-limb symmetry in:[20]
    - Full passive knee extension and flexion ROM
    - Quadriceps index of 90% or more measured with a maximal voluntary contraction (MVIC with the burst superimposition test or peak torque with isokinetic testing)
    - Single-legged hop symmetry index of 90% or greater
  - Single hop for distance
  - Triple crossover hop for distance
  - Triple hop for distance
  - 6-meter timed hop
  - Knee outcome survey, activities of daily living Scale (KOS-ADLS) of 90% or more
  - Global rating of perceived knee function (GRS) question of 90% or more
- One-on-one opposed practice of sport-specific skills without pain, effusion, or apprehension[20]
- Return to full practice in individual sports or with team without pain, effusion, or apprehension[20]

Evidence

Chmielewski TL, Hurd WJ, Rudolph KS, et al: Perturbation training improves knee kinematics and reduces muscle cocontraction after complete unilateral anterior cruciate ligament rupture. *Phys Ther* 85:740–749, Discussion 50–54, 2005.

This prospective, comparative cohort study of 17 potential copers following perturbation training compared with 17 healthy control on muscle cocontraction and knee kinematics. After perturbation training, muscle cocontractions were reduced and knee kinematics were normalized in potential copers. (Level III evidence)

Chmielewski TL, Rudolph KS, Snyder-Mackler L: Development of dynamic knee stability after acute ACL injury. *J Electromyogr Kinesiol* 12:267–274, 2002.

This prospective, cohort study of 9 potential copers evaluated the effect of perturbation training on muscle activation and function. Vastus lateralis muscle activation increased during walking and was dependent on lateral hamstrings and soleus activation. Patient-reported knee function improved and all subjects returned to preinjury activities without episodes of instability. (Level III evidence)

Eitzen I, Moksnes H, Snyder-Mackler L, et al: A progressive 5-week exercise therapy program leads to significant improvement in knee function early after anterior cruciate ligament injury. *J Orthop Sports Phys Ther* 40:705–721, 2010.

This prospective, cohort study of 100 patients evaluated changes in knee function after the completion of a rehabilitation program for patients with ACL injury. The progressive 5-week rehabilitation program resulted in significant improvements in thigh muscle strength and single-leg hop performance. (Level III evidence)

Fitzgerald GK, Axe MJ, Snyder-Mackler L: A decision-making scheme for returning patients to high-level activity with nonoperative treatment after anterior cruciate ligament rupture. *Knee Surg Sports Traumatol Arthrosc* 8:76–82, 2002.

This prospective, cohort study of 93 patients described the development of a screening examination for selecting patients most likely to achieve successful return to high-level physical activity with nonoperative management of an ACL injury. Of the 28 patients who were rehabilitation candidates, 79% were able to return to previous levels of activity without giving way episode of the knee. Those who successfully returned to preinjury level had higher scores in the knee outcome survey, sports activity scale, global ratings of knee function, and 6-meter timed hop indexes than those who failed. (Level III evidence)

Fitzgerald GK, Axe MJ, Snyder-Mackler L: The efficacy of perturbation training in nonoperative anterior cruciate ligament rehabilitation programs for physical active individuals. *Phys Ther* 80:128–140, 2000.

This prospective, randomized study of 26 rehabilitation candidates compared standard nonoperative rehabilitation versus standard rehabilitation augmented with perturbation training. The perturbation training group were more likely to have successful rehabilitation and greater long-term success than the standard group. (Level II evidence)

Hartigan E, Axe MJ, Snyder-Mackler L: Perturbation training prior to ACL reconstruction improves gait asymmetries in noncopers. *J Orthop Res* 27:724–729, 2009.

This prospective, randomized study of 19 noncopers who underwent ACL reconstruction compared preoperative

rehabilitation with aggressive quadriceps strengthening versus aggressive quadriceps strengthening augmented with perturbation training. Quadriceps strength improved similarly in both groups. The perturbation training group had greater knee excursions at mid-stance after training, whereas the strengthening group continued to have smaller knee excursions at mid-stance after training. (Level II evidence)

Hurd WJ, Axe MJ, Snyder-Mackler L: A 10-year prospective trial of a patient management algorithm and screening examination for highly active individuals with anterior cruciate ligament injury: Part 2, determinants of dynamic knee stability. *Am J Sports Med* 36:48–56, 2008.

This prospective, cohort study of 345 consecutive patients evaluated outcomes between potential copers and noncopers. No differences were seen in outcomes between the groups. Quadriceps strength influenced hop test performance more than preinjury activity level and anterior knee laxity. Self-reported global function was influenced by the 6-meter timed hop performance. (Level III evidence)

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Multiple-Choice Questions

QUESTION 1. Perturbation training is a specialized neuromuscular training program that incorporates the use of which of the following conditions?

A. Roller board and a platform
B. Rocker board
C. Roller board
D. All of the above

QUESTION 2. Athletes can progress to Phase III when:

A. They are 6 weeks from the initial injury
B. They meet the clinical milestones outlined
C. They have 85% strength and hop performance on the involved limb compared to the uninvolved limb
D. They have full knee extension and flexion range of motion

QUESTION 3. Athletes should consider operative management if:

A. They have any giving way episode with pain and swelling during or after the completion of Phase II
B. They are unable to return to preferred level of activity
C. Both A and B
D. Neither A nor B

QUESTION 4. Using the modified stroke technique, when a small amount of fluid moves into the medial sulcus after a lateral stroke, this is graded as:

A. 2+ effusion
B. 1+ effusion
C. Trace effusion
D. No effusion

QUESTION 5. A subject can be classified as a potential coper if:

A. ≤ 1 episode of giving way and ≥ 60% global rating score
B. ≥ 80% timed hop score and KOS-ADLS score
C. All of the above
D. None of the above

Answer Key

QUESTION 1. Correct answer: **D** (see Phase II)

QUESTION 2. Correct answer: **B** (see Phase II)

QUESTION 3. Correct answer: **C** (see Phase III)

QUESTION 4. Correct answer: **C** (see Phase I)

QUESTION 5. Correct answer: **C** (see Phase I)

POSTOPERATIVE REHABILITATION AFTER BONE-PATELLAR TENDON-BONE ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION (AUTOGRAFT AND ALLOGRAFT)

Donna Williams, PT, MHS, Mark Allen Jordan, MD, and Geoffrey S. Van Thiel, MD, MBA

Indications for Surgical Treatment

Although there are no absolute criteria for delineating candidates for nonoperative management versus surgical reconstruction, the following are general indications for ACL reconstruction:

- High demand and high risk lifestyles (athletes)
- Concomitant injuries to other ligaments and/or menisci
- Generalized ligamentous laxity
- Repeated episodes of giving way despite rehabilitation
- Recurrent instability with activities of daily living

Brief Summary of Surgical Treatment

Major Surgical Steps

- Physical exam under general anesthesia with the patient in the supine position
  - Lachman and pivot shift tests
- Harvest and preparation of autograft from middle-third of patellar tendon/thawing of allograft
- Diagnostic and therapeutic arthroscopy for concomitant pathology (meniscectomy, debridement, etc.)
- Debridement of remnant ACL down to tibial stump
- Tibial tunnel creation
- Femoral tunnel creation
- Graft passage through tibial and femoral tunnels
- Fixation of the ACL graft in femoral tunnel
- Fixation of ACL graft in tibial tunnel
- Wound closure

Factors that may Affect Rehabilitation

Anesthetic

- Femoral nerve block usually provides excellent pain relief for the first 8 to 24 hours postoperatively. After wearing off, however, other methods will likely need to be employed including nonsteroidal antiinflammatories and cryotherapy.
- Patients using cryotherapy postoperatively have been demonstrated to require less narcotic analgesics for pain control.

Surgical

- Surgical
  - Concomitant knee pathology:
    - Preoperatively or during diagnostic arthroscopy, concomitant pathology (tendinous injuries, cartilage lesions, meniscal, and ligamentous tears) are often identified. These may dictate alteration to the rehabilitative protocol, and thus make it important to identify, before rehabilitation, which other lesions are present or procedures were performed.
  - Bone-patellar tendon-bone (B-PT-B) autograft versus allograft:
    - Patellar tendon grafts can be obtained either from the patient's own knee (autograft) or from a cadaver source (allograft). A goal of rehabilitation is to gain quadriceps strength, because this has been demonstrated to decrease following ACL injury. Current literature suggests that this extensor weakness is caused by the ACL injury itself rather than surgery or graft choice; thus, progressive gains in quad strength should be a goal of rehabilitation regardless of graft choice.
    - Patients with autograft experience graft site morbidity which may need to be addressed including patellar tendonitis and patellofemoral syndrome.
    - As patients with allograft tend to experience less postoperative pain, they may be prone to putting early excess stress on their grafts. In addition, allografts have been demonstrated to take longer to incorporate caused by their foreign origin. Thus, some authorities suggest using less aggressive rehabilitative programs for those with allografts, although this is not a consensus opinion.
    - Because allografts are foreign tissue, there is an increased (albeit rare) incidence of prolonged sterile inflammation.
  - Graft type and graft fixation
    - Bone-patellar tendon-bone autograft is considered the gold standard of ACL reconstruction caused by its demonstrated track record of strength; however, occasional anterior knee pain is considered its major drawback.
    - Bone to bone healing takes approximately 8 weeks to complete in the majority of cases, whereas soft tissue to bone healing takes approximately 12 weeks.

Before Surgery: Overview of Goals, Milestones, and Guidelines[1]

Goals

Patients with an ACL injury initially present with a swollen, painful knee. While patient's comfort is an issue in its own right, this acute inflammation can also lead to postoperative arthrofibrosis if surgery is undertaken before return of normal range of motion. As such, preoperative management aims to decrease pain and swelling, increase strength, increase range of motion back to preinjury level, and to begin early therapy training. These parameters should be the factors by which a patient is judged ready for surgery, rather than setting absolute time limits from the injury. The following are tools in achieving these goals:

- Management of swelling
  - Cryo/compression devices: there are multiple commercially available devices useful in both the pre- and postoperative period. These devices have been demonstrated to be superior to icepacks in analgesia most likely caused by their compression effect and the ability to use during ambulation
  - Regardless of the method, the knee should be iced, compressed, and elevated at least 3 to 4 times per day until swelling is eliminated.
- Restoration of normal knee range of motion (symmetry with contralateral knee)
  - Patients are restricted from competitive sports, but full weightbearing and range of motion are encouraged, and normal daily activities can be completed as tolerated.
  - The affected leg should be placed with a small roll under the ankle with nothing underneath the knee to encourage full extension.
  - The following exercises may be used both pre- and postoperatively:
    - Towel stretches (for extension): a towel looped around the midfoot is used to extend the knee and lift the heel, while the opposite hand holds the thigh down

    An advancement of this exercise is contract the quadriceps while releasing the towel to hold the heel off the ground.
    - Wall and heel slides (for flexion): laying supine with the affected leg's foot against a wall, the foot is slid into flexion with assistance from the opposite leg as needed
    - Quad sets and straight leg raises
  - The stationary bike and elliptical machine are good choices for maintaining physical activity

GUIDING PRINCIPLES OF POSTOPERATIVE REHABILITATION

- Early emphasis on obtaining full passive extension, progress knee flexion, and patellar mobility
- Early initiation of quadriceps and hamstring activity
- Control of swelling and pain to reduce muscle atrophy and inhibition
- Restoring neuromuscular control and proprioception
- Stepped progression based on achievement of specific therapeutic goals
- Functional testing and sport-specific training before return to play

[1] *Prehabilitation, if appropriate, is described in the Nonoperative Rehabilitation section of this chapter.*

Phase I: Immediate Postoperative Period (days 0 to 28)

Clinical Pearls

A frequent complication encountered following ACL reconstruction is the loss of full knee extension (extension lag), sometimes leading to a flexion contracture. Loss of extension often causes additional joint contact stresses, difficulty with quadriceps activation, and excessive muscular fatigue. During the first week postoperatively, a drop lock brace locked in extension during ambulation and sleeping can help prevent loss of extension.

Goals

- Protecting the graft
- Reducing joint swelling and pain
- Restoring patellar mobility and normal passive knee extension
- Progressively improving knee flexion
- Reestablishing voluntary quadriceps control
- Progressing towards independent ambulation

Protection

- Weight bearing as tolerated
- For the first week postoperatively, a drop lock knee extension brace is locked in full extension for ambulation and sleeping
- During weeks 1 to 4 (after the first postoperative visit), the brace is unlocked for ambulation and locked in extension for sleep
- If a concomitant meniscus repair/transplantation or articular cartilage procedure was performed, weight bearing parameters will be altered during this period

Management of Pain and Swelling

Treatment for pain/analgesia

- Pain causes reflex inhibition of muscle activity and can inhibit completion of strength and range of motion exercises.
- In additional to narcotic and/or antiinflammatory oral analgesics, cryotherapy and compression can be helpful in alleviating pain.
- Cryotherapy can be accomplished in a variety of ways including ice packs, ice baths, and continuous-flow cooling devices. A cryotherapy apparatus, consisting of a cooling apparatus and a wrap, can be useful during this period

Decrease swelling

- Swelling must be aggressively managed in the postoperative period as effusion can cause muscle inhibition.
- Cryotherapy and joint compression with a knee sleeve, ace wrap, or compression device are the most frequently used modalities.
- Cryotherapy can be done for 20 minutes hourly with the leg elevated.
- Muscle activities, such as quad sets and ankle pumps (active dorsi/plantar-flexion of ankle), can help reduce swelling by increasing venous return.

Techniques for Progressive Increase in Range of Motion

- As tolerated
- Early passive range of motion can be augmented by use of a continuous passive motion machine.
- In general, the patient should achieve full passive extension soon after surgery. This is facilitated by bracing in extension during ambulation and sleeping.

TIMELINE 32-2: **Postoperative Rehabilitation After Bone-Patellar Tendon-Bone ACL Reconstruction (Autograft and Allograft)**

PHASE I (weeks 1 to 4)	PHASE II (weeks 4 to 6)
• Knee extension brace locked in full extension for ambulation and sleeping • Crutches for comfort, WBAT • ROM: full passive knee extension and flexion as tolerated (goal of 90°) • Patellar mobilization • Ankle pumps, SLR, quad/ham sets, gastroc-soleus stretches in a nonweightbearing position • *After week 1, unlock brace for ambulation and remove for sleeping	• Gradually discontinue brace and crutches (brace off when no extension lag) • Continue self-performed ROM exercises 4 to 5 times daily • Overpressure into full knee extension • AROM from 0° to 115° flexion by the end of the phase • Continue patellar mobility • Bicycle, SLR • Isometric quad and hamstring sets • Begin closed chain extension (partial ROM squat, leg press, etc.) • Front and side lunges • Lateral step ups • Front step ups • Hamstring curls • Calf raises • Begin balance training (bilateral stance on tilt board and medicine ball throws) • Perturbation training

- Patellar mobilizations
  - Pushing up on the patella, hold the patella superiorly for 5 seconds for 10 repetitions. Repeat for the inferior, medial, and lateral positions.
- Initiate scar mobilizations as needed.

Other Therapeutic Exercises

- Heel slides (see Before Surgery section)
- Quadriceps/hamstring sets
  - Quad sets: Sitting on the floor with affected leg in front of body, tighten quadriceps by pressing the posterior knee flat to the floor. Hold for 10 seconds, and repeat. Neuromuscular electrical stimulation can be used to facilitate the quad contraction.
  - Hamstring sets: Laying on back with knees partially flexed and heels resting against the ground, press heels against the ground and isometrically contract hamstrings (no sliding). Hold for 10 seconds, and repeat
- Gastrocnemius/soleus stretching in a nonweightbearing position
  - Sitting with affected leg out in front of body, wrap a towel around ball of foot and pull back and hold until moderate tension is achieved in calf.
- Straight leg raise in flexion, extension, abduction, and adduction with brace in full extension until quad strength prevents extension lag (Figure 32-8)
- Prone hangs: Lie prone with legs hanging with the edge of the table at the thighs
- Gait training emphasizing full extension and quad activation
- Stationary bike, half to full revolutions without resistance to facilitate flexion

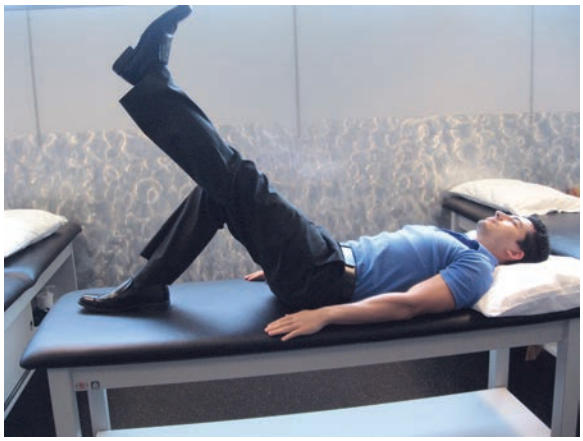

FIGURE 32-8. Straight leg raise (flexion, extension, abduction, and adduction).

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Quad and hamstring sets
- Straight leg raise with brace in full extension until quad strength prevents extension lag (hip flexion, abduction, adduction, extension)

Milestones for Progression to the Next Phase

- Adequate wound healing
- Straight leg raise with or without extension lag
- Ability to put weight on affected limb
- Minimal knee swelling
- Good patellar mobility

TIMELINE 32-2: Postoperative Rehabilitation After Bone-Patellar Tendon-Bone ACL Reconstruction (Autograft and Allograft) (Continued)

PHASE III (week 6 to 4 months)	PHASE IV (months 4 to 6)	PHASE V (months 6+)
• No brace or crutches (gait should become normal without assistance) • PT modalities as needed • PROM-full, continue self-performed ROM exercises 4 to 5 times daily • Bicycle, stair stepper, NordicTrack, straight ahead running • Resisted SLR • Advance close chain exercises (leg press, squat, etc.) • Hamstring curl with band • Progress isometric strength program • Unilateral balance training on tilt board and with medicine ball throws • Lunge exercises • Wall squats, vertical squats, calf raises • Perturbation training • Biodex Stability System	• PT modalities as needed • Consider a functional brace in certain patient populations • PROM-full • Continue ROM exercises 4 to 5 times daily • Patient should have quiet knee (minimal to no swelling or pain) • SLR, hamstring curls and variations, leg press, squats, lunges • Continue and progress endurance work • Progress isometric strengthening programs • Perturbation training on a single leg • Continue balance training with medicine ball and tilt board • Continue Biodex Stability System • Initiate plyometric leg press and jumping exercises (observe and correct landing) • Initiate sport-specific exercises (cone drills, side shuffles, cariocas, cutting) • Backward/forward running	• PROM-maintain full motion • Gradual return to unrestricted sport • SLR, hamstring curls and variations, single-leg squats, lunges, and leg press • Continue and advance endurance training (consider interval training) • Increase cutting maneuvers • Progress isometric strengthening programs • Perturbation training on a single leg • Biodex Stability System • Progress plyometric leg press and sport-specific plyometric drills • Continue sport-specific exercises (sudden start/stops, cone drills, agility drills) • Sport-specific skill training (e.g., coming out of 3-point stance for football lineman) • After return to sport, encourage maintenance program for strength/endurance

Phase II (weeks 4 to 6)

Clinical Pearls

To facilitate discontinuation of crutches, it is useful to have the patient use a single crutch for 3 or 4 days to ease the transition.

Goals

- Maintain range of motion (particularly full passive knee extension) and patellar mobility established in previous phase
- Progressively increase knee flexion
- Discontinuation of brace once patient can perform straight leg raise without extension lag
- Discontinuation of crutches
- Initiate muscle strength, proprioception, and balance training

Protection

- During this phase, patient should progress to ambulation without brace or crutch use
- The brace should be discontinued once patient can perform a straight leg raise without extension lag
- The graft is at its weakest point from weeks 4 to 8

Management of Pain and Swelling

Treatment for pain/analgesia
- In addition to oral analgesics and cryotherapy, electrical stimulation and transcutaneous electrical neuromuscular stimulation (TENS) devices may be useful

Decrease swelling
- Cryotherapy and joint compression with a knee sleeve or ace wrap are the most frequently used modalities
- For cryotherapy the patient can ice for 20 minutes hourly and elevate the lower extremity

Techniques for Progressive Increase in Range of Motion

- Maintain full extension gained during previous phase
- Self-performed range of motion exercises should be done 4 to 5 times per day
- Continue to increase active and passive flexion, with a rough goal being 115° of flexion by the end of this phase
- Continue patellar mobility
- Perform scar mobility work as needed

Other Therapeutic Exercises

- Continue heel slides, quad and hamstring sets, and straight leg raises as in Phase I
- Progress to weightbearing gastrocnemius/soleus stretch (with towel)
- Begin standing heel raises (knees in extension)
- Begin closed chain extension exercises (see below)
- Begin balance and proprioception exercises (see below)
- Hamstring curls (begin with standing and no resistance)
- Stationary bike

Clinical Pearls

Closed chain extension exercises, such as partial squats, which cocontract the hamstrings along with the quadriceps while compressing the knee joint, place less strain on the ACL than open chain extension exercises (e.g., leg extension machine). Open chain flexion exercises (e.g., hamstring curls) put comparatively less strain on the ACL as well. With patellar tendon grafts, closed chain extension exercises and open chain flexion exercises are both appropriate and useful during this period. Due to applying a significant shearing force on the ACL, open chain extension exercises (leg extensions) are not used early in most protocols.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Isometric quadriceps and hamstring sets
- Straight leg raises
- Leg press and squats (partial range of motion)
- Hamstring curls (standing)
- Calf raises (in extension and with knees at 90°)

Sensorimotor Exercises

- Begin balance training with bilateral stance on a tilt board and medicine ball throws
- Single-leg balance with emphasis on full extension

Open and Closed Kinetic Chain Exercises

- Partial squats
- Leg press (Figure 32-9)
- Weight shifts
- Front and side lunges
- Lateral step-ups
- Front step-ups
- Standing terminal knee extensions with resistance

Techniques to Increase Muscle Strength, Power, and Endurance

Stationary bicycle for endurance

Neuromuscular Dynamic Stability Exercises

- Begin perturbation training
  - Roller-board translations
  - Tilt board perturbation
  - Roller board and stationary platform perturbation

Milestones for Progression to the Next Phase

- Active range of motion from 0° to 115° for knee flexion
- Discontinuation of brace along and full active extension without lag
- Single stance on affected leg with upper extremity assist
- Lack of knee effusion

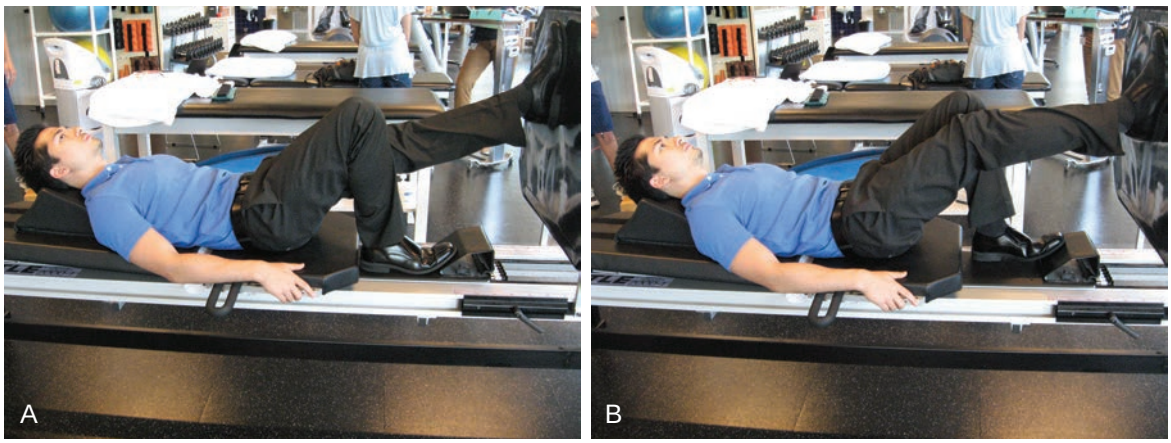

FIGURE 32-9. A, B, Leg press.

Phase III (week 6 to 4 months)

Clinical Pearls

At weeks 4 to 8, the graft is at its weakest point of the postoperative period. Accordingly, high-graft stress activities, such as jumping, squatting below 60°, pivoting, and cutting should be avoided. Scar tissue also sometimes becomes an issue at this point and may necessitate soft tissue mobilizations.

Goals

- Continue to increase strength, proprioception, balance, and neuromuscular control
- Gain full pain-free range of motion equal to nonsurgical knee
- Achieve normal gait without assistance device
- Improve endurance
- Improve limb confidence

Protection

- The graft is at its weakest point during the postoperative period from weeks 4 to 8
- Early in Phase III, avoid activities that place high stress on the graft (see Clinical Pearls above)
- Conditioning activities which avoid shifting and pivoting
  - Stair stepper/NordicTrack, and straight ahead running may be started at week 12

Management of Pain and Swelling

Treatment for pain/analgesia
- Narcotic analgesics should be discontinued by the start of week 4 and thus should be avoided in Phase III if possible.
- Cryotherapy, electrical stimulation, and transcutaneous electrical neuromuscular stimulation (TENS) devices may be continued, but pain should become minimal to nonexistent during this phase

Decrease swelling
- Continue the joint compression with a knee sleeve or ace wrap as needed
- Ice the knee for 20 minutes hourly and elevate lower extremity as needed
- Joint sleeve may be discontinued when swelling is no longer an issue, but some feel psychologically more comfortable with the sleeve

Techniques for Progressive Increase in Range of Motion

- Continue range of motion exercises 4 to 5 times per day focusing on maintaining full extension and increasing flexion. During this phase, flexion should become equal to unaffected leg.

Other Therapeutic Exercises

- Continue and progress on flexibility and isometric strength work
- Continue stationary bicycle
- Stair stepper/NordicTrack starting at week 12
- Straight ahead running starting at week 12
- Advance closed chain exercises (see below)
- Advance hamstring curls (add band resistance)
- Advance balance/proprioceptive training (see below)

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Advancement of isometric strength program (quad sets, hamstring sets, straight leg raises, etc.)
- Advance hamstring exercises
  - Hamstring curls with band resistance
  - Swiss ball hamstring curls (Figure 32-10)
- Advance close chain strengthening (see below)

Sensorimotor Exercises

- Balance training on a tilt board (bilateral to unilateral, eyes open/closed)
- Balance training with medicine ball throws

Open and Closed Kinetic Chain Exercises

- Lateral lunge step-overs
- Front and side lunges

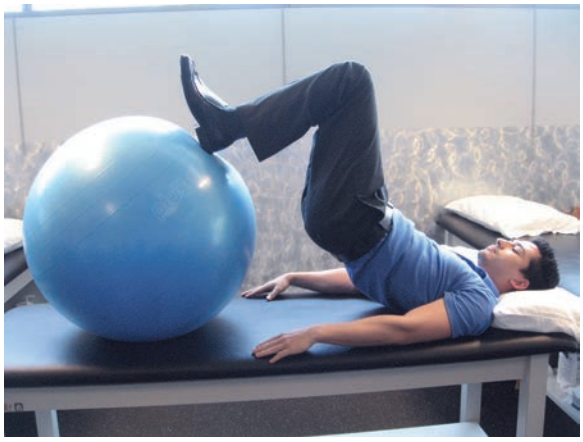

FIGURE 32-10. Chair walk. Sitting in a rolling desk chair with the unaffected foot off the ground, reach the foot of the injured forward and flex at knee to move the chair forward.

- Lateral step-downs
- Front step-downs
- Wall squats
- Vertical squats
- Calf raises
- Stair stepper machine
- Lateral side stepping

Techniques to Increase Muscle Strength, Power, and Endurance

- Stair stepper/NordicTrack
- Stationary bicycle
- Walking program
- Straight ahead running

Neuromuscular Dynamic Stability Exercises

- Biodex Stability system
- Perturbation training
  - Roller-board translations
  - Tilt-board perturbation
  - Roller board and stationary platform perturbation

Milestones for Progression to the Next Phase

- Active range of motion equal in both knees
- No joint effusion
- Normal gait without assistance
- Single-leg stance without assistance
- Understanding of precautions with regard to state of graft healing

Phase IV (4 to 6 months)

Clinical Pearls

This phase sometimes presents an issue with athletes being overly eager to resume sport-specific training. Many patients need to be reminded that as with Phases I and III, progression is necessary and commitment to the process and protocol is key.

Goals

- Return leg strength to normal
- Improve muscular power and endurance
- Enhance neuromuscular control
- Gradual incorporation of higher stress movements, such as cutting and pivoting
- Initiate plyometric program and sport-specific drills

Protection

- Most patients do not require crutches or a brace by this point
- Some patients, such as downhill skiers or football lineman, may benefit from functional bracing to decrease the chance of injury recurrence

Management of Pain and Swelling

Treatment for pain/analgesia
- Patient should have a quiet knee by this point (minimal to no pain and minimal swelling with activity)
- Narcotic analgesics should not be necessary at this point in time
- Cryotherapy, electrical stimulation, and transcutaneous electrical neuromuscular stimulation (TENS) devices can be used when necessary

Decrease swelling
- If swelling is still an issue, joint compression with a knee sleeve or ace wrap is useful.
- Ice for 20 minutes hourly and elevate lower extremity as needed.

Clinical Pearls

Patients with patellar tendon autografts are more prone to patellofemoral syndrome or patellar tendonitis than those with allografts or soft-tissue grafts. Dynamic exercises, such as plyometric work, put increasing stress on the patellar tendon, and anterior knee pain may become an issue during this phase. An infrapatellar strap, patellar taping, or patellofemoral brace may be of use, and programming may need to be adjusted.

Techniques for Progressive Increase in Range of Motion

- Self-performed range of motion stretching exercises should still be performed 4 to 5 times daily with an emphasis on maintaining the full passive extension and flexion that has been gained.

Other Therapeutic Exercises

- Continue to progress on flexibility and isometric strength work
- Stair stepper, NordicTrack, straight ahead running, or stationary bicycle to continue increasing endurance
- Advance closed chain exercises (see below)
- Advance hamstring exercises
- Advance balance/proprioceptive training (see below)

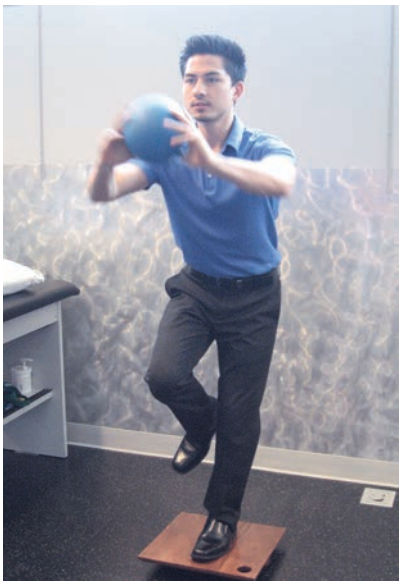

FIGURE 32-11. Single-leg balance training with medicine ball throws. This medicine ball exercise is performed while balancing on a tilt board with one leg.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Progress isometric strengthening program (quad and hamstring sets, straight leg raises, etc.)
- Hamstring curls and advanced hamstring exercises
- Continued progression of closed chain extension exercises (bilateral to unilateral, increasing resistance, increasing range of motion, etc.)

Sensorimotor Exercises

- Continue balance training on a tilt board and with medicine ball throws (Figure 32-11)
- Another advanced balance exercise is to have patient do a single-leg stance while reaching to cones on the floor or pulling a band laterally
- Progress unilateral perturbation training (Figure 32-12)

Open and Closed Kinetic Chain Exercises

- Lateral lunge step-overs
- Front and side lunges
- Lateral step-downs
- Front step-downs
- Wall squats
- Vertical squats
- Toe calf raises
- Stair stepper machine

Techniques to Increase Muscle Strength, Power, and Endurance

- Stair stepper/NordicTrack (Logan, UT)
- Bicycle
- Walking program
- Straight-line running

Neuromuscular Dynamic Stability Exercises

- Biodex stability system (Shirley, NY)
- Balance training on a tilt board and medicine ball throws (see Sensorimotor Exercises)
- Perturbation training

Plyometrics

- Initiate plyometric leg press and plyometric jumping exercises (Figure 32-13)
- Correct form as needed

Clinical Pearls

It is particularly important to observe landing mechanics during jumping exercises to reduce risk of recurrent injury. Things to watch for and correct include the following:

- Landing with low flexion angles (knee in too much extension)
- Landing with genu varum/valgum (watch for dynamic valgus)
- Landing and jumping with uninvolved limb dominating the effort

Functional Exercises

- Lunges with sport cord (Figure 32-14)
- Forward and backward running
- Jogging in place with sport cord
  - Can advance by pulling from various directions
- Pool running (backwards and forwards)

Sport-Specific Exercises

- Cone drills
- Side shuffles
- Grapevine drill
- Cariocas

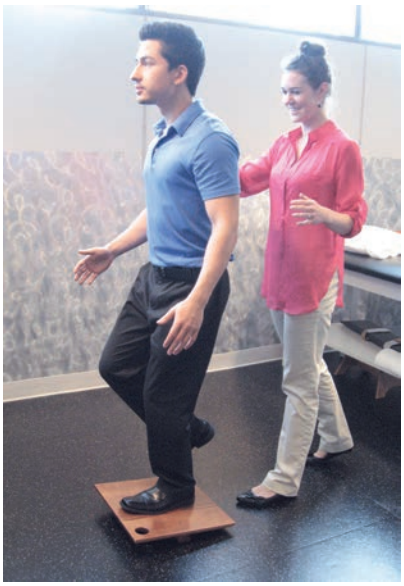

FIGURE 32-12. A–C, Single-leg perturbation training using a tilt board.

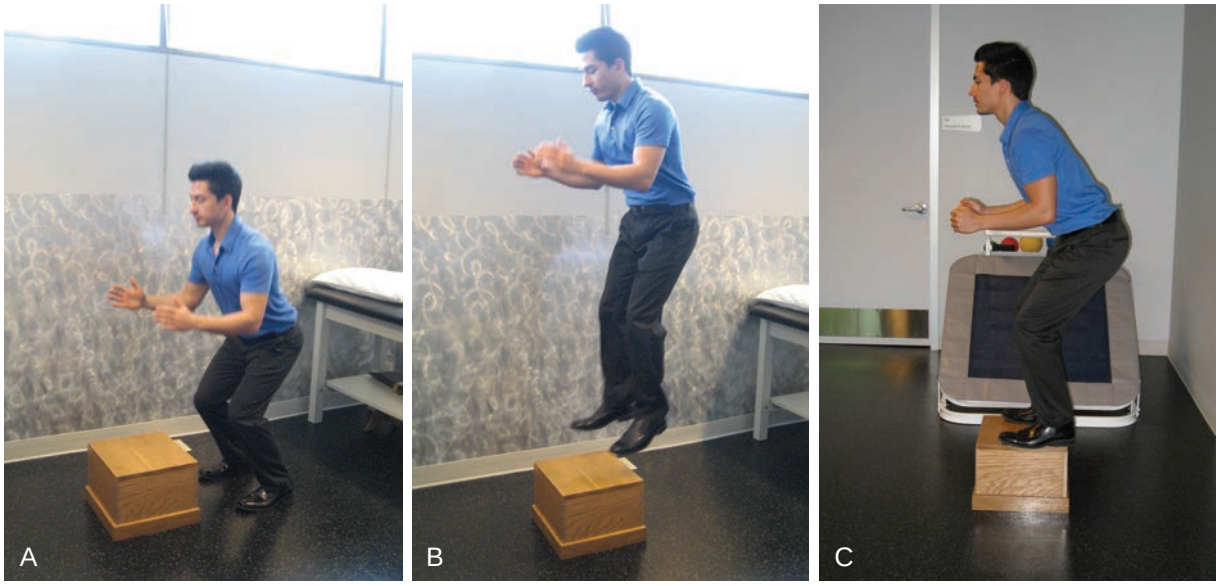

FIGURE 32-13. Plyometric jumping exercises.

- Sudden start/stops
- 45° cutting maneuvers
- 90° cutting maneuvers
- Combinations of agility drills
- Progress to sport-specific plyometric training drills
  - Hop variations, skipping and bounding variations, return to throwing program in overhead throwers, etc.

Milestones for Progression to the Next Phase

- Full range of motion
- Quiet knee (pain and effusion free)

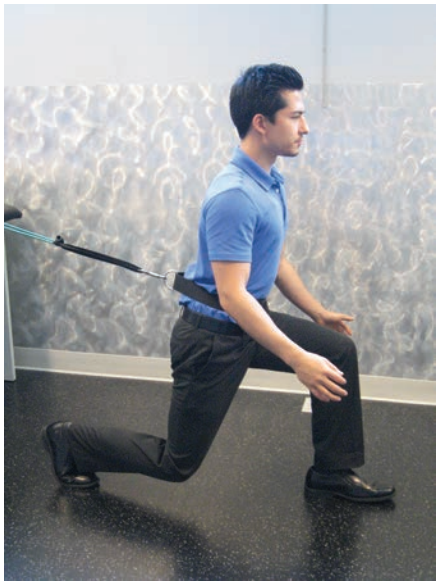

FIGURE 32-14. Lunges with sport cord.

- Quadriceps strength 80% or greater than opposite extremity
- Hamstring strength 110% or greater than opposite extremity
- Quadriceps torque/body weight ratio 55% or greater
- Hamstrings/quadriceps ratio 70% or greater
- Proprioceptive test equivalent to contralateral leg
- Return-to-sport testing/functional testing 85% or greater to contralateral leg

Phase V (months 6+)

Clinical Pearls

The overriding goal of Phase V is to return the patient back to their preinjury level of play, and building confidence in the reconstructed knee is a major factor in accomplishing this. Progressively increasing the difficulty level and applied loads in exercises and drills will help the patient achieve this. The workhorse exercises of this phase include single leg squats and lunges in addition to sport-specific drills.

Goals

- Gradual return to unrestricted sports
- Maximizing leg strength and endurance
- Normalizing neuromuscular control
- Progressing skill training
- Continuing to build limb confidence

Protection

- No more rehabilitative brace or crutches, although some patients may be using a functional brace at this point (e.g., football lineman, downhill skiers)

Management of Pain and Swelling

Treatment for pain/analgesia
- Pain should be minimal to absent at this point
- Cryotherapy, electrical stimulation, and transcutaneous electrical neuromuscular stimulation (TENS) devices can be used when necessary
- Narcotic pain medication should not be necessary at this point

Decrease swelling
- Joint compression with a knee sleeve or ace wrap are the most frequently used modalities
- Knee sleeve can be discontinued but some patients psychologically feel more comfortable when wearing it
- Ice for 20 minutes hourly and elevate lower extremity

Techniques for Progressive Increase in Range of Motion

- Self-performed range of motion stretching exercises should still be performed 4 to 5 times daily with an emphasis on maintaining the full passive extension and flexion that has been gained

Other Therapeutic Exercises

- Continue to progress on flexibility and isometric strength work
- Stair stepper, NordicTrack, straight ahead running, or stationary bicycle to continue increasing endurance
- Progression on closed chain exercises (see below)
- Progression on hamstring exercises
- Continue balance/proprioceptive training (see below)

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Hamstring curls and advanced hamstring exercises
- Leg press and squats
- Progress isometric strengthening program

Sensorimotor Exercises

- Continue balance training on a tilt board
- Continue balance training with medicine ball throws
- Continue perturbation training on single leg

Open and Closed Kinetic Chain Exercises

- Lateral lunge step-overs
- Front and side lunges
- Lateral step-downs
- Front step-downs
- Wall squats
- Vertical squats
- Toe calf raises
- Stair stepper machine

Techniques to Increase Muscle Strength, Power, and Endurance

- Stair stepper/NordicTrack
- Bicycle
- Walking program
- Straight-line running
- Advanced sport-specific endurance exercises (e.g., interval training)

Neuromuscular Dynamic Stability Exercises

- Biodex stability system
- Balance training on a tilt board
- Balance training with medicine ball throws
- Perturbation training

Plyometrics

- Can progress plyometric leg presses
- Continue other plyometric training drills

Functional Exercises

- Lunges with sport cord
- Forward and backward running
- Jogging in place with sport cord
  - Can advance by pulling from various directions
- Pool running (backward and forward)

Sport-Specific Exercises

- Cone drills
- Side shuffles
- Cariocas
- Sudden start/stop
- 45° cutting maneuvers
- 90° cutting maneuvers
- Combinations of agility drills
- Continue other plyometric training drills
- Sport- and position-specific skill training (e.g., coming out of a 3-point stance for football lineman, changing direction from backpedal to sprint, lateral mobility drills for linebackers, etc.).

After Return to Sport

Continuing Fitness or Rehabilitation Exercises

- Athletes are encouraged to continue strength and agility exercises on their own to preserve strength, functional, and proprioceptive gains
- Female athletes may benefit from using an ACL prevention program for warmup before practice/games versus a traditional warmup. Compared to a traditional warm-up, these 15-minute programs emphasize posterior chain strength and proper plyometric landing mechanics.

Exercises and Other Techniques for Prevention of Recurrent Injury

- Lateral box jumps
- Single leg hurdles
- Single leg lunges and squats

Evidence

Krych AJ, Jackson JD, Hoskin TL, et al: A metaanalysis of patellar tendon autograft versus patellar tendon allograft in anterior cruciate ligament reconstruction. *Arthroscopy* 24:292–298, 2008.

This metaanalysis of 6 nonrandomized cohort studies compared the outcomes of 256 patients with patellar tendon autograft versus 278 patients with patellar tendon allograft. Overall, allografts had a higher rate of rupture (OR, 5.66;

p < .01) and allograft patients were more likely to have a hop test less than 90% of the nonoperative side (OR, 5.66; p < .01). When irradiated and chemically treated allografts were excluded from analysis, however, there were no significant differences in graft rupture, rate of reoperation, IKDC scores, Lachman exam, pivot shift exam, patellar crepitus, hop test, or return to sport. (Level III evidence)

Melegati G, Tornese D, Bandi M, et al: The role of the rehabilitation brace in restoring knee extension after anterior cruciate ligament reconstruction: A prospective controlled study. *Knee Surg Sports Traumatol Arthrosc* 11:322–326, 2003.

This randomized controlled trial compared 18 patients braced in extension for 1 week postoperatively (Group B) versus 18 patients braced from 0° to 90° (Group A). The braces were unlocked twice daily for physical therapy in the first week, unlocked at the beginning of week 2, and removed at the beginning of week 3. All participants followed the same accelerated rehabilitation protocol. Both groups had similar preoperative bubble-level heel height difference (HHD) measurements, and HHD measurements at 4 and 8 weeks showed significantly greater extension in the extension braced group (2.2 cm in Group A vs. 0.6 cm in Group B at week 4, 1.6 cm in Group A vs. 0.1 cm in Group B at week 8). There were no differences in KT-arthrometry at 4 months.

Risberg MA, Holm I, Myklebust G, et al: Neuromuscular training versus strength training during first 6 months after anterior cruciate ligament reconstruction: A randomized clinical trial. *Phys Ther* 87:737–750, 2007.

This randomized controlled trial compared the effect of 6 months of neuromuscular training (NT) to a traditional strength training program (ST) following ACL reconstruction in 74 patients. Both groups were evaulated preoperatively and at 3 and 6 months postoperatively. At the 6-month follow-up, the NT group had significantly improved Cincinnati knee scores and VAS scores for global knee function compared to the ST group. There were no significant differences for hop, balance, proprioception, and muscle strength tests. (Level I evidence)

Shelbourne KD, Gray T: Minimum 10-year results after anterior cruciate ligament reconstruction: How the loss of normal knee motion compounds other factors related to the development of osteoarthritis after surgery. *Am J Sports Med* 37:471–480, 2009.

This prospective cohort study evaluated the long-term subjective outcome after ACL reconstruction in 502 patients at a mean follow-up of 14.1 years. Regression analysis was then used to determine which factors affected subjective scores. The most statistically significant factor leading to a lower IKDC score was lack of normal extension, followed by loss of flexion. Normal knee motion was defined as within 2° of extension (including hyperextension) and 5° of flexion of the nonoperative knee. Patients with meniscectomy or articular cartilage procedures had statistically significantly lower subjective scores only if they also had less than normal range of motion. A total of 98% of patients with intact cartilage, normal knee motion, and intact menisci had normal radiographs; 29% of patients with normal range of motion had abnormal radiographs versus 71% with abnormal motion. IKDC score was normal in 48%, nearly normal in 42%, abnormal in 9%, and severely normal in 0.5%. The authors concluded that a loss of extension of 3° to 5° (including hyperextension) after ACL reconstruction adversely affected long-term subjective and objective outcomes, especially with concurrent meniscectomy or articular cartilage damage. (Level III evidence)

Yoo JH, Lim BO, Ha M, et al: A meta-analysis of the effect of neuromuscular training on the prevention of the anterior cruciate ligament injury in female athletes. *Knee Surg Sports Traumatol Arthrosc* 18:824–830, 2010.

This metaanalysis aimed to evaluate the effectiveness of neuromuscular training in preventing ACL injuries in female athletes, and to identify essential programming factors by subgroup analysis. Seven randomized controlled trials or prospective cohort studies were included in the analysis. Overall, the effect of a preventative training program in preventing ACL injury was found to be significant (OR 0.4, 95% CI 0.27–0.6). Age under 18, soccer (rather than handball), pre- and in-season preventative training (vs. pre- or in-season), and plyometrics and strengthening exercises (vs. balance exercises) were found to be significantly associated with program effectiveness. Metaanalysis showed that pre- and in-season neuromuscular training with an emphasis on plyometrics and strengthening was effective in preventing ACL injury in female athletes, especially in those under age 18.

References

1. Brotzman SB: Knee injuries. In Kay D, editor: *Clinical orthopaedic rehabilitation: An evidence-based approach*, ed 3, St. Louis, Missouri, Mosby, 2011.
2. Wheeless CR: Bone-patellar-bone ACL reconstruction. In Nunley JA, Urbaniak JA, editors: *Wheeless' textbook of orthopaedics*, Baltimore, Maryland, Data Trace Publishing Company, LLC, 2012.

Multiple-Choice Questions

QUESTION 1. At which milestone can bracing be discontinued?

A. At a predetermined time point (week 5)
B. After week 4 and when there is no longer an extension lag during SLR
C. When pain and swelling has become minimal
D. When there is 90° of passive flexion

QUESTION 2. Which of the following exercises should not be performed by week 5?

A. Partial ROM squats
B. Partial ROM leg presses
C. Hamstring curls
D. Quadriceps extensions

QUESTION 3. At which point should use of a functional brace be considered?

A. When starting closed chain extension exercises
B. At the onset of cutting and plyometric work
C. As soon as the extension brace is discontinued
D. After return to sports practice

Answer Key

QUESTION 1. Correct answer: **B** (see Phase II)

QUESTION 2. Correct answer: **D** (see Phase II)

QUESTION 3. Correct answer: **B** (see Phase IV)

BEYOND BASIC REHABILITATION: RETURN TO SKIING AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

Nicole A. Strick, MPT, and Timothy S. Mologne, MD

Introduction

ASPECTS OF SKIING THAT REQUIRE SPECIAL ATTENTION IN REHABILITATION

- Knee injuries are some of the most common injuries reported with downhill skiing, with ACL tears accounting for up to 28% of injuries in competitive alpine skiers.[1]
- Safe skiing requires adequate quadriceps strength and endurance, and most ski-related knee injuries occur in the late morning or late afternoon when thigh muscle fatigue is common.
- Safe and effective skiing also requires a stable knee to cut and carve the skis through the snow. Skiing with an unstable knee can predispose one to further injury to the menisci, other ligaments, and to the articular surfaces on the knee.
- Skiing is one of the sports that are associated with ACL tears, even in elite skiers.
- There are three main mechanisms of ACL injuries among professional skiers:
  - A slip-catch, in which the skier is turning and loses balance backward or inward. The outer ski pressure is lost, causing that ski to drift away from the body's center of mass. This knee then extends to regain balance but catches the snowy surface, forcing this straight knee into flexion, internal rotation, and valgus.
  - A dynamic snowplow, in which the skier loses his balance backward with most weight to one ski. The unweighted ski then drifts away from the body, creating a split position while the loaded ski rolls from the outside to the inner edge, catching the snow and forcing an internal rotation of the knee and/or a valgus force.
  - Landing from a jump with backward balance. In this situation, the skier will assume a deeply flexed knee position and may use a strong quadriceps contraction to recover. In the deeply flexed position, hamstring cocontraction is limited during the strong quadriceps pull, which can rupture the ACL. Also, as the skis accelerate forward in relation to the upper body, the stiff ski boot pulls the tibia forward, creating an anterior drawer strain on the ACL[2,3]
- In recreational skiers, an injury coined phantom foot syndrome may occur when a skier falls backward with an increasing load on the inner edge of the ski. The ski then turns uphill, creating a rotational hyperflexion injury.[2,3]

- Following an ACL reconstruction, patients require prolonged rehabilitation to regain adequate motion, strength, and proprioception.
- ACL tendon grafts undergo a ligamentization process, with the graft tissue changing mechanically and biologically for over a year following surgery.
- Clancy et al.[4] has shown that an ACL graft has degradation in strength during this process, with the graft ultimately achieving about 80% of its initial strength at one year following implantation.
- Competitive alpine skiing and racing includes downhill racing, slalom racing, and freestyle mogul and aerial skiing. The forces on the knee during these various skiing styles differ, and each can lead to forces that exceed the tensile strength of the ACL and/or ACL graft.
- As ACL injuries are common, and ACL graft ruptures are reported as high as 22% with competitive alpine skiers[5], patients need to understand and accept the increased risk of reinjury associated with an early return to skiing, particularly freestyle skiing.
- A study of gender differences among competitive alpine ski racers found the rate of re-injury to an ACL graft to be 27% in females and 13% in males.[5]

Literature

- There are no strict medical guidelines with regard to when a patient may return to sports after knee surgery. However, it is generally accepted that one should not begin any sport that places the operative knee at risk until that individual has regained at least 85% of the strength of their unaffected knee, has a stable knee, and does not experience pain or swelling with strenuous activities.[6]
- Extrapolating from Clancy's work[4], ACL grafts achieve about 80% of their initial strength at one year out from implantation.
- Adequate knee strength, proprioception, and patient confidence, along with adequate graft strength and revascularization/incorporation usually occur within 6 to 9 months after ACL reconstruction.
- Returning to skiing for advanced skiers can probably occur sooner than 6 months from surgery, as long as these skiers return to gentle runs on groomed slopes, avoid moguls and other more extreme conditions or techniques, and ski with shorter skis.

Phase I: Advanced Strength and Conditioning Programs

- The principles of progression, overload, and variation should be used to advance training throughout the rehabilitation phases.
- Begin with 3 sets of 10 repetitions for the best strength and power gains, increasing resistance to produce fatigue by the last several repetitions. Progress to 3 sets of 6 to 8 repetitions for advanced weight training when muscular hypertrophy is desired.
- Olympic lifts are recommended for elite athletes and not necessarily recreational competitors unless properly coached.

Phase II: Performance Enhancement Training Techniques

- Training with optimum posture is of the utmost importance. While skiing on a slope, posture should be with slight knee flexion, a neutral spine with forward bent posture at hips, and weight centered above the skis. Arms should be relaxed slightly in front of the body. The forward bent posture increases hamstring activity, a synergist of the ACL, and decreases the knee extension moment and quadriceps activity.[7] Neuromuscular training throughout an athlete's rehabilitation process must stress proper posture with strengthening, balance, plyometric jumping, functional training, sport-specific training, and speed and agility drills for proper muscle memory.
- The principles of progression, overload, variation, individualization, and specificity are all used.
- Repetitions, sets, rest intervals, intensity, training frequency, duration, and volume are based on the specific demand of the downhill event to which the athlete will return.

Phase III: Sport-Specific Training

Program Design/Performance Training Program

Flexibility/Joint Mobility for Joint Stability

- Dynamic warmup prior to activity may include lunge walk with trunk rotation, heel/toe walk, shuffles, cradle walk, backpedalling, skipping, inch worm, high knees, buttock kicks, and straight leg kick with opposite arm touch. Each dynamic exercise is performed for 15 yards. These should be done prior to a workout.
- Good flexibility of hamstrings, quadriceps, gastrocnemius, soleus, hip adductors, ITB, hip flexors and lower and upper trunk rotators is needed to respond to challenging terrain. Static stretches are done after the activity, 3 times for 30 seconds.

Sensorimotor and Balance Training

- Hold each balance challenge for at least 30 seconds times 3. Progress to the next level of difficulty once balance is no longer challenged. Perform daily.
- Move from a narrow base of support to single-leg stance
- Progress from level ground to uneven surfaces (mini trampoline, foam, BOSU, disc, wobble, and balance boards)
- Progress eyes open to eyes closed and use dynamic head, trunk, or upper extremity movement (PNF patterns, body blade movements)

Core Training

Many activities exist, but a few examples are listed below.

- Prone planks (progress from most to least stable: on forearms and knees to being on straight arms and tip toes; from static to dynamic: holding in place versus walking each arm or leg out, then back in or lifting the leg and arm while keeping chest and hips square to the floor). May begin holding for 20 seconds and work to 3 sets of 30 to 60 seconds.
- Side-lying planks (progress from most to least stable: on forearm and knees to being on straight arms/forearm and toes; from static to dynamic: holding in place versus performing a leg lift with the top leg). May begin holding for 20 seconds and work to 3 sets of 30 to 60 seconds. (Figure 32-15)
- Superman (back extension holds) on the ground or using an exercise ball to perform back extensions. May begin holding for 20 seconds and work to 3 sets of 30 to 60 seconds.
- Bicycle crunches (opposite shoulder to knee crunch leading with shoulder, not elbow). Work up to 3 sets of 30 seconds.

Cardiorespiratory/Functional Training

- Running, stationary biking, rollerblading, jump roping, elliptical machine (low resistance), stair machine (low resistance, low stroke), ski machines (begin with short stride, level, low resistance and progress); should use interval training to replicate the demands of skiing (periods of moderate to high level intensity followed by periods of lower intensity) for a duration of at least 20 to 30 minutes, 3 times per week.
- A short duration, straight jogging program may begin when the physician allows, usually around 13 to 16 weeks.



FIGURE 32-15. Side-lying plank with leg lift.

- Physician criteria and timeline vary on return to running. The Cincinnati Sports Medicine Accelerated ACL Rehabilitation Protocol allows ¼ mile straight jogging at weeks 9 to 12 with painless ROM 0° to 135°, at least 4/5 knee and hip manual muscle test, no effusion, no greater than 30% difference from involved to contralateral limb with isometric testing, mean average torque and quadriceps, and hamstrings deficits. There should be joint arthrometer testing of 3 mm or less, good patellar mobility and minimal to no knee crepitus. Progression of running weeks 13 through 26 depends on further criteria of isokinetic testing with goal of no greater than a 20% to 25% difference in torque at 300° per second, and in the percent difference of quadriceps and hamstrings, all tested monthly. At this time, the straight running program distance may be increased to a mile with progression of speed to full by week 26. Further progression at weeks 27 to 52 is based on additional criteria of no greater than 10% to 15% difference in torque at 180° per second and 300° per second, percent difference of quadriceps and hamstrings and isometric testing if a symptomatic patellofemoral joint exists. Functional tests, such as the one-legged distance hop or one-legged timed hop, must be at least 75% of the uninvolved leg at weeks 13 to 26, and 85% at weeks 27 to 52.[8]

Multiplanar Training Activities

- Recommend performing at least 3 days per week.
- Single leg stance star drill (Figure 32-16) (3 sets of 5 repetitions each leg)
- Figure eight runs and, circle runs with affected leg outside and inside (3 sets of 10 repetitions)
- Lateral/diagonal lunges with a medicine ball; onto a BOSU, disc, fitter (3 sets of 10 repetitions)



FIGURE 32-16. Star drill: single-leg stance, maintaining stance knee control while tapping heel or toe to the points of a star with athlete at the center of the star.

- Ski jumps: double or single leg side to side or diagonal jumps (begin 10 seconds times 3 and work up to 3 sets of 30 seconds)
- Diagonal sport cord lunges (3 sets of 10 repetitions), runs (3 times to fatigue)

Training for Optimum Muscle Functional Strength and Power

- Recommend 3 sets of 10 repetitions for the best strength and power gains, increasing resistance to produce fatigue by the last several repetitions. Strengthening

TIMELINE 32-3: **Return to Skiing After ACL Reconstruction**

Weeks 13 to 26 (3 to 6 months)

- Flexibility: hamstring, gastroc-soleus, quadriceps, ITB stretches
- Strengthening: PREs with patellofemoral precautions (3x10)
- Quadriceps: CKC (progress from double to single leg), OKC (90° to 30°)
- Hamstrings/gluteus maximus: machine curls, ball curls, dead lifts
- Hip abductors/adductors: band walks, clams, standing band kicks
- Gastroc-soleus: bent/straight knee raises (progressing double to single)
- Core: prone/side planks with UE/LE raises, superman, bicycle crunches
- Upper body: lat pulldowns, rows, pushups, biceps/triceps, PNF diagonals, rotator cuff
- Balance/neuromuscular Retraining: double to single leg, stable to unstable surfaces, multiplanar, perturbations
- Cardiorespiratory: stationary biking, elliptical, stair or ski machine, walking, swimming
- Running (straight) once criteria are met, usually for 3 to 4 months
- Jogging: 1/4 to 1 mile, progressing speed
- Walking
- Backward running
- Cutting drills: lateral, carioca, figure 8's
- Plyometrics: progress double legged to single, line and box jumps, multiplanar, stable surfaces
- Sport-specific drills: slide board, weighted downhill walks
- PT modalities, cryotherapy as needed

Weeks 26 to 52 (6 to 12 months)

- Flexibility : hamstring, gastroc-soleus, quadriceps, ITB stretches
- Dynamic stretching before activities, static stretching after activities
- Strengthening: PREs with patellofemoral precautions
- Progress to 3 sets of 6 to 8 repetitions for weight training
- Quadriceps, hamstrings/gluteus maximus, hip abductors/adductors, gastroc-soleus, core, upper body
- Balance/neuromuscular: dynamic single leg jumps onto unstable surfaces, multiplanar, with perturbations, UE strengthening
- Cardiorespiratory: progress duration of stationary biking, elliptical, stair or ski machine, walking, swimming
- Running (straight)
- Begin interval training, sprinting
- Backward running
- Plyometrics :progress to multiplanar, multiple jumps onto and over boxes, landing on unstable surfaces in double or single stance
- Speed, agility, and quickness drills: agility ladder, cone and dot drills, speed circuits
- Sport-specific drills progressed
- PT modalities, cryotherapy as needed



FIGURE 32-17. Dynamic knee curl in bridged position. Hips should remain level throughout.

days should be alternated with plyometric and agility days. With further training on weight machines, PREs may be increased to 3 sets of 6 to 8 repetitions and eventually progressed to 1-repetition maximum training.

- Hamstrings/gluteus maximus: hamstring curl machine, supine bilateral knee curl on exercise ball (Figure 32-17), dead lift with row, bridging with leg lift
- Quadriceps: single leg squats (Figure 32-18),[9] wall sits and single leg wall squats with ball, knee extension machine (30° to 90°), single and double-legged leg press, plyometric leg presses, lunges (back leg on exercise ball, dumbbells in hands) (Figure 32-19)
- Hip abductors/adductors: Thera-band hip abductor walks keeping hips level (Figure 32-20), side-lying hip abduction, standing hip abduction and adduction with Thera-Band, side-lying clam with band around knees
- Gastrocnemius and soleus: bent and straight knee heel raises (double or single leg) with resistance

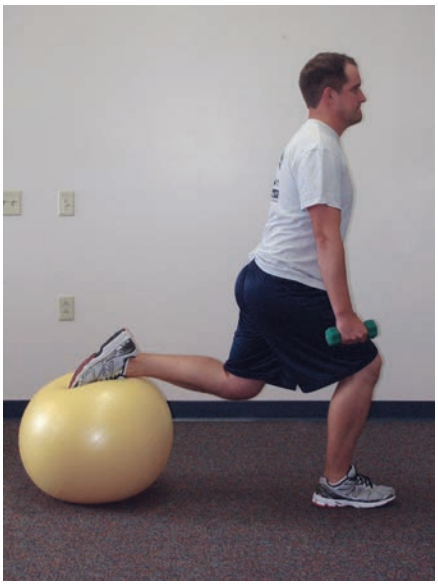

FIGURE 32-19. Lunges with back leg on exercise ball with dumbbells. Ensure proper knee control with no valgus moments. Toes point straight ahead. Front knee does not go beyond toes.

- Upper extremities: lat pulldowns, bilateral upper extremity PNF diagonals, dumbbell rows, pushups, biceps curls, and triceps extension for strength in pushing off of ski poles

Neuromuscular Dynamic Stability Exercises

- Recommend 3 sets of 10 repetitions working up to 3 sets of 30 seconds, at least 5 days per week. Proper form is crucial throughout these activities. This includes maintaining level hips, good trunk control, avoiding genu valgum moments, and avoiding placement of knees beyond toes.



FIGURE 32-18. Single-leg squat. Do not allow knee valgus, a dropped pelvis, or knees to go past toes.



FIGURE 32-20. Thera-Band hip abductor walk. Maintain squatted position, feet and knees pointed forward.

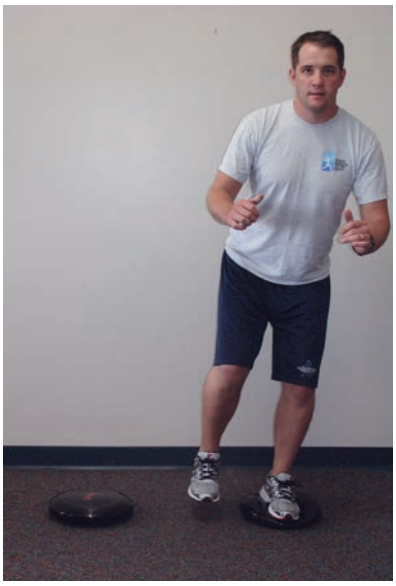

FIGURE 32-21. Single-legged jump side to side onto disc. Maintain proper LE alignment and good trunk control.

- Using a wobble board or BOSU in single-leg activities (catching a ball, using a body blade, performing PNF patterns, UE strengthening)
- Single leg lateral jumps onto a BOSU or disc (Figure 32-21)
- Forward or side lunges using a fitter
- Single-leg line jumps (forward/retro, side/side, diagonally)

Training for Speed, Agility, and Quickness

- Agility ladder drills: may begin with fast feet forward, retro, lateral; 180° slalom jump turns, forward and backward slalom jumps (Figure 32-22) and may be progressed further for mental and coordination challenges. Perform 2 to 3 agility ladder sessions per week, allowing at least 48 hours between. Select 4 to 6 drills and 3 to 5 sets of each per workout.
- Dot drills: double or single leg; work up to 3 sets of 20 to 30 seconds with 30 seconds rest between.
- Cone drills: T, clover, star, W drills (adding change in direction with cutting, sprinting, backpedaling, shuffling). Perform 4 to 6 sets in each direction with 1-minute rest between.
- Speed circuits (components of sprinting with cutting, jumping over hurdles, shuffling) Perform 4 sets in each direction with 1 to 2 minutes of rest between.

Plyometric Training

- Correct posture is extremely important for knee safety with jumping. A defensive or athletic posture is used. Shoulders should be gently retracted with an erect spine, chest over knees, and knees not going past the toes.
- Landings should be soft and quiet with knees bent and toe to heel rocking, avoiding knee valgus or varus moments. (see Figure 32-22 for posture) Jump may progress from 15 to 30 seconds and from 2 to 3 sets with 30 second rest times between jumps. Recommend performing 2 to 3 times per week with at least 24 hours between.
- Training should be performed while the athlete is fresh and should be stopped when fatigue limits proper technique.[10]
- Squat, tuck, lunge, broad, and 180° jumps, squat jump from floor to box, bounding for distance and height
- Line, cone, and hurdle jumps: increase height, perform multidirectional patterns, double to single leg
- Multiple single-leg jumps; double-leg to single-leg jumps, sticking the landings on soft, controlled knees (5 to 10 times per leg)
- Forward and lateral jumps onto and over plyo boxes with focus on soft, controlled landings, gradually increasing box height, 5 to 10 times each.

Sport-Specific Training

- Recommend 5 times per week, changing drills daily.
- Cutting and pivoting drills simulating turns: Distances and angles similar to specific downhill events or diagonal cutting 5 to 10 feet apart for 20 to 40 feet. The number of repetitions is dependent on the distance and fatigue. Consider 3 to 5 repetitions.
- Walking downhill with a weighted vest or back pack to simulate eccentric quadriceps loading: Repetitions dependent on hill slope and distance; consider 2 to 6 repetitions.
- Box jumps onto a BOSU or disc in double or single leg, sticking the landing (Figure 32-23): Perform 3 sets of 5 to 10 repetitions on each leg.
- Lateral single leg jumps onto a BOSU or disc (Figure 32-21): Perform 3 sets of 5 to 10 repetitions on each leg.
- Slide board conditioning (Figure 32-24): Work up to performing this for the time duration of a downhill run.



FIGURE 32-22. Proper skiing defensive position posture. Bilateral-legged slalom jump can be performed by starting to the right of the first square, then jumping across the ladder to the left of the second square. Repeat this sequence until the end of the ladder. May progress to single-legged jump.

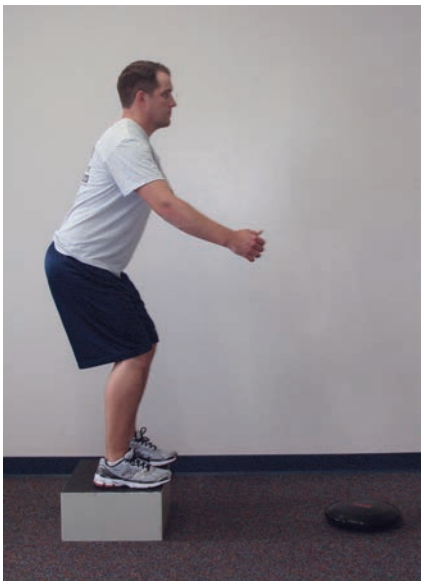

FIGURE 32-23. Bilateral leg to single-leg box jump onto a disc.

Application of Acute Training Variables

- The principles of progression, overload, and variation should be used to advance training. Every program should be individualized to the unique demands of the specific skiing style of the individual, whether vertical or forward explosion is needed or quick cutting movement. Exercises and repetitions should be varied throughout for continual strength gains.
- In general, one may begin with 3 sets of 10 to 20 repetitions for endurance, progressing to 3 sets of 6 to 8 repetitions for weight training, and eventually 1-repetition maximum training.
- Intensity of aerobic conditioning should be matched to the demands of the particular skiing style. For skiing, this is usually periods of moderate to high-level intensity followed by periods of rest to lower intensity.
- Both strengthening and conditioning should occur 3 days per week on alternating days for a total of 6 days per week.

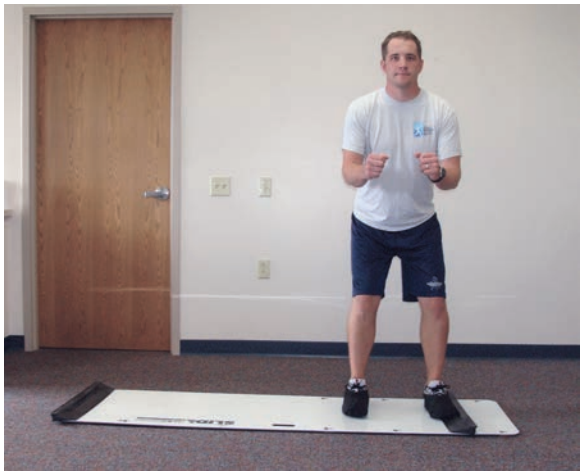

FIGURE 32-24. Slide board conditioning.

- Conditioning should last at least 20 to 30 minutes. Plyometrics should be done 3 times per week.

Sports Performance Testing

General Information

- General history
- Medical history, including medical ailments, genetic conditions that might affect strength, ligamentous laxity, and proprioception
- Sports injury history, including the specifics of the current knee injury and prior knee injuries
- Surgical history, including specifics on the ACL reconstruction (graft type, concomitant pathology to collateral ligaments, menisci, and articular surfaces, as well as specific treatment for these concomitant injuries; occurrence of any postoperative complications, including motion loss, infection, neurologic injury, or thromboembolic events.

Objective Tests

- Single-leg hop for distance and one-legged hop time: During weeks 13 to 26, affected leg should be at least 75% of unaffected; during weeks 27 to 52, affected leg should be at least 85% of unaffected to return to sport.[6,8]
- Drop jump test: Video record and visually analyze an athlete jumping from a 12-inch box. Require proper landing techniques of flexed knees, level hips, a soft landing on the ball of the foot, and an absence of a valgus moment at the knees. An athlete should meet these requirements before plyometric progression. Video analysis can be qualitatively performed frame by frame by a physical therapist trained in proper biomechanics. More quantitative measurements can be made if a biomechanics lab and equipment for joint marking is available. The goal is greater than 60% normalized knee separation distance. This measures combined hip, knee, and ankle mechanics.
- Physiological assessments: At this stage, knee AROM should be at least 0° to 135° and nearing equal to the uninvolved knee if this is more. Hip, ankle, and knee MMT should be a full 5 of 5.
- Static/dynamic postural assessments of gait, running, and jump training are made visually, with a recording or with the use of a biomechanics lab.

Sport-Specific Testing

- Ability to perform any sport-specific exercises with proper core and lower extremity muscular control. The functional testing algorithm presented by Davies and Zillmer should be completed by the athlete at the end of this phase if they plan to return to sport.[12]
  - Subjective: pain <3 on VAS
  - Basic measurements: <10% bilateral comparison
  - KT 1000 ligamentous test: <3 mm bilateral comparison
  - Balance test: <30% bilateral comparison

- CKC supine isokinetic test: <30% bilateral comparison
- OKC isokinetic test: <25% bilateral comparison
- CKC squat isokinetic test: <20% bilateral comparison
- Functional jump test: <20% bilateral comparison
- Functional hop test: <15% bilateral comparison
- Lower extremity functional test (LEFT): <90 seconds for males; <120 seconds for females
- Sport-specific test: <10% bilateral comparison

Specific Criteria to Determine Readiness for Skiing

- To enter Phase III, an athlete should have a normalized gait pattern with full nonpainful knee active range of motion (0° to 135°) and no swelling.
- To return to skiing, an athlete should complete the functional testing algorithm presented by Davies and Zillmer.[12]

Specific Criteria for Releasing an Athlete to Unsupervised Complete Participation in Skiing

- Unfortunately, a systematic review involving 21 clinical outcome studies for return to athletics, after ACL reconstruction from April 2001 to April 2011, found that few objective functional criteria have been published. The most common criterion was lower extremity muscle strength, followed by lower limb symmetry testing and knee examination parameters of range of motion and effusion.[11] Many authors advocate for a functional testing program versus a time based return to sport, however.
- It is generally accepted that one should not begin any sport that places the operative knee at risk until that individual has regained at least 85% of the strength of their unaffected knee. This is assessed functionally with a single-leg hop for distance or one-legged hop time test or more objectively with dynamometer, isokinetic, or isotonic 1-repetition maximum testing of quadriceps and hamstrings.
- Other return to sport variables as recommended by the Sportsmetrics ACL return to play checklist may include:
  - Jump analysis (previously described)
  - Single-leg squat test: Athlete stands on a box with hands on hips and performs 5 squats on each leg. Athlete is rated on position of hip and knee joints. Measures core, hip, and knee muscle strength. Goal is subjective rating of good; no knee valgus or pelvic tilt.
  - Vertical jump: The highest point the athlete can reach while jumping straight up minus the highest point they can reach while standing flat-footed. Measures explosive power and muscle strength. Goal is ≥ 14 inches
  - Core strength: Number of full sit-ups (knees to elbows) an athlete can perform in 1 minute. Measures abdominal/core strength. Goal is ≥ 70th percentile: 38 or more curl-ups per minute
  - Cutting drill: Athlete performs a 45° cut. Ability to keep erect posture, stable trunk (no rotation or lean), increased knee and hip flexion, maintain upper body over knees
- Again, the functional testing algorithm presented by Davies and Zillmer is recommended before an athlete returns to sport.[12]

Recommended Ongoing Exercises

- An athlete must continue with a program to maintain proper conditioning, flexibility, core strength, and balanced lower extremity strength, especially quadriceps and hamstrings, to participate safely in skiing.

Evidence

Barber-Westin S, Noyes F: Objective criteria for return to athletics after anterior cruciate ligament reconstruction and subsequent re-injury rates: A systematic review. *Phys Sports Med* 39:100–110, 2011.

This systematic review assessed the objective functional criteria used to determine when patients can return to athletics postoperatively and to determine the rates of reinjury to ACL reconstructed knees. (Level IV evidence)

Bere T, Florenes TW, Krosshaug T, et al: Mechanisms of anterior cruciate ligament injury in World Cup alpine skiing. *Am J Sports Med* 39:1421–1429, 2011.

This case series of 20 anterior cruciate ligament injuries reported through the International Ski Federation Injury Surveillance System for the 2006 to 2009 World Cup seasons was obtained on video. Seven international experts in skiing biomechanics and sport medicine performed visual analyses of each case, describing injury mechanisms in detail and created 3 main categories of injury in the elite skier: slip-catch, landing back-weighted, and dynamic snowplow. (Level IV evidence)

Beutler AI, Cooper LW, Kirkendall DT, et al: Electromyographic analysis of single-leg, closed chain exercises: Implications for rehabilitation after anterior cruciate ligament reconstruction. *J Athl Train* 37:13–18, 2002.

This prospective study of 18 normal subjects measured the knee angle and surface EMG activity from thigh muscles while performing unsupported one-legged squats and step-ups. Their findings indicate that one-legged squats and step-ups would be effective in muscle rehabilitation and may be protective of the ACL graft as functional, closed chain activities. (Level IV evidence)

Clancy WG, Narechania RG, Rosenberg TD, et al: Anterior and posterior cruciate ligament reconstruction in Rhesus monkeys. *J Bone Joint Surg Am* 63:1270–1284, 1981.

This study of 29 young adult Rhesus monkeys used microangiographic, histological, and biomechanical techniques to study the vascularity and tensile strength of the medial third of the patellar tendon after being implanted as a graft for the ACL or PCL. Grafts were found to revascularize at week 8.

At one year, they had approximately 80% of the tensile strength prior to the transfer. (Level IV evidence)

Davies G, Zillmer D: Functional progression of exercise during rehabilitation. In Ellenbecker TS, editor: *Knee Ligament Rehabilitation*, London, 2000, Churchill Livingstone, pp 345–360.

The functional testing algorithm presented in this article serves as a guideline for clinicians to determine when an athlete is ready to return to sport after injury. (Level IV evidence)

Heckmann T, Noyes FR, Barber-Westin SD: Rehabilitation of primary and revision anterior cruciate ligament reconstructions. In Noyes FR, Barber-Westin SD, editors: *Noyes' Knee Disorders: Surgery, Rehabilitation, Clinical Outcomes*, Philadelphia, 2009, Saunders, pp 306–336.

This rehabilitation protocol for primary ACL reconstruction with early return to strenuous activities describes weeks 6 through 52 after ACL reconstruction using a central one-third bone patellar tendon bone graft, isometrically placed. This protocol was not recommended for low strength grafts, nonisometric grafts, or grafts not securely fixed. The protocol is supported primarily by clinical success rates. (Level V evidence)

Hewett TE, Stroupe AL, Nance TA, et al: Plyometric training in female athletes: Decreased impact forces and increased hamstring torques. *Am J Sports Med* 24:765–773, 1996.

This prospective study of 11 female high school volleyball players tested the effect of a jump training program on landing mechanics and lower extremity strength. The program goal was to decrease landing forces after proper training with neuromuscular control exercises; 10 of 11 female subjects decreased peak landing forces. (Level IV evidence)

Johnson SC: Anterior cruciate ligament injury in elite alpine competitors. *Med Sci Sports Exerc* 27:323–327, 1995.

This article discussed modern ski bindings and their effect on ACL injuries as well as the mechanism of ACL injury in the recreational and elite skier. (Level V evidence)

Koyanagi M, Shino K, Yoshimoto Y, et al: Effects of changes in skiing posture on kinetics of the knee joint. *Knee Surg Sports Traumatol Arthrosc* 14:88–93, 2006.

This prospective study of 10 females with no past history of leg injury compared forward versus backward bent postures. It found that a forward bent posture with the knee slightly bent was the safest form of skiing for prevention of ACL injury. (Level IV evidence)

Noyes FR, Barber SD, Mangine RE: Abnormal lower limb symmetry determined by function hop tests after anterior cruciate ligament rupture. *Am J Sports Med* 19:513–518, 1991.

This prospective, randomized study of 67 patients compared the sensitivity of four different types of one-legged hop tests to determine alteration in lower limb function in ACL deficient knees. It found a low sensitivity, high specificity, and low false positive rate, allowing the tests to be used only to confirm suspected lower limb functioning deficits. A limb symmetry index of 85% or greater was found to be within the normal range for both males and females, regardless of dominance, sports activity level, or gender. (Level IV evidence)

Pujol N, Blanchi MPR, Chambat P: The incidence of anterior cruciate ligament injuries among competitive alpine skiers: A 25-year investigation. *Am J Sports Med* 35:1070–1074, 2007.

This descriptive study of 379 elite French national ski team members evaluated epidemiologic aspects of ACL injuries from 1980 to 2005. They found overall ACL incidence rates and reinjury rates to the same knee as well as the rate of ACL injury to the contralateral knee. (Level IV evidence)

Stevenson H, Webster J, Johnson R, et al: Gender differences in knee injury epidemiology among competitive alpine ski racers. *Iowa Orthop J* 18:64–66, 1998.

This retrospective study included 404 returned questionnaires from Vermont Alpine Racing Association Members and several New England NCAA Division I ski racing programs. The survey included questions regarding the racer's age, gender, number of skiing years, injury and surgery to knees, and reinjury to an ACL repaired knee. It found that 36% of those having ACL reconstructions required subsequent surgery to the same knee. (Level IV evidence)

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Multiple-Choice Questions

QUESTION 1. With plyometric jumping, which of the following is not true?

A. Landings should be soft so that muscles absorb the shock from the knee joint.
B. Landings should be with heel to toe contact.
C. Landings should be without knee valgum or varus moments.
D. Landings should be with knees flexed.

QUESTION 2. What percent of the unaffected leg should an athlete attain on the single-leg hop test before returning to sport?

A. 60%
B. 75%
C. 85%
D. 95%

QUESTION 3. At one-year postoperative ACL reconstruction, what percent strength is the graft compared to its original tensile strength?

A. 30%
B. 50%
C. 80%
D. 100%

QUESTION 4. Which mechanism of injury is not included in current research describing ACL rupture in the elite skier?

A. Landing toe-weighted
B. Slip-catch
C. Landing back-weighted
D. Dynamic snowplow

Answer Key

QUESTION 1. Correct answer: **B** (see the Plyometric Training of Phase III: Sport-Specific Training)

QUESTION 2. Correct answer: **C** (see Objective Testing)

QUESTION 3. Correct answer: **C** (see Clancy et al.[4])

QUESTION 4. Correct answer: **A** (see Bere et al.[2])

POSTOPERATIVE REHABILITATION AFTER SOFT TISSUE ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION (AUTOGRAFT AND ALLOGRAFT)

Sanjeev Bhatia, MD, Geoffrey S. Van Thiel, MD, MBA, John Bojchuk, ATC, and Bernard R. Bach, Jr., MD

Indications for Surgical Treatment

The decision to go forward with an ACL reconstruction procedure is dependent on various factors and is highly individualized to each patient. Nonetheless, ACL reconstruction is generally recommended in the following circumstances:

- Young, highly demanding patients
- Those with a desire to return to competitive or frequent recreational sports requiring cutting or pivoting
- Patients with combined ligament knee injuries, significant instability, or repairable meniscus tears

Brief Summary of Surgical Treatment

Major Surgical Steps

- General anesthesia with the patient in the supine position
- Physical exam or diagnostic arthroscopy to document all pathology
- Soft tissue graft harvest and/or preparation
- Preparation of notch and takedown of leftover ACL stump
- Tibial tunnel creation
- Femoral tunnel creation
- Graft passage through tibial and femoral tunnels
- Fixation of the ACL graft in femoral tunnel
- Fixation of ACL graft in tibial tunnel
- Wound closure

Factors That May Affect Rehabilitation

Anesthetic

- Regional anesthesia, frequently in the form of a femoral nerve block, may provide excellent postoperative analgesia, leading to improved outcomes. However, the block may wear off 8 to 24 hours after surgery. Be cognizant of rebound pain, and be quick to use other modalities.

Surgical

- Presence of other knee pathology
  - Frequently, patients undergoing ACL reconstruction are noted to have other knee pathology preoperatively or at the time of diagnostic arthroscopy. These may include other ligamentous injuries, meniscus tears, or cartilage injuries. It is important to determine whether any other injuries exist or concomitant procedures were performed, as this may change postsurgical rehabilitation.

- Autograft versus allograft ligament reconstruction
  - ACL grafts may be derived from the patient's own tissue (autografts) or cadaveric tissue (allografts). The autograft soft tissue most commonly used for ACL reconstruction is the hamstring tendons (semitendinosus and gracilis tendons, frequently a quadrupled stranded construct). However, it is becoming more common to also use an autograft quadriceps tendon. Allograft options for soft tissue ACL reconstruction include hamstring tendons, tibialis anterior tendon, and Achilles tendon grafts. It is important to know whether any autograft tendon was harvested in your patient as this may influence hamstring postsurgical rehabilitation.
- Graft type and graft fixation
  - ACL reconstruction can be performed with a soft-tissue graft (hamstring, Achilles tendon, tibialis anterior, quadriceps) or a bone-tendon-bone graft (patellar tendon with two bone plugs).
  - Accelerated rehabilitation programs, similar to those commonly used following ACL reconstructions using the patellar tendon autograft, have been shown to be equally successful following reconstruction with a hamstring graft.
  - In cases where tibial or femoral tunnel fixation of the grafts are not as strong, a slightly less aggressive rehabilitation protocol may be suggested.
  - Soft tissue-to-bone healing takes 12 weeks to complete in most instances whereas bone-to-bone healing occurs in approximately 8 weeks.

Before Surgery: Overview of Goals, Milestones, and Guidelines[1]

A patient with an ACL tear can commonly present with a swollen, stiff, and painful knee. The hemarthrosis after the injury can produce an inflammatory reaction that causes significant discomfort/dysfunction. The goals of preoperative rehabilitation are to decrease swelling, return knee motion to normal or near normal, improve strength, and begin early therapy training. Achieving normal knee range of motion has been shown to decrease the probability of postreconstruction stiffness. To achieve preoperative goals:

Tools to Manage Swelling

- Cryo/compression devices: there are multiple commercially available devices that provide cooling and/or compression to the knee. These devices can also be used in the postoperative time period.

Restoration of Normal Knee Range of Motion

- Exercise training preoperatively that can also be used postoperatively.

[1]*Prehabilitation, if appropriate, is described in the Nonoperative Rehabilitation section of this chapter.*



FIGURE 32-25. Towel stretch exercise. The towel is used to lift the heel of the affected leg to end range knee hyperextension by pulling the towel upwards.

- Towel stretches: a looped towel around the midfoot is held with one hand as the foot is lifted and the other hand holds the thigh down (Figure 32-25).
  - An advancement of this is to have the patient contract the quadriceps and release the towel to hold the heel off the bed/ground.
- The affected leg should also be allowed to rest on a pillow with nothing under the knee. This encourages full extension.
- Wall and heel slides can be implemented to assist with flexion. The patient can be laying supine with the affected leg/foot extended against a wall. The foot is then allowed to slide down into flexion with assistance from the other leg as necessary.
- Quad sets and straight leg raises
- Full weight bearing and ROM is encouraged.
- Activity can be completed as tolerated and good exercises include the stationary bike and elliptical machine.

GUIDING PRINCIPLES OF POSTOPERATIVE REHABILITATION

- Obtaining full passive knee extension and patellar mobility immediately following surgery
- Reducing postoperative inflammation and pain with the use of various modalities
- Restoring neuromuscular control with electrical muscle stimulation (for reestablishing voluntary quadriceps control), proprioceptive training, and other biofeedback modalities
- Gradually increasing applied loads to the knee
- Progressing to sport-specific training

Phase I: Immediate Postoperative Period (days 0 to 14)

Clinical Pearls

One of the most frequently seen complications following ACL reconstruction is the loss of full knee extension, thus creating an environment ripe for scar

tissue formation. Lack of extension also often leads to increased patellofemoral and tibiofemoral joint contact pressure, difficulty with quadriceps activation, and excessive muscular fatigue. A drop-lock knee brace locked at full extension is often helpful, particularly when patients use it while ambulating and sleeping at night for 2 to 3 weeks after surgery.

Goals

- Restoring full or near normal passive knee extension
- Reducing joint swelling and pain
- Restoring patellar mobility
- Progressively improving knee flexion
- Reestablishing voluntary quadriceps control
- Restoring independent ambulation

Protection

- A drop-lock knee extension brace locked in full-extension is used immediately postoperatively
- The brace is worn in extension for 6 weeks during ambulation and sleeping activities if an autograft tendon was used, and 10 to 14 days if an allograft tendon was used.
- Crutches may be used for comfort initially but patients should try to assume full weightbearing by the second week. To facilitate the transition from crutches to full weightbearing, one may allow 2 crutches for the first 7 to 10 days, then progress to 1 crutch and finally full weightbearing by 14 days.
- Weightbearing may be altered if the patient has other concomitant injuries (bone bruise) or other concomitant procedures are performed

Management of Pain and Swelling

Management of Pain/Analgesia

- In addition to oral analgesic medication, cryotherapy devices can be helpful. These units consist of a cooling apparatus and wrap that helps to decrease pain and spasm. It is thought that cryotherapy works by inhibiting afferent nerve conduction and decreases the local inflammatory response.
- Passive range of motion may support the neuromodulation of knee pain following surgery and improve symptoms.

Management of Swelling

- It is imperative to reduce knee swelling whenever possible in the immediate postoperative period.
- Knee effusions may cause muscle inhibition.
- Cryotherapy and joint compression with a knee sleeve, ace wrap, or compression device are the most frequently used modalities.
- The patient can also ice 20 minutes hourly and elevate lower extremity.

Techniques for Progressive Increase in Range of Motion

- Full passive knee extension (days 1 to 7)
- Achieve 90° of knee flexion (days 2 to 7)
- Patellar mobilization

Other Therapeutic Exercises

- Ankle pumps
- Heel slides/wall slides
- Prone leg hangs for extension
- Hamstring stretches (Do not do until 4 weeks postoperatively if hamstring autograft used in surgery)
- Straight leg raises (hip flexion, abduction, adduction)
- Aerobic conditioning
  - Upper extremity ergometry
  - Well-leg bicycling

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Quadriceps isometric (days 1 to 14)
- Standing hamstring curls (Do not do until 6 weeks postoperatively if hamstring autograft used in surgery)
- Straight leg raise in all planes with the brace until the quadriceps are strong enough to prevent an extensor lag.
- Electrical stimulation of quads (4 to 6 hours daily)

Sensorimotor Exercises

- Active/passive joint positioning
- Balancing activities
- Stable platform, eyes open
- Stable platform, eyes closed
- Seated ball throwing and catching

Open and Closed Kinetic Chain Exercises

- Mini-squats
- Weight shifts

Milestones for Progression to the Next Phase

- Ability to achieve full passive knee extension
- Passive knee flexion from 0° to 90°
- Minimal knee swelling
- Good patellar mobility
- Quad strength and control as demonstrated by ability to perform good quad set and straight leg raise with no extensor lag
- Ambulation without crutches

Phase II: Postoperative (weeks 2 to 4)

Clinical Pearls

At this phase, patients should be able to ambulate independently without crutches. The brace should be discontinued around week 2 if an allograft was used but should be continued until week 6 if an autograft tendon was used. As this phase progresses, closed chain exercises gradually become more difficult. Pool work should only be performed if surgical wounds are fully closed.

Goals

- Maintain range of motion (full knee extension) and patellar mobility established in previous phase.
- Gradually increase knee flexion.
- Diminish swelling.
- Muscle training
- Muscle proprioception

Protection

- Full ambulation without crutches or a brace should be achieved by this phase

Management of Pain and Swelling

Management of Pain

- In addition to oral analgesic medication, cryotherapy, electrical stimulation, and transcutaneous electrical neuromuscular stimulation (TENS) devices may be helpful.

Management of Swelling

- Cryotherapy and joint compression with a knee sleeve or ace wrap are the most frequently used modalities.
- The patient can ice for 20 minutes hourly and elevate the lower extremity.

Techniques for Progressive Increase in Range of Motion

- Self-performed range of motion stretching exercises should be performed 4 to 5 times daily. There should be an emphasis on maintaining full, passive range of motion (full extension and full flexion).
- Overpressure into extension
- Passive range of motion from 0° to 115° flexion (by week 3)
- Continue patellar mobility

Other Therapeutic Exercises

- Bicycle
- Straight leg raises (hip flexion, adduction, abduction, extension)
- Pool walking (begin at earliest during week 3, only if incision is fully closed)

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Isometric quadriceps sets
- Leg press (Figure 32-26)
- Knee extension 90° to 40° without weight
- Leg external and internal rotation maneuvers with knee bent 30° to engage popliteus and hamstring muscles
- Calf raises with knee in extension
- Bent knee calf raises for soleus
- Hamstring curls (Do not do until 6 weeks postoperative if hamstring autograft used in surgery)

Sensorimotor Exercises

- Bicycle
- Progress to proprioception drills as tolerated

Open and Closed Kinetic Chain Exercises

- Half squats
- Weight shifts
- Front and side lunges
- Eccentric quadriceps program (isotonic exercises only)
- Lateral step-ups
- Front step-ups
- Stair-stepper machine

TIMELINE 32-4: **Postoperative Rehabilitation After Soft Tissue ACL Reconstruction (Autograft and Allograft)**

PHASE I (weeks 1 to 2)	PHASE II (weeks 2 to 4)	PHASE III (weeks 4 to 10)
• Knee extension brace locked in full extension • Crutches for comfort, WBAT • ROM: full passive knee extension and 90° knee flexion • Patellar mobilization • Ankle pumps, wall slides, SLR, prone leg hangs	• Slowly discontinue brace and crutches • PT modalities • Overpressure into full knee extension • Passive ROM from 0° to 115° flexion • Continue patellar mobility • Bicycle, SLR • Isometric quad sets, half squats • Front and side lunges • Lateral step-ups • Front step-ups • Perturbation training • Bicycling for endurance	• No brace or crutches • PT modalities as needed • PROM-full, continue self-performed ROM exercises • Bicycle • SLR (hip flexion, adduction, abduction, extension) • Pool running (backwards/forward) • Leg press • Hamstring curl (begin at 6 weeks postop if hamstring autograft was harvested) • Progress isometric strength program • Balance training on tilt board and with medicine ball throws • Lunge exercises • Wall squats, vertical squats, toe calf raises • Open chain resistance with extension; begin slowly with 1 lb weight • Stair-stepper machine • Perturbation training

Techniques to Increase Muscle Strength, Power, and Endurance

- Bicycling for endurance

Neuromuscular Dynamic Stability Exercises

- Perturbation training

Milestones for Progression to the Next Phase

- Active range of motion from 0° to 115° knee flexion
- Isometric quadricep strength is at least 60% of the contralateral side
- No joint line or anterior knee pain
- Lack of knee effusion



FIGURE 32-26. Leg press.

Phase III: Postoperative (weeks 4 to 10)

Clinical Pearls

As this phase progresses, difficulty of exercises (particularly those involving neuromuscular control and proprioception) also increases. Plyometrics may be incorporated by week 6.

Goals

- Continue to increase strength
- Continue to increase range of motion (0° to 125°)
- Increase proprioception, balance, and neuromuscular control
- Improve endurance
- Improve limb confidence

Protection

- No more brace or crutches if an allograft was used, continue the brace until week 6 with an autograft.

Management of Pain and Swelling

- Cryotherapy, electrical stimulation, and transcutaneous electrical neuromuscular stimulation (TENS) devices may be helpful.
- Narcotic pain medication should not be used at this point.
- Continue the joint compression with a knee sleeve or ace wrap.
- Ice the knee for 20 minutes hourly and elevate lower extremity.

TIMELINE 32-4: **Postoperative Rehabilitation After Soft Tissue ACL Reconstruction (Autograft and Allograft)** (Continued)

PHASE IV (weeks 10 to 16)	PHASE V (weeks 16 to 22)	Weeks 22 to 52
• PT modalities as needed • PROM-full • Bicycle • Straight leg raises • Progress pool running • Can start running straight ahead at 12 weeks • Leg press, hamstring curls • Progress isometric strengthening programs • Perturbation training on a single leg • Continue balance training with medicine ball • Continue open chain resistance training • Biodex stability system • Initiate plyometric leg press by weeks 12 to 16 • Initiate sport-specific exercises (cone drills, side shuffles, cariocas, cutting) • Combinations of agility drills	• PROM-maintain full motion • Bicycle • Straight leg raises • Continue to progress pool running; full forward and backwards running • Increase cutting maneuvers • Leg press, hamstring curls • Progress isometric strengthening programs • Perturbation training on a single leg • Progress open chain resistance training • Biodex stability system • Progress plyometric leg press and sport-specific plyometric drills • Continue sport-specific exercises (sudden start/stops, cone drills, agility drills) • Sport-specific skill training (e.g., coming out of 3-point stance for football lineman)	• Gradual return to sports participation • Contact athletes should first return to practice on limited basis before full contact • Maintenance program for strength and endurance • Continue sport-specific skill training

Techniques for Progressive Increase in Range of Motion

- Self-performed range of motion stretching exercises should be performed 4 to 5 times daily. There should be an emphasis on maintaining full, passive range of motion (full extension and full flexion).
- Perform hamstring stretching at this stage if a hamstring autograft was used during ACL surgery.

Other Therapeutic Exercises

- Bicycle
- Straight leg raises (hip flexion, adduction, abduction, extension)
- Pool running (provided no wound healing problems); begin with backward running and hip/leg exercises, then progress to forward running

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Leg press
- Hamstring curls (begin at 6 weeks postoperatively if hamstring autograft used during ACL reconstruction)
- Progress isometric strengthening program

Sensorimotor Exercises

- Balance training on a tilt board
- Balance training with medicine ball throws
- Perturbation training

Open and Closed Kinetic Chain Exercises

- Lateral lunge step-overs
- Front and side lunges
- Lateral step-downs
- Front step-downs
- Wall squats
- Vertical squats
- Toe calf raises
- Open chain resistance with extension can begin with 1 lb weight only. Increase no more than 1 lb per week. (Figure 32-27)
- Stair-stepper machine



FIGURE 32-27. Open chain knee extension with leg weight. This exercise should begin with no more than 1 lb of resistance. Each week, increase resistance by 1-lb increments if tolerated.

Techniques to Increase Muscle Strength, Power, and Endurance

- Stair-stepper machine
- Bicycle
- Walking program

Neuromuscular Dynamic Stability Exercises

- Biodex stability system
- Balance training on a tilt board
- Balance training with medicine ball throws
- Perturbation training

Milestones for Progression to the Next Phase

- Active range of motion maintained at 0° to 125° flexion
- Isometric quadricep strength is greater than 80% of the contralateral side
- Knee flexor/extensor strength ratio is at least 70% to 75%
- No pain
- No joint effusion
- Hamstring strength is equal bilaterally
- Hop test (80% that of contralateral leg)

Phase IV: Postoperative (weeks 10 to 16)

Clinical Pearls

> This is the phase that most patients have been waiting for: a gradual return to sport-specific training. The eager athlete must be reminded that a progression is necessary and they need to remain committed to the process and protocol.

Goals

- Return leg strength to normal
- Improve muscular power and endurance
- Enhance neuromuscular control
- Perform sport-specific drills

Protection

- No more brace or crutches for the majority of patients. However, some patients such as football lineman may benefit from the use of a functional ACL brace at this point.

Management of Pain and Swelling

- Pain should be minimal to nonexistent at this point.
- Cryotherapy, electrical stimulation, and transcutaneous electrical neuromuscular stimulation (TENS) devices can be used when necessary.
- Narcotic pain medication should not be necessary at this point.
- Joint compression with a knee sleeve or ace wrap are the most frequently used modalities.
- Ice for 20 minutes hourly and elevate lower extremity.

Techniques for Progressive Increase in Range of Motion

- Self-performed range of motion stretching exercises should be performed 4 to 5 times daily. There should be an emphasis on maintaining full, passive range of motion (full extension and full flexion).

Other Therapeutic Exercises

- Bicycle
- Straight leg raises (hip flexion, adduction, abduction, extension)
- Pool running (provided no wound healing problems); forward and backwards running
- Can start running straight ahead at 12 weeks

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Hamstring curls
- Leg press
- Progress isometric strengthening program

Sensorimotor Exercises

- Continue balance training on a tilt board
- Continue balance training with medicine ball throws (Figure 32-28)
- Continue perturbation training on single leg (Figure 32-29)

Open and Closed Kinetic Chain Exercises

- Lateral lunge step-overs
- Front and side lunges
- Lateral step-downs
- Front step-downs
- Wall squats (Figure 32-30)
- Vertical squats
- Toe calf raises
- Continue open chain resistance with extension; after beginning with 1 lb in week 3, increase no more than 1 lb per week.
- Stair-stepper machine



FIGURE 32-28. Single-leg balance training with medicine ball throws. This medicine ball exercise is performed while balancing on a tilt board with one leg.



FIGURE 32-29. Single-leg perturbation training using a tilt board.

Techniques to Increase Muscle Strength, Power, and Endurance

- Stair-stepper machine
- Bicycle
- Walking program

Neuromuscular Dynamic Stability Exercises

- Biodex stability system
- Balance training on a tilt board
- Balance training with medicine ball throws
- Perturbation training

Plyometrics

- Initiate plyometric leg press by weeks 12–16 (Figure 32-31)



FIGURE 32-30. Wall squats.



FIGURE 32-31. Plyometric jumping exercises.

Functional Exercises

- Lunges with sport cord
- Running and agility progression
- Pool running (backward and forward)

Sport-Specific Exercises

- Cone drills
- Side shuffles
- Cariocas
- Sudden start/stops
- 45° cutting maneuvers
- 90° cutting maneuvers
- Combinations of agility drills
- Sport-specific plyometric training drills by weeks 12 to 16

Milestones for Progression to the Next Phase

- Full range of motion
- Quadriceps strength 80% or greater than opposite extremity
- Hamstring strength 110% or greater than opposite extremity
- Quadricep torque/body weight ratio 55% or greater
- Hamstrings/quadriceps ration 70% or greater
- Proprioceptive test equivalent to contralateral leg
- Functional testing 85% or greater to contralateral leg
- Pain-free knee

Phase V: Postoperative (weeks 16 to 22)

Clinical Pearls

The key goal in Phase V is returning patients to their preoperative level of sports or activity. Much of this also includes building confidence in their reconstructed knee. Continuing to progress strengthening, functional, proprioceptive, and sport-specific drills, all while increasing applied loads and difficulty will help your patients achieve these goals. The workhorse exercises of this phase include single leg squats and lunges in addition to sport-specific drills.

Goals

- Gradually returning the patient to full, unrestricted sports
- Maximizing leg strength and endurance
- Normalizing neuromuscular control
- Progressing skill training
- Continuing to build limb confidence

Management of Pain and Swelling

- Pain should be minimal to nonexistent at this point.
- Cryotherapy, electrical stimulation, and transcutaneous electrical neuromuscular stimulation (TENS) devices can be used when necessary.
- Narcotic pain medication should not be necessary at this point.
- Joint compression with a knee sleeve or ace wrap is the most frequently used modality.
- Knee sleeve can be discontinued but some patients psychologically feel more comfortable when wearing it.
- Ice for 20 minutes hourly and elevate lower extremity.

Techniques for Progressive Increase in Range of Motion

- Self-performed range of motion stretching exercises should be performed 4 to 5 times daily. There should be an emphasis on maintaining full, passive range of motion (full extension and full flexion).

Other Therapeutic Exercises

- Bicycle
- Straight leg raises (hip flexion, adduction, abduction, extension)
- Pool running (provided no wound healing problems); forward and backward running

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Hamstring curls
- Leg press
- Progress isometric strengthening program

Sensorimotor Exercises

- Continue balance training on a tilt board.
- Continue balance training with medicine ball throws.
- Continue perturbation training on single leg.

Open and Closed Kinetic Chain Exercises

- Lateral lunge step-overs
- Front and side lunges

- Lateral step-downs
- Front step-downs
- Wall squats
- Vertical squats
- Toe calf raises
- Stair-stepper machine

Techniques to Increase Muscle Strength, Power, and Endurance

- Stair-stepper machine
- Bicycle
- Walking program

Neuromuscular Dynamic Stability Exercises

- Biodex stability system
- Balance training on a tilt board
- Balance training with medicine ball throws
- Perturbation training

Plyometrics

- Can progress plyometric leg presses
- Continue other plyometric training drills

Functional Exercises

- Lunges with sport cord
- Progress running and agility training

Sport-Specific Exercises

- Cone drills
- Side shuffles
- Cariocas
- Sudden start/stops
- 45° cutting maneuvers
- 90° cutting maneuvers
- Combinations of agility drills
- Continue other plyometric training drills
- Sport-specific skill training (e.g., coming out of a 3-point stance for football lineman, changing direction from backpedal to sprint, etc.).

Criteria for Return to Sport

6-Month Time Point

- No knee effusion
- Full knee range of motion
- Quad atrophy less than 2 cm
- No more than 3 mm on Lachman test
- No more than a trace pivot shift
- Lysholm score > 75
- SANE score > 75
- No subjective sense of instability
- No difficulty with activities of daily living
- Knee extension and flexion at least 70% of normal
- Single-leg press at least 70% of normal
- Single leg squat possible

Specific Situations

- Contact athletes (e.g., football or hockey players) should first return to practice on a limited basis before full contact is allowed. Often, this can be achieved by allowing the athlete to participate in practice while wearing a noncontact (e.g., red colored) jersey.

After Return to Sport

Continuing Fitness or Rehabilitation Exercises

- Athletes are encouraged to continue strength and agility exercises on their own to preserve strength, functional, and proprioceptive gains.

Exercises and Other Techniques for Prevention of Recurrent Injury

- Lateral box jumps
- Single leg hurdles
- Single leg lunges and squats

Evidence

Grinsven S, Cingel REH, Holla CJM, et al: Evidence-based rehabilitation following anterior cruciate ligament reconstruction. *Knee Surg Sports Traumatol Arthrosc* 18:1128–1144, 2010.

Following a bone-patellar tendon-bone autograft (BPTB) or four-stranded semitendinosus/gracilis tendons autograft (ST/G) anterior cruciate ligament (ACL) reconstruction, the speed and safety with which an athlete returns to sports (or regains the preinjury level of function) depends on the rehabilitation protocol. Considering the large differences in clinical and outpatient protocols, there is no consensus regarding the content of such a rehabilitation program. Therefore, we conducted a systematic review to develop an optimal evidence-based rehabilitation protocol to enable unambiguous, practical and useful treatment after ACL reconstruction. The results clearly indicated that an accelerated protocol without postoperative bracing, in which reduction of pain, swelling, and inflammation, regaining range of motion, strength, and neuromuscular control are the most important aims, has important advantages and does not lead to stability problems. Preclinical sessions, clear starting times, and control of the rehabilitation aims with objective and subjective tests facilitate an uncomplicated rehabilitation course. Consensus about this evidence-based accelerated protocol will not only enhance the speed and safety with which an athlete returns to sports, but a standardized method of outcome measurement and reporting will also increase the evidential value of future articles.

Gulotta LV, Rodeo SA: Biology of autograft and allograft healing in anterior cruciate ligament reconstruction. *Clin Sports Med* 26:509–524, 2007.

Excellent review article regarding the biology of anterior cruciate ligament healing written by experts in the field. (Level V evidence)

Howell SM, Deutsch ML: Comparison of endoscopic and two-incision technique for reconstructing a torn anterior cruciate ligament using hamstring tendons. *Arthroscopy* 15:594, 1999.

This study compared the differences in clinical outcome between an endoscopic (67 of 70) and two-incision (41 of

49) technique used to reconstruct torn anterior cruciate ligaments (ACL) using a double-looped semitendinosus and gracilis (DLSTG) graft. The postoperative treatment featured an aggressive rehabilitation protocol without a brace and allowed unrestricted sports participation 4 months after reconstruction. Age, sex distribution, duration from injury to surgery, and preoperative laxity were not significantly different between treatment groups.(Level III evidence)

Janssen RPA, Wijk J, Fiedler A, et al: Remodelling of human hamstring autografts after anterior cruciate ligament reconstruction. *Knee Surg Sports Traumatol Arthrosc* 19:1299–1306, 2011.

Human hamstring grafts showed typical stages of graft remodelling, which was not complete up to 2 years after ACL reconstruction. The remodelling process in humans was prolonged compared with the results obtained in several animal studies.

MacDonald P, Hedden D, Huebert D: Effects of an accelerated rehabilitation program after anterior cruciate ligament reconstruction with combined semitendinosus-gracilis and a ligament augmentation device. *AJSM* 23:588, 1995.

Forty patients undergoing ACL reconstruction using semitendinosus and gracilis autografts and a ligament augmentation device were retrospectively reviewed at minimum 20 months postoperatively to determine if accelerated rehabilitation was detrimental. Of the 37 patients available for follow-up, 34 had good-excellent results. The study concluded that early, accelerated rehabilitation of ACL reconstruction using this type of graft does not adversely affect outcome. (Level III evidence)

Majima T, Yasuda K, Tago H, et al: Rehabilitation after hamstring anterior cruciate ligament reconstruction. *Clin Orthop Relat Res* 397:370–380, 2002.

A prospective comparative study was conducted involving 62 patients to determine the effects and limits of accelerated rehabilitation on clinical outcome. The study focused on whether aggressive rehabilitation after anterior cruciate ligament reconstruction with the doubled semitendinosus and gracilis tendon autograft results in stretching the graft. A total of 30 patients had postoperative rehabilitation according to the current conservative protocol, and 32 patients had rehabilitation using an accelerated regime. Each patient was evaluated subjectively and objectively 36 months or more after surgery. Concerning the side-to-side difference in the anterior laxity, 87% of the patients in the conservative rehabilitation group had 3 mm or less laxity and 80% of the patients in the accelerated rehabilitation group had the same acceptable laxity. There was no significant difference between the two groups. Muscle torque was restored significantly earlier in the patients in the accelerated rehabilitation group than in the patients in the conservative rehabilitation group. Nine months after surgery, however, there were no significant differences in the torque between the two groups. Accelerated rehabilitation significantly increased the incidence of knee effusion during rehabilitation. This study showed that acceleration of postoperative rehabilitation could rapidly restore muscle strength without significantly compromising graft stability in anterior cruciate ligament reconstruction with the doubled hamstring tendon autograft. However, this study also showed that acceleration significantly increases the incidence of synovitis. Acceleration of postoperative rehabilitation has advantages and disadvantages for clinical outcome after anterior cruciate ligament reconstruction.

Wright RW, Preston E, Fleming BC, et al: A systematic review of anterior cruciate ligament reconstruction rehabilitation: Part I: Continuous passive motion, early weight bearing, postoperative bracing, and home-based rehabilitation. *J Knee Surg* 21:217–224, 2008.

Many issues regarding ACL reconstruction rehabilitation have been evaluated using randomized controlled trials. The methodologic quality of the studies reviewed is mixed. Most of the studies have some form of potential bias. This is especially true of the studies published prior to 2000, when many of the study quality issues were not yet recognized. Despite this, some reasonable conclusions can be made from the studies and used in developing an ACL reconstruction rehabilitation protocol. Early weight bearing appears beneficial and may decrease patellofemoral pain. Early motion is safe and may help avoid problems with later arthrofibrosis. Continuous passive motion is not warranted to improve rehabilitation outcome in patients and can avoid the increased costs associated with CPM. Minimally supervised physical therapy in selected motivated patients appears safe without significant risk of complications. Postoperative rehabilitative bracing either in extension or with the hinges opened for range of motion does not offer significant advantages over no bracing.

Wright RW, Preston E, Fleming BC, et al: A systematic review of anterior cruciate ligament reconstruction rehabilitation: Part II: Open versus closed kinetic chain exercises, neuromuscular electrical stimulation, accelerated rehabilitation, and miscellaneous topics. *J Knee Surg* 21(3):225–234, 2008.

Early weightbearing appears beneficial and may decrease patellofemoral pain. Early motion is safe and may help avoid problems with later arthrofibrosis. Continuous passive motion is not warranted to improve rehabilitation outcome in patients and can avoid the increased costs associated with CPM. Minimally supervised physical therapy in selected motivated patients appears safe without significant risk of complications. Until further studies are performed, protocols should use closed kinetic chain exercises in the first 6 weeks. Postoperative rehabilitative bracing either in extension or with the hinges opened for range of motion does not offer significant advantages over no bracing. Neuromuscular electrical stimulation, if deemed necessary for patients, should be instituted early in the postoperative period and should be of high intensity to achieve meaningful results. Accelerated rehabilitation appears safe, at least in the 5-month to 6-month time frame. Water-based therapy, stair climber, and slideboard exercise programs appear safe and may add variety if available for patients. Gait, proprioception, and psychological training may be of some benefit. Creatine, at least in the dosage and time frame used, offered no benefit. Restricting blood flow during rehabilitation sessions requires further studies before it becomes regularly prescribed by most clinicians. Despite more than 50 randomized controlled trials in the field, many questions remain, and further studies are warranted to continue to add evidence to our ACL reconstruction rehabilitation protocols.

References

Wilk KE, Macrina LC, Reinold MM, et al: Recent advances in the rehabilitation of anterior cruciate ligament injuries. In Bach B, Jr, Provencher M, editors: *ACL surgery: How to get it right the first time and what to do if it fails*, Thorofare, NJ, 2010, SLACK, pp 341–356.

Multiple-Choice Questions

QUESTION 1. When should bracing be discontinued?

A. 2 to 4 weeks
B. 16 weeks
C. 10 weeks
D. 12 weeks

QUESTION 2. Which of the following are not good treatments for postoperative pain in the immediate postoperative period?

A. Cryotherapy
B. TENS devices
C. Passive range of motion
D. Open chain exercises

QUESTION 3. Which of the following is not a goal for the immediate postoperative period?

A. Restore full passive knee extension
B. Reduce joint swelling
C. Reestablish voluntary quadriceps control
D. Return leg strength to normal

Answer Key

QUESTION 1. Correct answer: **A** (see Weeks 2 to 4)

QUESTION 2. Correct answer: **D** (see Weeks 0 to 2)

QUESTION 3. Correct answer: **D** (see Weeks 0 to 2)

BEYOND BASIC REHABILITATION: RETURN TO SOCCER AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

Jason L. Koh, MD, FAAOS, and Julie O'Connell, PT, DPT, OCS, ATC

Introduction

- Soccer demands near constant running, twisting, and pivoting activity while simultaneously handling the ball with the feet.
- Kicking and one-legged balancing are requirements, and jumping to trap or head the ball is an integral part of the game.
- Physical contact with other athletes during these activities and tackling is common, and field conditions can be quite variable.
- These are all key aspects of the sport that require particular attention during the rehabilitation of soccer players.

ASPECTS OF SOCCER THAT REQUIRE SPECIAL ATTENTION IN REHABILITATION

- Ability to perform cutting, twisting and pivoting maneuvers with and without a ball
- Ability to perform extensive running activity with change of speed and direction.
- Ability to perform kicking activities of a ball
- Soccer requires jumping and landing on uneven surfaces in cleated shoewear.
- Ability to sustain and initiate contact with other athletes
- Ability to tolerate uneven surfaces with cleated shoewear

- Soccer (or football) is the most popular sport in the world, with an estimated number of over 250 million players[1].
- Anterior cruciate ligament (ACL) tears are common injuries in soccer players at all levels, from youth[2] to professional[3] athletes. The incidence of ACL injuries is quite high, with rates of 0.13 per 1000 exposures in male NCAA soccer players[4], and 4.9% to 6.2% at the professional level[5], with even higher rates for female athletes of up to 0.31 per 1000 exposures for female soccer players[4,6].
- The majority of ACL tears in soccer players are noncontact injuries[7], suggesting that neuromuscular factors may play a significant role in the etiology of these injuries.
- Multiple intervention programs have been used to attempt to decrease this incidence[8-21], with variable amounts of success. Several have demonstrated no difference in injury incidence[18]; others have demonstrated that appropriate training can substantially decrease the numbers of ACL injuries[8,10,11,13,14,21]. A recent systematic review[15] stated that evidence existed to recommend prevention programs for female athletes, but that insufficient data existed to support this conclusion for male athletes. It does appear that appropriately focused programs can be successful, even in a predominantly low income urban population[8].
- However, despite the presence of these various prevention programs, there is evidence that the overall incidence of ACL injuries has remained essentially unchanged[6], at least for women.[22]

- Since soccer is a sport that has near constant motion with extensive cutting, pivoting, and twisting, patients with ACL injured knees typically require reconstruction to return to play, but even after reconstruction, there have been challenges in returning to their previous level of activity.[3,23-25]
- Extensive physical rehabilitation, combined with psychological factors and confidence, is critical for athletes to return to competition.[26-30] Patients who undergo ACL reconstruction often have a prolonged course to return to full activity[23], with many patients not returning to soccer even at twelve months.[31,32]
- Eventual return to sports activity can be very high in some populations, such as European professional athletes[33], but many patients never return to their previous level of activity.[31,32,34]
- Many patients who do participate will leave the sport within several years.[31] Even in those who do return to sports activity, reinjury is common[35-40], with rates as high as 44%.[41] Recurrent tears of the reconstructed ligament or tears of the contralateral ACL are also common.[42] Given this information, the rehabilitation of ACL injured patients for soccer is particularly challenging and critical.

Literature

- A limited number of articles have discussed specifically the process and return to soccer after anterior cruciate ligament reconstruction.
- Return-to-sport criteria have typically been relatively non–sports-specific, with suggestions that hop tests and strength testing of at least 85% of the contralateral knee are necessary.[43]
- The Delware-Oslo ACL cohort study found that: "Hop tests conducted 6 months postoperatively statistically significantly predicted self-reported knee function ($p < .02$)"[44] Minimal other guidance has been provided for soccer.
- The return-to-sport rate after ACL injury is often an aggregate of multiple different athletic activities. Some authors have reported extremely high (94%) rates of return to soccer, but others have reported lower rates of 72%[24] or even 19%.[25] A recent paper found a 77% return to sport after injury in American Major League Soccer.[45]
- Persistent residual neuromuscular deficits[46] and abnormal kinematics[47] are not uncommon after anterior cruciate ligament reconstruction and may be related to lower levels of return to sport and repeat injury.[38]
- Increased knee abduction motion, asymmetry in internal hip rotation moment, asymmetry in knee extensor moments during a drop vertical jump, and deficits on single-legged postural assessment predicted a second injury with excellent sensitivity (92%) and specificity (88%).[47]
- Female athletes have been identified as having abnormal abduction angles and knee adductor moments and are particular risk for injury and reinjury.[48]
- Neuromuscular rehabilitation and control training can help address these issues.[20,49-51] Proprioception training, as in the PEP (Prevent injury and enhance performance) program pioneered by Dr. Bert Mandelbaum (head team physician for US Soccer), has been demonstrated to reduce the rate of ACL injury in soccer players by up to 50%.[14]
- Repeat ACL injuries or other lower extremity injuries are common after ACL reconstruction[40], and appropriate soccer-specific rehabilitation techniques that go beyond the basic rehabilitation program have been demonstrated to return patients to soccer effectively and decrease the risk of reinjury.[36,52,53]
- A randomized trial of coach-controlled rehabilitation involving return-to-match-play criteria has been demonstrated to be successful in reducing the rate of reinjury.[36]
- Sport-specific rehabilitation for soccer has shown improvements in patient function allowing a return to competition at an average of 185 days with a knee outcome survey-activity scale score of 96.[53]

Advanced Rehabilitation Program

- Match analysis shows that soccer involves substantial bursts of maximal activity with brief recovery periods, including running, jumping, pivoting, and cutting.[52]
- In addition, ball handling, contact, block, sliding tackles, and collisions on the ground and in the air are important elements of the sport.
- Enhanced rehabilitation techniques involving passing drills, shooting, dribbling, jumping, and sprinting. Block tackles, kicking into pads, and then simulated in-air contact and slide tackles are later incorporated to bring athletes back to a level where they can return to full competition.
- Our principles for athletes for return to play include both physical and psychological preparedness.
- Physical preparedness includes strength, flexibility, agility, and power; coupled with ball-specific and live contact activity. This can be done through self-report on a scale, such as the Tegner Activity Scale.[65] This scale grades activity related to ability to perform work and sport function. Also, it is important to compare returning athletes to their health counterparts in measures, such as maximum vertical jump, ball-shooting, 30-meter sprint, and yoyo intermittent endurance run.[66]
- Psychological preparedness can be assessed when watching the athlete participate in sport-specific activities and looking for apprehension during specific drills. The Tampa Scale for Kinesiophobia (TSK-11) is a self-report questionnaire used to assess pain-related fear of movement related to reinjury. The TSK-11 has 11 items, ranging with scores from 11 to 44. Higher scores are associated with higher kinesiophobia with worse self-reported knee function and a lower rate of return to sport. Characterization is made into two categories of potential coper and noncopers and the testing is done preoperation, after postoperative treatment, at 6 months postoperatively and at 12 months postoperatively.[67]

- Rehabilitation after ACL injury for soccer involves several phases, initially starting with clinic and gym sessions, followed by on field rehabilitation and progressive advancement of soccer-specific activity.
- Progression is criterion-based, rather than according to a strict timeline, and should be individualized to a specific athlete's ability to meet goals. Our program is evidence-based as much as possible and reflects the best available knowledge at this time for rehabilitation for ACL injured patients to return to soccer.
- We acknowledge the significant contribution of Dr. Lynn Snyder-Mackler and her group in developing a criterion-based rehabilitation program, particularly as it relates to soccer players recovering from ACL injuries[53-55], Drs. Holly Silvers and Bert Mandelbaum for their work with PEP[14,56], and the insight of Bizzini et al.[52,53] in training methods.

Phase I: Early Postoperative Program (weeks 0 to 6)

- Initial postoperative goals during the first 6 weeks are to control pain/swelling, to improve ROM, to achieve quadriceps activation, and to progress to full activities of daily living, including reciprocation on stairs and normalized gait.
- It is critical to obtain full knee extension (equivalent to the contralateral side) in the first 2 weeks, since extension loss has been associated with significant limitations of function and quadriceps inhibition[57-59] and is not associated with increased laxity. Prone hangs or use of an extension strap are useful to help obtain extension.
- Flexion should be at least 90° within the first week, and full flexion should be obtained by 6 to 8 weeks. This can be achieved by doing heel slides in supine, sitting or with feet on wall. Patella, patella tendon, and portal site mobilization (as incisions tolerate) are helpful to restore normal joint motion, as is use of a stationary bicycle.
- Quadriceps activation activities should begin immediately, with quadriceps contraction starting postoperatively day 1. High intensity neuromuscular electrical stimulation (NMES) has been demonstrated to improve quadriceps function[49,60] and can be initiated and progress until quadriceps strength is at 80% of the contralateral leg.
- Standing wall slides, step-ups, and other closed chain exercises in a pain-free range are typically used and may have lower graft stresses[61], although use of open chain exercises from 45° to 90° also appear to be safe.[62,63]
- Eccentric strengthening exercises starting at 3 weeks between 20° to 60° have been demonstrated to substantially (2 times) increase quadriceps muscle volume and also increase strength.[64]
- The initial goal is to achieve a straight leg raise without an extensor lag by 2 weeks, and 65% of quadriceps limb symmetry index (LSI) of opposite side by 6 weeks.[65]



FIGURE 32-32. Bridging with adduction via soccer ball squeeze.

- The use of a functional brace once straight leg raising is demonstrated can assist with athlete confidence postoperatively.
- Maintenance of cardiovascular fitness is important and we suggest use of an upper body ergometer, (arm bike), elliptical, or swimming.
- In addition to sagittal plane exercises, it is essential to address frontal plane stability including use of hip adductors and hip abductors, and this can be achieved by doing straight leg raises and isometric adductor squeezes of a soccer ball (Figure 32-32). Resisted lateral band walking is essential for gluteus medius stability.
- The transverse plane needs to be emphasized as well, including resisted side-lying hip external rotation and internal rotation.
- As described by PEP[14,56], the strengthening exercises that should be emphasized include walking lunges, Russian hamstrings, and single-toe raises. PEP also recommends an extensive lower extremity stretching program including calf stretch, quadriceps stretch (Figure 32-33), hamstring stretch, inner thigh stretch, and hip flexor stretch.
- In a desire to return to soccer, the Federation Internationale de Football Association has put together a complete warmup program related to soccer players called FIFA-11+, which has elements related to running, strength, plyometrics, and balance and strength activities, such as element #7 the bench, #8 the sideways bench, #9 hamstrings can be initiated here.[68,69]



FIGURE 32-33. Single-leg standing balance with contralateral foot on ball and movement forward and backward.

- The focus of strengthening the uninvolved leg must be addressed as well to create symmetry.

Goals (Adapted from University of Delaware Practice Guidelines[55])

Immediate Postoperative Phase (week 1)
- Achieve 0° to 90° PROM/AROM
- **Essential to achieve full knee extension to 0°.
- Ability to perform an active quadriceps contraction
- Achieve WBAT gait with proper heel strike to toe off
- Pain on VAS scale of less than 5 and trace swelling[28]

Weeks 2 to 4
- Achieve 0° to 110° PROM/AROM
- Ability to perform a straight leg raise without quad lag
- Normalizing gait with full knee extension at heel strike during gait
- Ability to climb stairs reciprocally

Weeks 4 to 6
- Achieve 0° to 130° of PROM/AROM
- Achieve 60% of quadriceps strength of uninvolved leg
- Normalized walking gait



FIGURE 32-34. Single-leg standing balance with inside of foot passing motion.

Phase II: Late Postoperative/ Transitional Phase (weeks 6 to 12)

- This phase is characterized by increasing intensity and duration of exercises, running progression, as well as the addition of soccer-specific activities including neuromuscular training and ball handling.
- A criterion-based progression for advancement is used, where the athlete may advance to running if there is a minimum of 80% quadriceps strength of LSI compared to contralateral extremity, trace effusion,[28] and no soreness.
- Soreness rules, such as in Box 32-1, and the absence of an effusion can guide advancement through a walk-to-run straight ahead program. This is initiated on a treadmill in a controlled speed environment with a basis of 10 minutes per mile pace. The program begins with walking 10 minutes and running 5 minutes and repeating twice. This progression is repeated every other day. The ratio is then decreased walking time and increased running time based on pain and swelling until full running is achieved for 2 miles or 20 minutes. The goal would be to increase distance and frequency with intensity as the third and final variable to increase. The progression occurs within a 4 to 6 week time period.
- Neuromuscular training for lower-extremity stabilization are also introduced in weightbearing positions starting with static and progressing to dynamic and reactive exercises.[65] Single-leg balance exercises can be performed when holding a ball, when throwing ball to a partner, or when a partner provides perturbations to you. Perform for 30 seconds and then compare to uninvolved side and then repeat twice. Squatting with toe raises, walking lunges, and one leg squats can also be performed as described in the FIFA11+ program[68,69] (Figures 32-33 and 32-34).
- These activities have shown to significantly improve function at 6 months and 1 year after surgery. The athlete is encouraged to begin ball-handling exercises including bouncing and juggling the ball and gentle passes with the internal and external sides of the foot.
- Gentle plyometric activities are started emphasizing quality of movement and landing, heading the ball is practiced once proper take-off, and landing techniques can be demonstrated.

BOX 32-1 Soreness Rules

No soreness	Progress
Soreness next day	Progress or hold depending on if discomfort requiring medication
Soreness > 2 days	Drop down
Soreness that goes away during session	Progress

Goals

Weeks 6 to 8
- Achieve full AROM.
- Achieve 80% of quadriceps limb symmetry index (LSI) as compared to contralateral side.
- Trace swelling. Effusion can be assessed by a stroke test and graded on a 5-point scale (none, trace, 1+, 2+ and 3+)[28]

Weeks 8 to 12
- Functional strength progression to 100% of quadriceps strength as compared to LSI of contralateral extremity leg

TIMELINE 32-5: :Return to Soccer After Anterior Cruciate Ligament Reconstruction

PHASE I (weeks 0 to 6)

- Weeks 0-2: Early Postop Phase
- Goals: Control pain/swelling; achieve quadriceps contraction
- AROM/PROM including heel slides, wall slides, and prone hang
- Mobilizations for patella, portals and patellar tendon
- Quadriceps strengthening with quad sets (NMES if necessary), TKE from 45°–90°, SLR, mini-squats
- Gait training
- Stair training
- Cardiovascular conditioning on upper body ergometer
- Ice for swelling management
- Ankle pumps in elevated position
- Weeks 2 to 6: Intermediate Postop Phase
- Goals: Achieve full extension and flexion to 110°, reciprocal stair climbing; begin frontal plane stability exercises; focus on neuromuscular control of lower extremity
- AROM/PROM to achieve 110° of knee flexion then progress to stationary bicycle and 0° of knee
- Mobilizations for patella, portals, and patellar tendon
- Quadriceps strengthening (NMES if necessary) followed by quad stretching
- Lower extremity strengthening with frontal plane emphasis for soccer ball adductor squeeze, and side-lying SLR
- Resisted lateral band walking
- Hamstring strengthening with hamstring curl and dead lift position followed by hamstring stretch
- Hip ER strengthening with clam shell exercise
- Gluteus maximus strengthening with prone SLR and bridging
- Calf strengthening with calf raises followed by calf stretch
- Single-leg standing balance and neuromuscular training exercises, such as a cone pickup
- Cardiovascular conditioning including elliptical and treadmill including retro
- Return to strengthening uninvolved leg

PHASE II (weeks 6 to 12)

Weeks 6 to 8: late postop phase

- Goals: Achieve full AROM; achieve 80% of quadriceps strength of uninvolved leg; trace swelling
- Continue progression of previous exercises
- Quadriceps strengthening with lunges in forward, lateral, and diagonals
- Eccentric quadriceps strengthening with step-downs program
- Frontal plane progression with lateral step-downs activities
- Core strengthening
- Lower extremity flexibility program

Weeks 8 to 12: transitional phase

- Goals: Increase intensity and duration of exercises; running progression
- Running progression begins:
  - A walk-to-run straight ahead program is initiated on a treadmill in a controlled speed environment with a basis of 10 minutes per mile pace for walking 10 minutes and running 5 minutes and repeating twice and repeating every other day.
  - The ratio can decrease walking and increase running based on pain and swelling until full running is achieved.
  - The goal would be to increase distance and frequency with intensity as the third and final variable to increase.
  - The progression occurs within a 4–6-week time period.

PHASE III (weeks 12 to 24)

Weeks 12 to 16: return-to-sport criteria

- Goals: Neuromuscular training and return to ball specific training; hop tests are performed if 80% of quadriceps strength index has been reached; hop tests include single hop, x-hop, triple hop, and timed hop
- For the on-field phase: On-field functional training progression on grass field with and without ball in molded cleats with progression to studded cleats; successful accomplishment of tasks allows for continued progression
  - straight ahead running without the ball in running shoes with progression to cleats and increasing speed
  - straight ahead dribbling with the ball in cleats with speed variations and stop and start
  - diagonal/backward running without the ball in cleats
  - Change of speed/direction with running without ball in cleats
  - Change of speed/direction with dribbling the ball
  - Initiate jumping and landing drills without the ball in running shoes and progress to cleats

Weeks 16 to 20: on field progression

- Goals: Aerobic/anaerobic fitness training intensity for to return to soccer activity
- Two-footed jumping and progression to one-footed jumping/landing in cleats
- Passing of a soccer ball at short distance with progression to longer distances and higher intensities with inside of foot/outside of foot and striking or shooting of ball
- Dribbling a ball beginning in a straight line and increasing speed and increasing change of direction using instep and outstep
- Partner passing and running onto a ball forward and lateral

Weeks 20 to 24

- Goals: Return to sport should include at least 90% of quadriceps maximal volitional isometric contraction and repeated and timed hop of 85% of the uninvolved side
- Practicing corner kicks, free kicks, dribbling, shooting, including quick change of direction during pass or volley.
- Progression to small sided 1 vs. 1, and 3 vs. 3 live soccer drills with contact
- Progression towards 11 vs. 11 high-intensity soccer including tackling and contact.
- Full cardiovascular anaerobic and aerobic tolerance to complete 90 minutes of soccer
- Ability to achieve preinjury status of fitness testing.



FIGURE 32-35. Single-leg standing balance with contralateral ball hold and then switch to contralateral limb.

- Balance and proprioceptive training with ability to maintain single leg balance for 60 seconds (Figure 32-35).
- Running progression on a treadmill in running shoes beginning with walk-to-run program straight ahead

Phase III: On-Field Phase (weeks 12 to 24)

- This phase is characterized by a progression of function and also increasing familiarity with soccer-specific activities to prepare the athlete physically and psychologically for a return to full soccer activities.
- The criteria to progress to an increase in activity are determined by having no physiologic changes in knee function, such as ROM or swelling changes, and no qualitative apprehension behavior demonstrated during functional progression as determined by a medical practitioner.
- Minimum criteria for progression to the on-field phase includes at least 80% quadriceps index, no instability or giving way, minimal pain, or effusion, and full or near full range of motion, as well as successfully being able to run without a limp.
- Hop tests are performed when 80% LSI has been reached. The authors describe the hop sequence as including single hop, crossover-hop, triple hop, and 6-meter timed hop.
- The elements of the plyometric portion of the FIFA-11+ program can be initiated with consisting of element #12, which is jumping vertical with knees flexed to 90° and repeating for 30 seconds and doing 2 sets followed by #12.2, which are lateral jumps from supporting leg 1-meter to the side and landing on the contralateral limb and holding for 1 second and repeating for 30 seconds for 2 repetitions. The #12.3 box jump is described as drawing a cross on the ground and jumping forward, backward, side to side, and diagonally across the cross for 30 seconds and repeating 2 times.[68,69]
- On-field progression (preferably on a well-maintained grass field) initially starts without the ball with molded cleats with progression to studded cleats.
- Initial activity (weeks 12 to 16) starts with running drills beginning with running shoes in a straight line on a grass field, with gradual increases in speed and with addition of cleats and the ball. Based on the FIFA-11+ program, running activities include straight ahead, hip out (ER position) and hip in (IR position), and elements of #13 running across the pitch at 75% to 80% acceleration, #14 bounding with 6 to 8 high steps.[68,69]
- Following successful completion of this figure-of-8 runs, followed by diagonal/backward running and changes of direction with cleats without the ball, light jumping and landing can proceed. Recommendations would be to set up 6 cones that are 5 to 6 meters apart and run forward, stop, and run backwards, then proceed to each cone. This could be repeated 3 times. A 30-meter sprint is also recognized as an appropriate training for conditioning for healthy soccer players where there would be 3 minutes in between and then repeat 3 times.[66] Also the #14 plant-and-cut of the FIFA 11+ program could begin, which includes 4 to 5 steps straight ahead followed by 5 to 7 steps at 80% to 90% acceleration to the right and changing directions to the left and going across the pitch and repeating twice.[68]
- As proficiency is demonstrated, increased intensity of speed, distance, repetitions, and turns can be implemented. PEP includes a forward run with 3-step deceleration, lateral diagonal runs, and bounding runs as important elements of agility as related to soccer players.
- During weeks 16 to 20, increased intensity for aerobic/anaerobic fitness is progressed. Fitness testing in soccer is measured with 30-meter sprint test, which is performed with a 3-minute rest in between each session and repeated 3 times as well as yoyo endurance test (also called a beep test), which is to perform a series of 20-meter shuttle runs at a pace set by an audio metronome, with a standard rest interval determined. The speed is progressively increased until the player cannot keep up with beep speed. A VO_2 max test can also be used.[66]
- Two-footed jumping with progression to one-footed jumping in cleats.
- Passing drills using the inside and outside of the foot, starting with short distances, can progress to longer distances and higher velocity. Passing and shooting on the laces can begin once confidence in side footing is established (Figure 32-36).
- Dribbling, starting with straight-line control and progressing to turns and instep/outstep control should be mastered, followed by lateral dribbling, increasing speed, and changing direction. Partner passing and running onto a ball forward and lateral can occur.
- Weeks 20 to 24 are characterized by increased intensity including running rotations, practicing corner kicks,



FIGURE 32-36. Passing and shooting of ball with involved extremity.

free kicks, and shooting, and quick sharp turns on receiving a pass or volley (Figure 32-37).
- There is a progression to small sided live soccer drills with contact (3 vs. 3, 1 vs. 1) that increase in intensity, with progression towards 11 versus 11 high-intensity soccer.
- Tackling and contact drills can occur in preparation for competition.
- Intensity of cardiovascular activity including anaerobic training should occur to return the athlete to full cardiovascular tolerance to complete 90 minutes of soccer.
- We also recommend ability to achieve preinjury status of fitness testing. This can be performing a 30-meter sprint test or the yoyo intermittent endurance run or the VO_2 max test.[66]
- Return to sport should include at least 90% of quadriceps limb symmetry index (LSI) of the opposite side quadriceps and repeated and timed hop of 85% of the uninvolved side.



FIGURE 32-37. Example of receiving a volley with the involved extremity at knee or could be at foot as well.

- Return can include reduced team training without contact; full team training with contact; friendly games with limited minutes, and return to competition, with gradual increases in duration. The reintegration process involves both a physical and mental progression for the athlete, and contact drills can help the athlete regain confidence for full sports activity.
- In general, we have found that high-level soccer players can return to previous levels of sport and ability, but this is typically a prolonged process with early return occurring at 5 to 6 months after injury.

Specific Criteria for Progression to the Next Stage to Determine Readiness for Soccer

- The criteria to progress to an increase in activity are determined by having no physiologic changes in knee function, such as ROM or swelling changes, and described as a potential coper versus a noncoper on the TSK-11.[67] Soreness rules should be stated and followed.[55]

Specific Criteria for Releasing an Athlete to Unsupervised Complete Participation in Soccer

- Successful completion of phased rehabilitation without physiologic signs of pain, swelling, instability, limp, or psychological apprehension provide confidence for provider to release back to team-based activities.[36]

Recommended Ongoing Exercises

- Success related to return-to-play is reliant upon maintaining functional strength, balance, flexibility, and cardiovascular fitness. These activities need to be completed with and without a ball and in training environments, such as on a grassy surface, with cleated shoes to simulate function necessary with activity.
- Exercises that should be maintained include closed chain strengthening (e.g., squats and lunges), jumping and landing activities (e.g., single-leg hop), and frontal plane mechanical training including cutting and side-to-side activities.[48]
- FIFA-11+program for general warmup for soccer-specific exercises should be used as well.[68,69]

Evidence

Adams D, Logerstedt D, Hunter-Giordano A, et al: Current concepts for anterior cruciate ligament reconstruction: A criterion-based rehabilitation progression. *JOSPT* 42:601–614, 2012.

This is an update of previously published, evidence-based guidelines for the management of patients after anterior

cruciate ligament reconstruction from some of the acknowledged experts in the field. (Level V evidence)

Arendt E, Dick R: Knee injury patterns among men and women in collegiate basketball and soccer: NCAA data and review of literature. *Am J Sports Med* 23:694–701, 1995.

This important study used the NCAA injury surveillance system to evaluate anterior cruciate ligament injuries over a 5-year period and demonstrated that female soccer players had an ACL tears rate of 0.31 per 1000 exposures versus 0.13 in males. (Level II evidence)

Bizzini M, Hancock D, Impellizzeri F: Suggestions from the field for return to sports participation following anterior cruciate ligament reconstruction: Soccer. *JOSPT* 42:304–312, 2012.

This is a description of soccer-specific neuromuscular control and conditioning for an effective return to sports from the FIFA Medical Assessment and Research Center, Zurich, Switzerland and the physical therapist of the English National Team and former therapist for Chelsea and Leeds football clubs in the English Premier League. (Level V evidence)

Brophy RH, Schmitz L, Wright RW, et al: Return to play and future ACL injury risk after ACL reconstruction in soccer athletes from the Multicenter Orthopaedic Outcomes Network (MOON) group. *Am J Sports Med* 40:2517–2522, 2012.

In this prospective cohort study, 100 soccer players were contacted about return to play. A total of 72% initially returned to soccer, but only 36% were still playing at an average follow-up of 7.0 years, and 20% of female players had additional ACL surgery (compared to males, 5.5%). (Level III evidence)

Della Villa S, Boldrini L, Ricce M, et al: Clinical outcomes and return to sports participation of 50 soccer players after anterior cruciate ligament reconstruction through a sport-specific rehabilitation protocol. *Sports Health* 4:17–24, 2012.

This award-winning paper followed 50 patients who underwent a soccer-specific rehabilitation protocol that included specific on-field activities. Patients had significant improvements in activity, muscle strength, and aerobic threshold during on-field rehabilitation; and average time to return to competition was 185±52 days. (Level IV evidence)

DiStasi S, Logerstedt D, Gardinier E, et al: Gait patterns differ between ACL-reconstructed athletes who pass return-to-sport criteria and those who fail. *Am J Sports Med* 40:1–9, 2013.

A total of 42 patients were evaluated for return-to-sports criteria at 6 months; 48% passed and those patients demonstrated statistically significant differences between limbs. (Level III evidence)

Hagglund M, Walden M, Ekstrand J: Lower reinjury rate with a coach-controlled rehabilitation program in amateur male soccer: A randomized controlled trial. *Am J Sports Med* 35:1433–1442, 2007.

A study where 24 teams were randomized either into a coach-controlled rehabilitation group (n = 282) or a control group (n = 300). The rehabilitation program consisted of a 10-step progressive rehabilitation protocol with return-to-play criteria. In the intervention group, the r-injury rate was significantly less (11%) than the control group (29%), with the greatest risk reduction for lower extremity injuries (75%). (Level I evidence)

Logerstedt D, Grindem H, Lynch A, et al: Single-legged hop tests as predictors of self-reported knee function after anterior cruciate ligament reconstruction: The Delaware-Oslo ACL cohort study. *Am J Sports Med* 40:2348–2356, 2012.

Article discussing when 120 patients were treated with ACL reconstruction and underwent single-legged hop testing. The crossover hop and 6-meter timed hop symmetry index at 6 months predicted self-reported knee function and could discriminate those patients who had good function. Preoperation testing did not predict postoperative outcomes. (Level III evidence)

Mandelbaum BR, Silvers HJ, Watanabe DS, et al: Effectiveness of a neuromuscular and proprioceptive training program in preventing anterior cruciate ligament injuries in female athletes: 2-year follow-up. *Am J Sports Med* 33:1003–1010, 2005.

A key article following 1885 female competitive youth soccer players prospectively enrolled in a sport-specific neuromuscular and proprioceptive performance program (PEP) compared to 3818 age- and skill-matched controls in the same league over a 2-year period. During the first season, there was an 88% decrease in anterior cruciate ligament injury in the enrolled subjects; in the second season, there was a 74% reduction in anterior cruciate ligament tears. (Level II evidence)

Stearns K, Pollard C: Abnormal frontal plane knee mechanics during sidestep cutting in female soccer athletes after anterior cruciate ligament reconstruction and return to sport. *Am J Sports Med* 41:918–923, 2013.

Study where12 female soccer players with a history of anterior cruciate ligament reconstruction were compared to a control group and who demonstrated increased knee abduction angles and peak knee adductor moments, despite return to sports. (Level III evidence)

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Multiple-Choice Questions

QUESTION 1. In the Brophy et al. study of 100 soccer players returning to play after ACL, what percentage of players initially returned to soccer?

A. 36%
B. 20%
C. 72%
D. 80%

QUESTION 2. Which of the following is not an element of the FIFA 11+ warmup for soccer players?

A. Strengthening exercises
B. Flexibility exercises
C. Running
D. Plyometric exercises

QUESTION 3. All of the following exercises are elements of PEP EXCEPT:

A. Walking lunges
B. Russian hamstrings
C. Single-toe raises
D. Squats

QUESTION 4. What measure is available to assess the psychological preparedness of an athlete to return to sport?

A. The Tegner activity scale
B. The Tampa scale for kinesiophobia
C. PEP
D. FIFA 11+ program

QUESTION 5. When has eccentric strengthening from 20° to 60° been shown to increase quadriceps muscle volume (2 times) and to increase muscle strength after ACL reconstruction

A. 3 weeks
B. 4 weeks
C. 6 weeks
D. 12 weeks

Answer Key

QUESTION 1. Correct answer: **C** (see Evidence, Brophy et al.)

QUESTION 2. Correct answer: **B** (see Phase I: Early Postoperative Program)

QUESTION 3. Correct answer: **D** (see Phase I: Early Postoperative Program)

QUESTION 4. Correct answer: **B** (see Advanced Rehabilitation Program)

QUESTION 5. Correct answer: **A** (see Phase I: Early Postoperative Program)

POSTOPERATIVE REHABILITATION AFTER ANATOMIC ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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Indications for Surgical Treatment

- Participation in high-demand sports that involve cutting, jumping, pivoting, and quick deceleration.
- Heavy work and physically demanding occupations.
- Persistent knee instability in spite of rehabilitation.
- Multiligamentous and concomitant injuries to additional structures within the knee.
- The timing of ACL reconstruction surgery has a strong influence on postoperative knee stiffness and rehabilitation. To decrease the risk of postoperative stiffness and delayed rehabilitation, surgery should be performed when pain and swelling are well controlled, and when gait and range of motion have been restored to normal or near normal, and the patient can perform a good quad set and straight leg raise without a quadriceps lag.

Brief Summary of Surgical Treatment

Patient Set-Up

- Regional anesthesia when possible: femoral or sciatic nerve blocks or spinal anesthesia.
- A thorough exam under anesthesia compared to the contralateral knee is critical.
- Well-padded tourniquet placed high on the operative extremity. Positioned within leg holder to allow flexion greater than 125 degrees (Figure 32-38).



FIGURE 32-38. Operative extremity positioned in a well-padded tourniquet and a leg holder, which allows flexion angles greater than 125°.

Individualized Anatomic ACL Reconstruction: Major Steps in Technique

- Three portal techniques: A high anterolateral (AL) portal, an anteromedially placed central portal (CP), and an accessory anteromedial (AM) portal (Figure 32-39).
- Diagnostic arthroscopy is performed to characterize ACL rupture and associated pathology.
- Intraoperative measurements of the native ACL anatomy help determine operative technique. (Figure 32-40)
  - A patient's notch and insertion site size are variable and do not correlate to the patients height, weight, or BMI.
  - In cases with a smaller notch or insertion site a single bundle technique is preferred. In patients with a larger notch and insertion site, a double bundle technique is preferred.
- Anatomic SB ACL Reconstruction:
  - A single femoral tunnel is centered within the native femoral footprint.
  - The tibial tunnel is centered within the native footprint with the tibial guide set to 55 degrees.

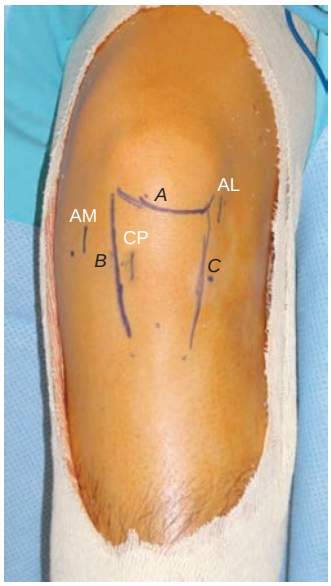

FIGURE 32-39. Three-Portal Arthroscopic Technique: High anterolateral (AL) portal, an anteromedially placed central portal (CP), and an accessory anteromedial (AM) portal. Patellar anatomic landmarks and joint line are used to make the incisions. (**A**) Inferior pole of the patella. (**B**) Medial border of the patella tendon. (**C**) Lateral border of the patella tendon.

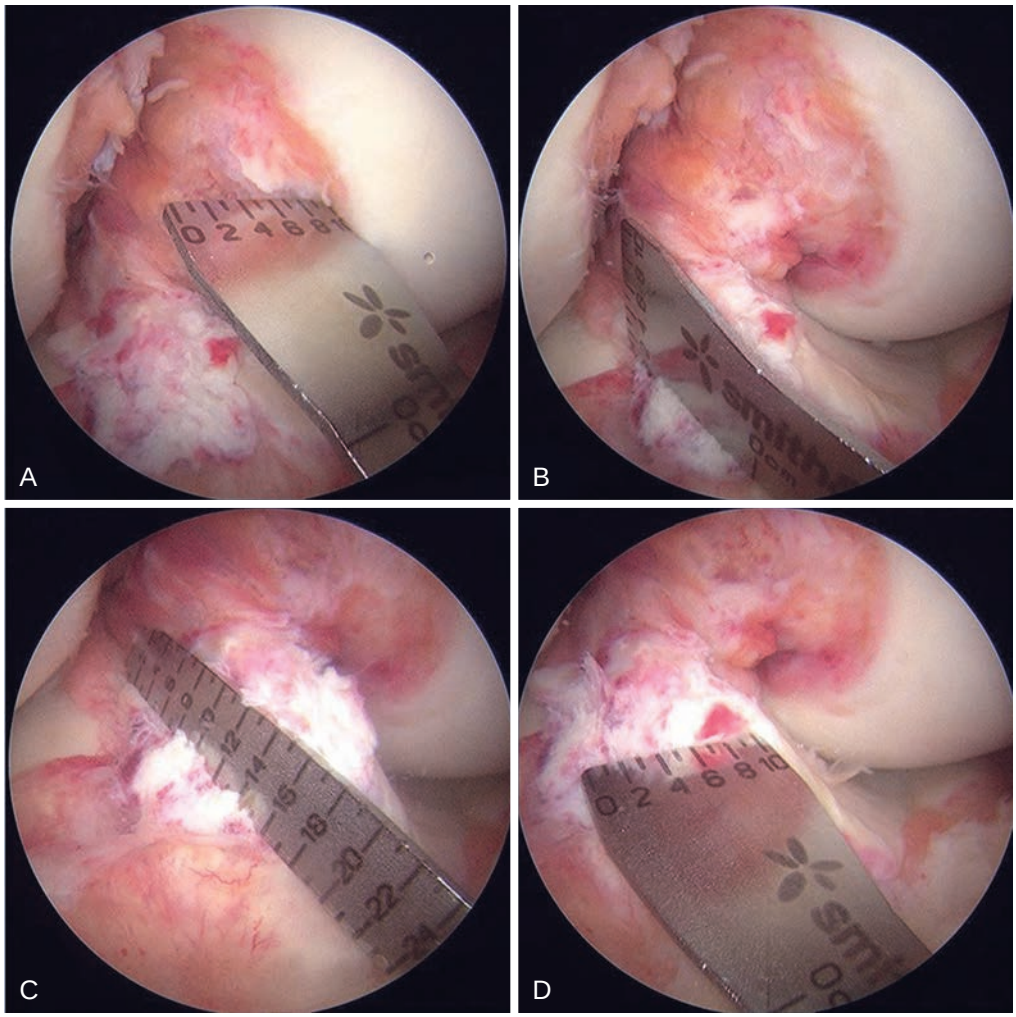

FIGURE 32-40. Intraoperative measurements with an arthroscopic ruler are used to determine operative technique. (**A**) Notch width. (**B**) Notch height. (**C**) Tibial insertion site length. (**D**) Tibial insertion site width.

  - The graft is tensioned and fixed in 10 to 15 degrees of flexion.
- Anatomic DB ACL Reconstruction:
  - The PL femoral tunnel is drilled first with the knee held in 110 degrees of flexion.
  - The tibial PL and AM tunnels sequentially drilled, being careful to avoid tunnel convergence.
  - Next, the femoral AM tunnel is drilled via AM/PL tibial tunnels or the AMP as the patient's anatomy dictates.
  - The AM tunnel can be drilled through either the PL tibial tunnel (50% of the time), or the AM tibial tunnel (10% of the time).[1]
  - Sequence of graft passage: The PL graft is passed before AM graft.
  - The PL bundle graft is tensioned and fixed in full extension.
  - AM graft is tensioned and fixed in 45 degrees of flexion.
- Graft Fixation:
  - Standard fixation techniques include tying over a post, suspensory fixation (i.e. endobutton), and interference screws.

Factors That May Affect Rehabilitation

Anesthetic

- Patients may complain of pain and weakness in the upper portion of the thigh secondary to the regional anesthesia injections. This pain is transient and should not interfere with normal rehabilitation protocol.
- Regional analgesia may wear off 8 to 24 hours after the case. A careful transition to oral analgesics is important to facilitate early rehabilitation.

Surgical

- Graft choice:
  - Allograft ACL reconstruction requires slower rehabilitation and return to sports to allow for slower graft incorporation and healing.[2,3]
  - Bone plugs facilitate a more rapid osseous integration within bone tunnels when compared to soft tissue grafts.
- Anatomic Placement of the Grafts:
  - An anatomically placed ACL experiences more forces than a nonanatomically placed ACL.[4] The

increased forces can result in early rupture and a careful rehabilitation must be followed.
- Postoperative donor-site morbidity and anterior knee pain:
  - Harvest of an autograft can lead to specific postoperative donor-site morbidity.
  - Anterior knee pain and decreased sensation are associated with patellar tendon autografts.[5]
  - Hamstring autografts have less anterior knee pain[6–8] but may produce weakness at higher flexion angles.[9]
- ACL reconstruction in association with concomitant injuries:
  - Modifications must be made to the rehabilitation program following repair or reconstruction of menisci or in cases of multiligamentous injury.
  - A higher incidence of stiffness is associated with MCL repair.
  - Chondral lesions require a more careful rehabilitation program.
- Tourniquet use:
  - Prolonged tourniquet use may affect lower limb strength.[10]
- Meniscal surgery
  - Meniscal surgery may require a modified rehabilitation protocol depending on surgeon and rehabilitation specialist preference.
  - Following meniscal repair, hyperflexion should be restricted. Immobilization at or near full extension (10° to 20° flexion) has been shown to allow for better approximation of longitudinal tears.[11]
  - Either partial weightbearing or no weightbearing is another common modification of ACL rehabilitation protocols following meniscal surgery.
  - Following meniscus repair, flexion is limited to 90° the first 4 to 6 weeks after surgery.

Before Surgery: Overview of Goals, Milestones, and Guidelines[3]

The goals of preoperative rehabilitation (or prehabilitation) are to control pain and swelling, restore normal range of motion, achieve a good quad set and the ability to perform a straight leg raise without a lag, and develop muscle strength sufficient for normal gait and activities of daily living (ADL). Additionally, prehabilitation can be used to mentally prepare the patient for surgery and the postoperative rehabilitation protocol thereafter.

Immobilization

- For isolated ACL rupture bracing is not routinely necessary.
- Crutches may be necessary for assistance immediately after injury. Once pain and swelling have resolved, quadriceps strength is sufficient for a normal gait and the patient can demonstrate a normal gait without a flexed knee at heel strike and mid-stance, assistive devices may not be discontinued.
- Patient should bear weight as tolerated.

Pain and Swelling

- Ice and elevation along with nonsteroidal antiinflammatory drugs (NSAIDs).
- NSAIDs should be continued for 7 to 10 days following acute injury.

Restoration of ROM and Strength

- Quadriceps function can be inhibited by post-injury disuse and the presence of an effusion.
- Preoperative ROM exercises and quadriceps strengthening exercises (e.g., quad sets, straight leg raises) should be started as soon as tolerated. These exercises will help to improve quadriceps strength and reduce the effusion.
- Aquatic therapy can be initiated for strengthening if normal weightbearing is not tolerated.

Prehabilitation exercises should be discontinued if pain and swelling worsen as a result.

GUIDING PRINCIPLES OF POSTOPERATIVE REHABILITATION

- Understand surgical technique, graft choice, and fixation method.
- Understand graft healing and adjust progression of functional activities accordingly.
- Understand the implications of associated pathology and multiligamentous injuries (e.g., meniscal tears, posterior cruciate and collateral ligament injuries, chondral damage).
- The importance of immediate mobilization in recovery of strength and ROM.
- Guidelines for return to sports and prevention of future ipsilateral and contralateral knee injury.

This chapter describes postoperative ACL reconstruction guidelines that are divided into six phases. Though approximate timeframes within each phase are mentioned, patient progression depends on the clinical impression of the surgeon and or rehabilitation specialist.

Phase I: Immediate Postoperative Period (days 0 to 14)

Clinical Pearls

- The highest incidence of knee stiffness occurs if ACL reconstruction surgery is performed in the presence of knee swelling, pain, limited range of motion, and the inability to perform a good quadriceps contraction. The risk of developing a stiff knee after surgery can be significantly reduced if the surgery is delayed until after the acute inflammatory response has subsided (e.g., reduced pain

[3]*Prehabilitation, if appropriate, is described in the Nonoperative Rehabilitation section of this chapter.*

and swelling, a near normal range of motion, a good quadriceps contraction, and normal or near-normal gait pattern has been re-established.
- Restoring ROM in an early phase decreases pain and prevents patellofemoral problems. It also prevents alterations in gait, quadriceps atrophy, scar formation, capsular contractions, and adverse chondral changes.

Goals

1. Control postoperative pain and swelling.
2. Protect the healing structures.
3. Obtain full passive and active knee extension symmetrical to the noninvolved side
4. Obtain 90° to 120° of flexion, provided a meniscus repair has not been performed. If a meniscus repair was performed, flexion is limited to 90° for the first 4 to 6 weeks.
5. Maintain or restore patellar mobility, especially superior glide which is necessary for full active extension of the knee.
6. Re-establish quadriceps control so that the patient can perform a good quad set, resulting in a full quadriceps contraction and superior migration of the patella and the ability to perform a straight leg raise without a quadriceps lag.

Protection

- Postoperative immobilization using a brace locked in full extension and axillary crutches to assist with weight bearing and encourage full extension.
- If no concomitant meniscal repairs, the brace may be unlocked for ambulation after the first week.
- Concomitant meniscal repairs require that the brace be locked in full extension for 4 to 6 weeks postoperatively.
- After unlocking the brace, weight bearing as tolerated is permitted with crutches during ambulation emphasizing a normal heel-toe gait pattern.

Management of Pain and Swelling

- Primary approach utilizing a combination of cryotherapy, compression, and elevation.
- A multimodal approach with oral pain medication in addition to nonsteroidal antiinflammatory drugs (NSAIDs) should be instituted to minimize inflammation.
- Early active and active-assisted motion exercises.[12]

TIMELINE 32-6: **Postoperative Rehabilitation After Anatomic Anterior Cruciate Ligament Reconstruction**

PHASE I (weeks 1 to 2)	PHASE II (weeks 2 to 6)	PHASE III (weeks 6 to 12)
• Crutches WBAT—brace may be unlocked for gait training after 1st week. Brace locked in extension, unlocked after 1st week • Cryotherapy, compression, and elevation to control pain and swelling • Passive and active-assisted ROM with emphasis on regaining full passive extension • Calf and hamstrings stretching • Quad sets and SLR • Gentle patellar mobilization (grade 1–2) • High-intensity electrical stimulation for quadriceps—10 s on/50 s off for 10 min once per day • Weight-shifting exercises	• Crutches WBAT, discontinue when symmetrical extension, no quadriceps lag, 120° flexion and normal gait • Brace is unlocked and continued until 120° flexion • Cryotherapy to control pain and swelling • Continue passive and active-assisted ROM • Continue calf and hamstring stretches • Continue quad sets and SLR—add resistance for SLR as tolerated • Progress weight-shifting exercises to unilateral balance exercise • Continue patellar mobilization as necessary to restore normal patellar mobility—emphasis is on normal superior glide to permit full active extension without a quadriceps lag • Continue high intensity electrical stimulation • Biofeedback training if difficulty initiating and maintaining a quad set • OKC knee extension from 90°–60° with light resistance (ankle weights) • OKC knee flexion from 0° to 90° with light resistance (ankle weights) • Weight-bearing CKC exercises from 0° to 45°—begin with weight equally distributed on each leg and progress to unilateral exercise as tolerated (mini-squats, wall slides, step-ups) • Pool therapy for ROM and gait training	• Crutches are discontinued • Brace is discontinued • If ROM goals are not met, additional physical therapy interventions may be necessary, such as cyclic or static stretching, joint mobilization, and serial casting or splinting • When the patient achieves full extension, 90° to 100° flexion, SLR without lag, no pain or swelling and normal gait, the intensity and frequency of physical therapy is increased to 2–3 times/wk • Continue passive and active-assisted ROM • Continue calf and hamstring stretches • Continue patellar mobilization • Progressive resisted OKC knee extension from 90° to 45° (progress to weight machine as tolerated) • Progressive resisted OKC knee flexion from 0° to 90° (progress to weight machine as tolerated) • Progressive resisted hip exercises • Progressive resisted unilateral weight-bearing CKC exercises from 0° to 60° (e.g., leg press, squats, lunges) • Balance and perturbation training exercises • Low-level plymometrics (e.g., step and land, bilateral low-level box drops) • Walking-based agility exercises • Low impact aerobic training (e.g., ergometer, elliptical, treadmill) • Continue high intensity electrical stimulation

Table 32-5 IKDC Guidelines Using Differences in Range of Motion as Compared to the Contralateral (Uninjured) Knee.

IKDC Guidelines	Extension	Flexion
Normal	<2°	<5°
Nearly Normal	3-5°	6-15°
Abnormal	6-10°	16-25°
Severely Abnormal	>10°	>25°

Techniques for Progressive Increase in Range of Motion

- Measure ROM using a goniometer and interpret according to IKDC guidelines (Table 32-5).

Manual Therapy Techniques

- Patellar mobilization in the directions of medial/lateral and superior/inferior glide should be performed to patella to prevent loss of patellar mobility, which can predispose to quadriceps inhibition, and arthrofibrosis.

Soft Tissue Techniques

- Wound care for incisions.
- Suture removal 1 week after surgery.

Stretching and Flexibility Techniques for the Musculotendinous Unit

Extension

- Hamstring and gastrocnemius stretches should be initiated immediately after surgery
- Full passive extension symmetrical to the noninvolved knee should be achieved by the first or second postoperative week.
- A safe, prolonged stretch into extension can be achieved by performing the "prone hangs" without (Figure 32-41*A*) or with a light weight (Figure 32-41*B*), or "heel props" (Figure 32-41C).
- Passive knee extension involves relaxing the knee under its own weight with the heel propped and the knee unsupported such as resting the heel on another chair or stool while sitting.

Flexion

- Flexion is gradually increased after the first postoperative week.
- 90 to 100 degrees of knee flexion should be achieved within 2 to 3 weeks after surgery (unless concomitant meniscus repair in which case knee flexion is limited to 90 degrees for 4 to 6 weeks after surgery).

TIMELINE 32-6: **Postoperative Rehabilitation After Anatomic Anterior Cruciate Ligament Reconstruction** (Continued)

PHASE IV (weeks 12 to 20)	PHASE V (weeks 20 to 32)	Phase VI (weeks weeks 32 to 52)
• Depending on progression, insurance and desired level of activity, physical therapy is continued • Home exercise program for continued strengthening • Gradually progress to functional re-training and conditioning program • Frequency of physical therapy can be decreased to 1–2 times/mo to monitor and progress the program • Progression of activity is dependent on absence of pain, swelling and instability, recovery of quadriceps strength, progression of physical activities, and physician clearance • Stretching exercises of hamstrings, calf, quad, iliopsoas, tensor fascia lata/IT band, and hip adductors • Full-arc, progressive, resisted OKC knee-extension exercises • Full-arc, progressive, resisted OKC knee-flexion exercises • Progressive resisted hip exercises • Quantify muscle strength regularly • Full-arc, progressive, resisted unilateral weight-bearing CKC exercises (e.g., leg press, squats, lunges) • Advanced balance and perturbation training exercises (e.g., random, larger destabilizing loads) • Start pool therapy for preparation to return to running and jumping • Gradually progress to in-line jogging (no jumping or cutting)	• Depending on the quad index, activity can be progressed. When symmetrical muscle bulk is achieved, use of a functional brace is recommended • Continue muscle stretching • Continue muscle strengthening (OKC/CKC) while increasing resistance • Gradually advance balance and perturbation training exercises to plyometric exercises. Depending on quad index advance to single-leg activities • Start submaximal agility exercises and gradually progress to sprinting and cutting drills, depending on the quad index	• Use of a functional brace is recommended for at least the duration of the first full season • Continue muscle strengthening (OKC/CKC), but decrease frequency to 1 to 2 times per week for maintenance when symmetrical strength is achieved • Make plyometric exercises more challenging and emphasize correct movement patterns • Progress agility drills to sport specific training activities • Gradual return to practice, starting with unopposed drills, progressing to opposed drills followed by return to competition

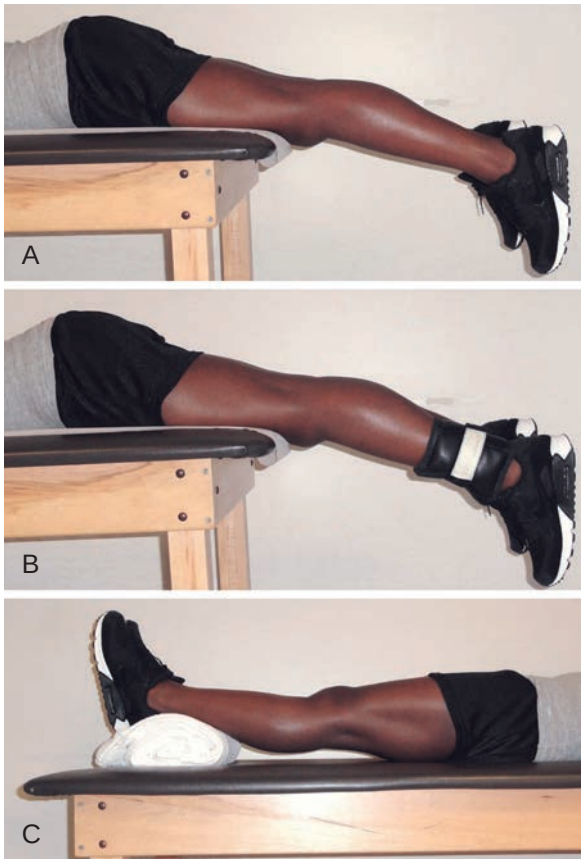

FIGURE 32-41. Prone hang exercise without (**A**) and with (**B**) a light ankle weight. Note that the knee is off the edge of the table. (**C**) Heel prop exercise using a rolled towel.

- Increase in knee flexion can be achieved through the initiation of heel slides (Figure 32-42) and passive, active-assisted, and or active knee flexion exercises (Figures 32-43 and 32-44) immediately after surgery.

ROM

- Continuous passive motion (CPM) may be considered to increase ROM.

Other Therapeutic Exercises

- Side-lying straight leg raises (Figure 32-45) may be performed to increase strength of the gluteus medius. When performing side-lying hip abduction, the hip should be slightly extended and externally rotated to facilitate activation of the gluteus medius.
- Prone hip extension may be performed to increase strength of the gluteus maximus and hamstrings.
- Side-lying hip adduction may also be performed, however if concomitant MCL repair was performed, hip adduction exercises should be deferred for 4 to 6 weeks to avoid premature valgus stress on the healing MCL.
- Standing heel raises with the weight equally distributed on both legs may be performed to provide exercise for the calf muscles. Resistance is limited to body weight only at this point in the rehabilitation process.



FIGURE 32-43. Wall slides. The patient is instructed to allow the operative knee to gently slide down the wall by bending the knee. The nonoperative leg can be used to apply an additional downward force (as shown).

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Quad sets and straight leg raises are used to regain control of the quadriceps muscle.
- Based on the current best evidence high intensity neuromuscular electrical stimulation (NMES) for the quadriceps should be used for all patients starting within the first week after surgery.[6,13] When performing high intensity NMES, the electrically elicited

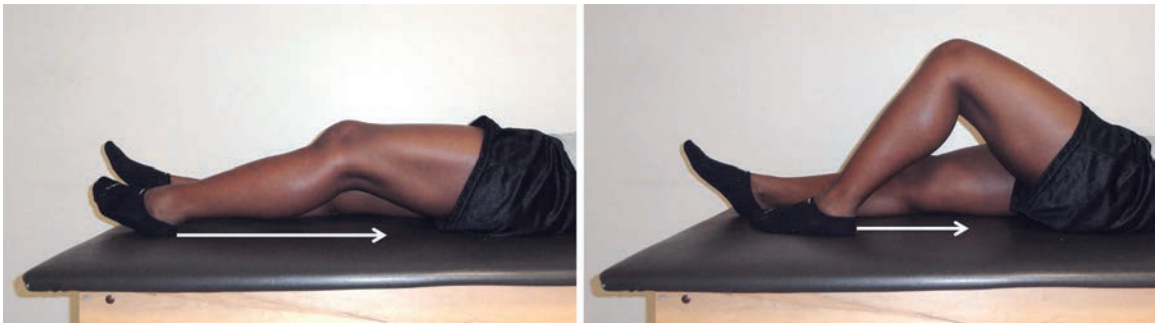

FIGURE 32-42. Heel slides. Heel is pulled towards the buttocks cycling in as full ROM as tolerated.



FIGURE 32-44. Beginning with the operative leg resting on top of the nonoperative leg in full extension, the patient is instructed to gradually allow the injured leg to fall into flexion. When the operative leg is maximally flexed (depending on the patient's comfort), the nonoperative leg is placed on top of the operative leg to apply a gentle force into further flexion.

contraction should be a sustained tetanic contraction of sufficient intensity to cause the patella to migrate superiorly.

- Prone isometric hamstring exercises with the knee in 30° to 45° of flexion may be performed for patients that underwent reconstruction with an allograft or bone–patellar tendon-bone autograft. For patients that underwent harvest of a hamstring graft or for those that had a meniscus repair, isometric hamstring exercises are avoided for the first 4 to 6 weeks to allow for soft tissue healing.
- If patients have difficulty regaining quadriceps control, as evidenced by the inability to perform an isolated quadriceps contraction, biofeedback training should be considered.



FIGURE 32-45. Straight leg raise. (**A**) Prone straight leg raise. (**B**) Seated straight leg raise.

Open and Closed Kinetic Chain Exercises

- Open kinetic chain exercises with resistance for the quadriceps and hamstrings are not indicated within the first 2 weeks of surgery.
- The patient may perform a simulated leg press from 60° to 0° against light elastic tubing in the seated position.
- Standing weight shifts, in which the patient shifts his or her weight to the surgical leg may be performed. Initially the patient should be encouraged to bear 50% body weight on the surgical leg. Gradually, the amount of body weight that can be borne by the surgical leg is increased until the patient can bear full body weight and maintain balance during single leg stance. When performing the weight shifts, the patient should keep the knee in extension, but not hyperextension, and the patient should also perform a standing quad set when shifting weight to the surgical knee. Care should be taken to avoid an instability episode of the surgically reconstructed knee.

Techniques to Increase Muscle Strength, Power, and Endurance

- Emphasis during the first 2 weeks after surgery is on regaining motor control, not on increasing muscle strength, power, and endurance.

Neuromuscular Dynamic Stability Exercises

- Neuromuscular dynamic stability exercises during the first 2 weeks after surgery are limited to regaining control of the muscles crossing the knee, straight leg raises for improved hip muscle function, and weight shifts in standing.
- Limited trunk and core stabilization exercises with an emphasis on the abdominal muscles (Figure 32-46) can be performed at this time.



FIGURE 32-46. Abdominal hold exercise for balance, core muscle stabilization, and lumbopelvic muscle strengthening.

Milestones for Progression to the Next Phase

- Minimal pain and swelling of the knee
- Full passive extension symmetrical to the noninvolved knee
- Ability to perform an isolated contraction of the quadriceps that results in full broadening of the muscle and superior migration of the patella
- Ability to perform a straight leg raise without a quadriceps lag
- 90° to 100° of knee flexion.

Phase II (weeks 2 to 6 postoperatively)

Clinical Pearl

During the early phases of rehabilitation, graft strength is suboptimal. Attention should focus on restoring ROM and improving muscle strength[14]. During this phase of rehabilitation, quadriceps and hamstring strength can be maximized without endangering the graft by utilizing isometric and limited arc progressive resistance exercises. Inadequate progression of ROM, especially with regards to extension, should be treated aggressively.

Goals

- Protect the healing structures.
- Reverse the effects of immobilization and restore ROM.
- Further develop muscle control and strengthening.
- Restore normal gait pattern and increase tolerance for ambulation.

Protection

- The brace is continued until the patient has comfortably achieved 120° of knee flexion.
- Weight bearing as tolerated (WBAT) with crutches assistance is continued until the following criteria are met:
  - Minimal pain and swelling
  - Full passive knee extension symmetrical to the noninvolved knee (measure ROM and use IKDC score in Table 32-5).
  - At least 100° to 120° of knee flexion.
  - Able to perform a straight leg raise without an extensor lag.
  - Normal gait pattern when walking without crutches.

Management of Pain and Swelling

- Cryotherapy, compression, and elevation should be continued to control pain, swelling, and inflammation. Persistent pain, swelling, and inflammation may result in decreased ROM, decreased quadriceps control, altered gait pattern, and a prolonged rehabilitation process.
- Transition to oral antiinflammatory medication is encouraged.
- Cryotherapy is recommended after exercise to control pain, swelling, and inflammation

Techniques for Progressive Increase in Range of Motion

- Measure ROM (using a goniometer) and interpret findings according to IKDC guidelines.

Manual Therapy Techniques

- Mobilization of the patella is continued to restore normal patellar mobility and to prevent arthrofibrosis.

Soft Tissue Techniques

- Scar mobilization of postsurgical incisions once closed.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Restore full extension symmetrical to the noninvolved side:
  - Continue hamstring and calf stretching.
  - Continue with passive knee extension including prone hangs and sitting with the heel propped and knee supported.
  - Passive manual stretching to increase knee extension may be used as necessary.
- Continue to gradually increase knee flexion to within 10° of the contralateral side by 6 weeks. If a meniscus repair was performed, ROM beyond 90° is permitted after 4 to 6 weeks and flexion and should be within 10° of the contralateral side 8 to 10 weeks after surgery. Activities to increase flexion include:
  - Active and active-assisted ROM—heel slides, wall slides (see Figure 32-42)
  - Manual and self-administered stretching
  - Riding stationary bike with seat adjusted to require increasing knee flexion. Resistance when pedaling stationary bike should be minimal at this time to avoid increased swelling and inflammation.
- Once the postsurgical incisions are closed, pool exercises can also be used to improve ROM, strength and gait. For example performing ROM of the knee, walking, and simulating bicycle motion in the pool. No jogging, diving, or whip kicks in the pool at this time.

Other Therapeutic Exercises

- Continue 4-way leg raises for strengthening hip flexors, extensors, abductors, and adductors. Light resistance can be applied below the knee. However, following MCL or LCL/posterolateral corner reconstruction, the resistance should be applied above the knee for hip adduction and abduction respectively.
- Continue heel raises, progressing to single leg heel raises as tolerated.
- Continue trunk and core stabilization exercises as tolerated.
- Upper body weight training can be initiated provided all exercises are performed in the seated or recumbent position.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Continue quad sets and straight leg raises. Emphasis should be on performing an isolated quadriceps contraction with hamstring co-contraction. During contraction of the quadriceps with the knee in full extension, the patella should glide superiorly symmetric to the contralateral side. Resistance can be added at ankle for SLR once the patient can perform a SLR without a quadriceps lag.
- High intensity NMES for the quadriceps should be continued.
- Biofeedback should be used if the patient has difficulty initiating a quad set. The physician should be alerted if the patient has a persistent knee extensor lag beyond 3 to 4 weeks after surgery.

Sensorimotor Exercises

- Standing weight shifts can be transitioned to single leg balance as tolerated. Initially this should be performed on a stable surface with eyes open with the knee in extension, but not hyperextension. The pelvis should remain level, and the trunk should remain stable.
- Single leg balance can be progressed to standing balance on a flexed knee (30°).
- When the patient can balance on a single leg with minimal deviations, balance activities can be progressed to an unstable surface (foam mat) and be performed with the eyes closed.

Open and Closed Kinetic Chain Exercises

- Limited arc open chain knee extension from 90 to 60° of flexion in seated position may be started once the patient has 100° of knee flexion. Light resistance up to 10 lbs. can be applied to ankle. Once the patient can perform limited arc knee extension with 10 lbs., the exercise can be transitioned to a leg extension machine.
- Unless the patient had a meniscus repair or a hamstring graft was harvested, the patient can begin performing resisted knee flexion in the prone and standing position from 0° to 90° once they have achieved 100° to 120° of active knee flexion. Light weight can be applied at the ankle. The exercise can be transitioned to a leg curl machine, once the exercise can be performed with 10 lbs. If the patient had a meniscus repair or a hamstring graft was used, resisted exercise for the hamstring is delayed until 6 to 8 weeks to permit sufficient soft tissue healing.



FIGURE 32-47. Mini-squats using a table for stabilization.

- Weight-bearing closed kinetic chain exercises; in the form of mini-squats (Figure 32-47) and wall slides may be performed in the range from 0° to 60° of flexion. Weight should be equally distributed on each leg. Weight-bearing CKC should be delayed until 6 to 8 weeks if there as a concomitant articular cartilage procedure performed.
- Leg press, using both legs simultaneously can be initiated with light resistance (less than body weight).
- Single leg CKC exercises in the form of single leg mini-squats and step ups/downs to and from a low height (3 inches) may be initiated if the patient demonstrates the ability to balance on a flexed knee with minimal hip or postural sway. During this phase, single leg CKC should be limited to 0° to 45° of knee flexion.

Techniques to Increase Muscle Strength, Power, and Endurance

- Progressive resistance exercises as described above are used to initiate muscle strengthening. Three to five sets of 8 to 12 repetitions are performed using resistance that is perceived to be light to moderate by the patient.
- Pedaling a stationary ergometer with low resistance can be initiated to improve cardiovascular endurance once the patient can comfortably pedal the bike freely without pain, stiffness, or swelling.
- Pain and swelling must be carefully monitored during this phase to avoid an increased or sustained inflammatory response of the knee.

Neuromuscular Dynamic Stability Exercises

- Neuromuscular dynamic stability training is essential for functional recovery following ACL reconstruction and secondary prevention (re-rupture or graft or contralateral ACL tear).
- During this period of time, neuromuscular dynamic stability training is limited to the hip, core, balance, and CKC exercises described above.

Functional Exercises

- Gait-training is performed to ensure that the individual uses a normal heel-toe gait and does not walk with a flexed knee during the mid-stance phase of gait.

Sport-Specific Exercises

- Sport-specific exercises are not encouraged during this phase of rehabilitation.
- Patients should be educated concerning their rehabilitation program and the expected time frame and requirements for return to activity.
- Careful adherence to the rehabilitation protocol and timely progression is necessary to allow for graft healing, especially for allograft ACL reconstruction.

Milestones for Progression to the Next Phase

- Minimal pain and swelling
- Full passive knee extension symmetrical to the contralateral knee and the ability to perform a SLR without a lag.
- 120° of knee flexion.
- Ability to walk without assistive devices or gait deviations.

If the patient is progressing well without complications (infection, signs and symptoms of instability or failed reconstruction, or intractable pain and swelling), he or she may progress to the next rehabilitation phase.

Phase III (weeks 6 to 12 postoperatively)

Clinical Pearl

The focus of Phase III rehabilitation is on increasing quadriceps strength and increasing tolerance for walking with a normal gait. Limited arc OKC and CKC quadriceps exercises with moderate to heavy resistance are used to increase quadriceps strength. To achieve normal gait, focus should be placed on achieving full extension at heel strike and at the end of the midstance phase. A "bent knee gait" that persists throughout midstance should be closely examined and treated. The ability to maintain a normal gait during sustained walking is emphasized.

Goals

- Continue to protect the healing structures.
- Restore full ROM symmetrical to the contralateral knee.
- Progress strength training for all key muscle groups in both lower extremities.
- Increase tolerance for walking.
- Increase cardiovascular endurance.
- Continue to progress hip and core muscle strengthening, balance, and development of neuromuscular dynamic stability.

Protection

- Use of crutches and rehabilitation brace have been discontinued.
- Functional brace is not used for rehabilitation activities during this phase of rehabilitation.

Management of Pain and Swelling

- Pain and swelling should be minimal. If present, continue oral analgesics as needed.
- Cryotherapy should be used after exercise to minimize pain and swelling associated with activity induced inflammation.
- Pain and swelling during rehabilitation exercises should guide the rehabilitation progression. If pain and swelling persist or increase, the pace and intensity of the rehabilitation program should be reduced.
- The soreness rules described by Lynch et al. are helpful to guide progression of the rehabilitation program.[15]
- Persistent, moderate to severe pain, and swelling should be brought to the attention of the referring surgeon.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Patellar mobilization may be used as needed to address hypomobility or complaints of patellofemoral pain
- Tibiofemoral joint mobilization may be used as needed to restore full ROM of the knee.

Soft Tissue Techniques

- Scar mobilization of incisions may be continued as needed.

Stretching/Flexibility Techniques for the Musculotendinous Unit

- Stretching for the hamstrings and calf muscles is continued.
- Stretching for the rectus femoris, iliotibial band, hip flexors, and hip adductors is initiated as indicated based on assessment of length of these muscle groups.
- Mobilization and passive stretching of the joint is used as indicated to restore full passive extension and flexion of the knee. Stretching to restore full joint motion may make use or prolonged low-load or repeated cyclic stretch as tolerated by the patient.

Other Therapeutic Exercises

- Hip and lumbopelvic stabilization exercises are continued to improve motion control of the lower extremity during functional activities. Emphasis is on developing muscles to prevent excessive hip adduction and internal rotation and trunk sway and lean.
- Four-way hip exercises in the recumbent position may be replaced with four-way hip exercises in standing with the use of elastic bands for resistance.
- Side steps and diagonal walking with elastic bands for resistance can be used for further strengthening of the

hip. Core and balance exercises should include activities that focus on strengthening the internal and external obliques, recuts abdominus, transverse abdominus, multifidus and erector spinae muscles, and paraspinal musculature.
- Core stabilization exercises, such as plank or Navy Seal holds, pelvic tilts, bridging, and lateral side support, have been used in injury prevention programs and should be incorporated in postoperative rehabilitation.
- Single-leg heel raises and double-limb heel raises with added external resistance are performed for continued strengthening of the calf muscles.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Full activation of the quadriceps as evidenced by the ability to perform a straight leg raise without a knee extensor lag should have been achieved before entering this phase of rehabilitation.
- Neuromuscular electrical stimulation (NMES) should be continued to further increase quadriceps muscle strength.

Sensorimotor Exercises

- Advance balance training by increasing the degree of task variability with less frequent verbal feedback or position cues.
- Additional activities, such as throwing and catching objects while balancing on one leg, will increase in task difficulty.
- Single-leg balance activities may be gradually increased in difficulty. For instance, through the addition of foam surfaces or a tilt-board introduces surface variability.
- Perturbations during balance exercises on a tilt and/or roller board have been shown to be beneficial for nonoperative treatment of ACL injuries.[16] As such, we recommend inclusion of perturbation training in rehabilitation following ACL reconstruction. Perturbation training should be initiated once the patient demonstrates mastery of balance activities on a tilt board or other unstable surface. Initially, perturbations should be done in a regular manner so that the patient is aware of the impending perturbation. Over time, the randomness and magnitude of the perturbation can be increased.
- These advanced balance techniques can be used during performance of activity related tasks to enhance the transfer of learned protective responses to actual functional performance situations.

Clinical Pearl

An ACL deficient knee suffers a loss of proprioception. Thus, neuromuscular balance training is critical for full functional recovery following ACL reconstruction. Furthermore, neuromuscular training in addition to bilateral strength training may aid in the prevention of graft re-rupture and contralateral ACL injury.[17,18]

Open and Closed Kinetic Chain Exercises

- Limited arc knee extension from 90° to 60° progressing to 90° to 45° on a leg extension machine should be continued for quadriceps strengthening.
- Resisted knee flexion exercises on a leg curl machine should be continued for hamstring strengthening.
- CKC exercises on both legs with weight evenly distributed on each leg was as well as single leg CKC chain exercises should be continued in the range from 0° to 60° progressing to 0° to 75° of knee flexion. Exercises may include step-ups/step-downs, leg press, squats, and lunges.
- During this phase, OKC and CKC must be done in a manner to protect the healing graft as well as to prevent the development of patellofemoral pain.

Techniques to Increase Muscle Strength, Power, and Endurance

- Moderate to heavy resistance should be used for 3 to 5 sets of 8 to 12 repetitions every other day (3 to 4 days per week) to ensure continued gains in strength. Resistance must be progressed to ensure continued strengthening as tolerated by the knee.
- Low-impact aerobic training activities should be performed for 30 minutes 3 times per week at an intensity sufficient to produce a cardiovascular training effect (60% to 80% maximum heart rate reserve). Aerobic training activities may include fast walking on treadmill, stationary ergometer, elliptical trainer, step machine, swimming (flutter kick only), and/or jogging in a pool.
- The soreness rules should be observed to prevent over training and an increased or persistent inflammatory response.

Neuromuscular Dynamic Stability Exercises

- Treatment techniques should be designed to allow for the development of individualized compensatory neuromuscular responses to potentially destabilizing loads on the knee.
- Gradually progress weight-bearing balance exercises from static to dynamic balance training.
- Doing so will prepare patients for plyometric exercises, agility training, and sport-specific exercises utilized in advanced phases of rehabilitation.

Functional Exercises

- Achieving normal gait and increasing tolerance for weight-bearing activities is a priority.
- While walking, the patient should focus on achieving full extension at heel strike and at the end of the midstance phase of gait.
- Gait training is helpful in the presence of an abnormal gait pattern despite full passive and active knee extension with adequate quadriceps strength.
  - Gait training on a flat surface focuses on the achieving a normal gait pattern by separating the walking movement into 3 phases: loading (or contact phase), midstance, and propulsion.

- In the loading phase, the knee should be extended at heel strike and then should flex slightly until the foot is loaded on the ground. During midstance, the knee should re-extend so that it is fully extended at heel off. After heel off, the knee should flex in preparation for the swing phase of gait.

Clinical Pearl

A "bent knee gait" is the lack of full knee extension at heel strike and/or the inability to achieve full knee extension at the end of midstance. A patient exhibiting this type of gait should be examined closely. Likely causes include a lack of passive extension, inadequate active knee extension, quadriceps muscle weakness, a motor control issue, pain, arthrofibrosis, or apprehension.

Milestones for Progression to the Next Phase

- Minimal pain and swelling.
- Passive and active extension of the operative knee should be symmetrical to the nonoperative knee.
- Flexion of the operative knee should be within 10o to15 o of the nonoperative knee.
- Adequate progression in neuromuscular balance training exercises.
- Tolerance for low impact aerobic activities.

Phase IV (weeks 12 to 20, or 3 to 5 months postoperatively)

Goals

- Restore full ROM of the knee symmetrical to the noninvolved side
- Continued improvement of strength with at least 70% quadriceps strength prior to initiation of running
- Continued improvement in neuromuscular control.
- Gradual increase in functional activity towards light in-line running.

Protection

- Functional brace is not used for rehabilitation activities during this phase of rehabilitation.

Management of Pain and Swelling

- Pain and swelling should be minimal and not hamper further rehabilitation.
- Cryotherapy after activity is recommended to control signs of inflammation.
- Soreness rules are followed to avoid increased or persistent inflammation.

Techniques for Progressive Increase in Range of Motion

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Stretching for the hamstrings, calf, rectus femoris, ITB, and hip flexors and adductors is continued as indicated based on assessment of musculotendinous length.
- Obtaining and maintaining full knee joint ROM remains important. Manual and self-administered stretching exercises as described above are continued if full ROM is not yet achieved.

Other Therapeutic Exercises

- Core, hip and lower leg muscle strengthening as described above is continued and advanced as tolerated.

Clinical Pearl

Anatomically placed grafts are exposed to increased loads compared to grafts that are placed nonanatomically.[19,20] Though the tensile strength of the graft is gradually improving throughout the phases of rehabilitation, care must be taken to avoid overloading the graft when rehabilitating patients after anatomic ACL reconstruction.

Sensorimotor Exercises

- Continue to advance balance training activities by increasing the degree of difficulty through reduced visual input, decreased surface stability and increased attention to other activities (catching/throwing a ball) while performing balance activities. Continue perturbation training with the use of tilt and roller boards. Perturbations should be larger and more random to allow the patient to develop strategies to adapt to potentially destabilizing loads.

Clinical Pearl

Perturbation training techniques (as used in the nonoperative ACL injury population) include the use of platforms and tilt-boards with application of controlled perturbation forces (Figure 32-48). In these techniques, the patient stands on the support surface on the involved limb and potentially destabilizing loads are applied to the knee through the roller board or tilt board. The load should be applied in a random manner without warning the patient. This will ensure the patient makes a quick, automatic response to the destabilizing loads. These techniques can also be used during the performance of activity related tasks, which may enhance carryover of learned protective responses to functional performance situations.[21]

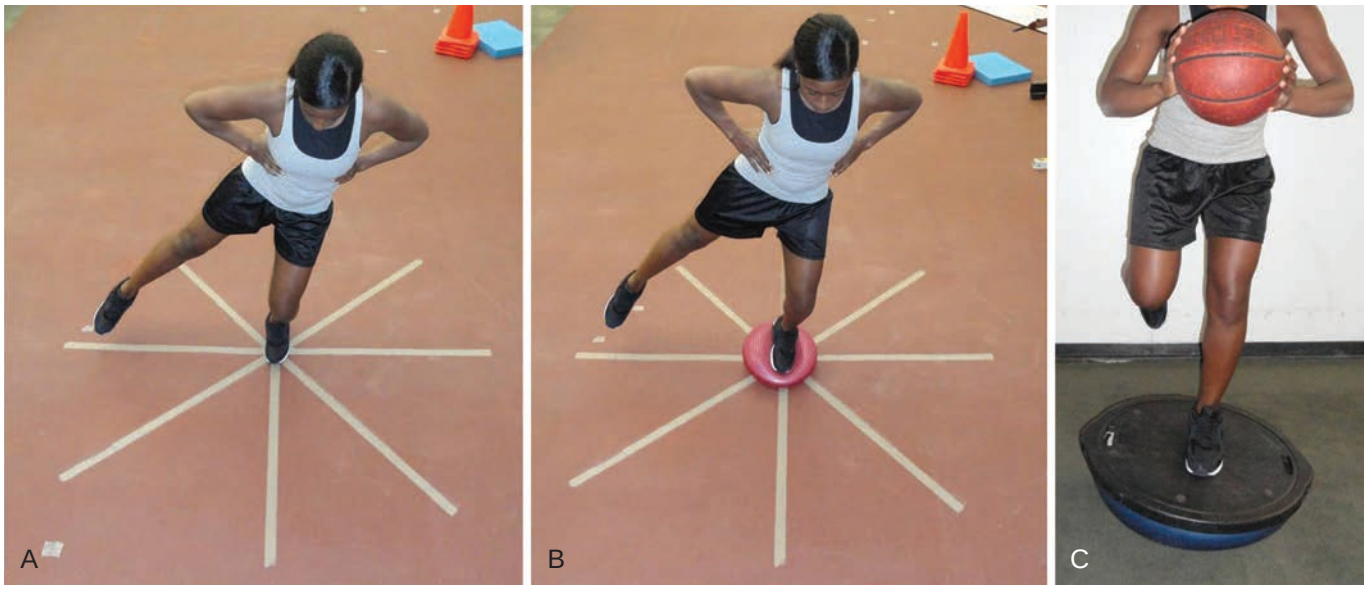

FIGURE 32-48. Perturbation exercises. (**A**) Single-leg outward reach drill requiring core stabilization and operative extremity strength. (**B**) Single-leg outward reach with surface variation (disc shown here). (**C**) Single-leg balance exercise on a balance ball while catching and passing a medicine ball or basketball (a sport-specific task).

Open and Closed Kinetic Chain Exercises

- OKC and CKC strengthening exercises should be continued and advanced as tolerated for further strengthening of the quadriceps and hamstrings.
- The range of OKC knee extension may be increased from 90° to 60° to 90° to 45° as tolerated by the patellofemoral joint.
- The range for CKC exercises may be increased from 0° to 60° to 0° to 90° as tolerated by the patellofemoral joint.
- More advanced CKC exercises include single leg press, single leg partial squats, and higher level step-up/step-down activities.
- Progressing from double- to single-leg extension activities will aid in avoiding compensation using the uninvolved extremity (Figure 32-49).
- Despite the fact that the tensile strength of the graft is increasing during this phase of rehabilitation, anatomic ACL reconstruction leads to increased loading of the graft.[19] Therefore, caution and prudence must be used in progressing the strengthening and functional training activities during this phase of rehabilitation.

Techniques to Increase Muscle Strength, Power, and Endurance

- Emphasis is on progressively increasing resistance with strength-training exercises.
- Generally 4 to 5 sets of 8 to 12 repetitions are performed with moderate to heavy resistance. Daily adjustable progressive resistance exercise program is used to progressively adjust working weight for resistance exercises. If greater than 12 repetitions can be

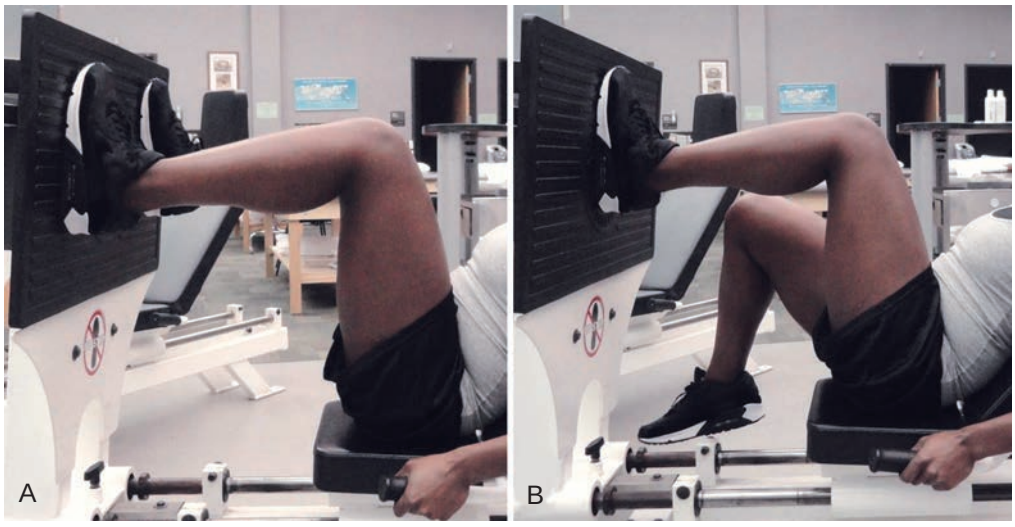

FIGURE 32-49. A, Double-leg press and **B,** single-leg press.

completed during third or fourth set, resistance for final set should be increased and new working weight for next training session should be established.
- Resistance exercises to increase strength are performed every other day, 3 days per week.
- Quadriceps strength should be assessed quantitatively. Options include isokinetic or isometric testing. If an isokinetic dynamometer is not available, a handheld dynamometer may be used. Use of a strap to stabilize the dynamometer and provide resistance may be necessary to ensure accurate use of the handheld dynamometer. If a dynamometer is not available, a 1- or 10-repetition maximum test may be used to assess strength.
  - The results of the quantitative strength test should be used to determine the quadriceps index, with this is the ratio strength of the involved knee to the uninvolved knee. Minimum quadriceps-index values required to progress to specific functional activities are as follows:
    - Running progression—70%
    - Agility training and jumping (both legs simultaneously)—85%
    - Hopping (single leg) and cutting—90%

Neuromuscular Dynamic Stability Exercises

- Continue to advance balance and perturbation training exercises as described above.
- Continue strengthening of hip and core trunk muscles as necessary to ensure good trunk and hip control during movement.

For all exercises, emphasize correct movement patterns. In particular, during weight-bearing exercises, ensure the patient performs the activity with good trunk and hip control. Provide cues as necessary to ensure that single leg weight-bearing exercises are performed with good technique and avoidance of excessive hip adduction and internal rotation as evidenced by medial collapse/valgus of the knee.

Functional Exercises

- In-line running on a treadmill or over the ground may be initiated if the patient's quadriceps index is at least 70%, and the patient can tolerate fast walking on a treadmill or over the ground for 15 minutes without gait deviations and signs of inflammation (pain, swelling).
- Running should begin at a slow, comfortable speed for short durations and distances. Alternating jogging and walking may be used as a transition to running.
- Running distance, time, and speed may be progressed as tolerated as long as there are no signs or symptoms of inflammation (pain, swelling) or gait deviations/asymmetries. A 10% to 15% increase in running volume per week is recommended.
- Running should only be straight ahead on a level surface. Avoid hills, inclement weather, and uneven surfaces.
- If increased joint pain (tibiofemoral or patellofemoral) or swelling or if asymmetry of gait develops, the jogging program should be reduced or eliminated, and the potential cause should be identified and addressed.

Clinical Pearl

Rehabilitation programs must be individualized to match each patient's needs. Next to the actual surgical procedure and the surgeon's preferences, individual factors play an increasing role in rehabilitation as time from surgery increases. Thus, the time frame for advancing to successive rehabilitation phases depends on individual progression. Initiation of higher-level functional activities (e.g., jumping, cutting, and pivoting) may differ by individual, sometimes deviating from the postoperative guidelines discussed.

Sport-specific Exercises

- As mentioned above, patients may begin in-line jogging with progression in speed and duration as tolerated.
- Jumping and cutting are not advised at this time.

Milestones for Progression to the Next Phase

- During this phase of rehabilitation, any residual deficits in ROM and flexibility should be resolved.
- Quadriceps strength should be 70% of the noninvolved knee as determined by isometric testing with a handheld dynamometer, on an isokinetic dynamometer in the isometric mode, or with a 1-repetition maximum quadriceps strength test.
- Ability to run for up to 2 miles without any pain or swelling or gait asymmetries.
- Surgeon's clearance should be obtained before advancing to the next phase.

Phase V (weeks 20 to 32, or 5 to 8 months postoperatively)

Clinical Pearls

More objective outcome measures are needed to assess a patient's readiness for return to sports. At this time, some institutions are using MRI to evaluate graft healing in conjunction with findings from the physical examination, the patient's subjective feelings of knee stability and the results of performance-based measures of function (single-leg hop tests, etc.). As described in a review by van Grinsven et al., current outcome measures used to inform the decision for return to sports include[21]:
- Visual Analog Scale (VAS) for pain
- Circumference measurement with a measuring tape to assess swelling and atrophy using comparison with the noninvolved leg used as a control.
- Goniometer to assess ROM.
- The International Knee Documentation Committee Subjective Knee Form can be used to assess symptoms and functional limitations.

- Hop tests to measure differences in total leg function between the involved and uninvolved knee. A minimum of 2 hop tests should be performed to increase sensitivity of detecting performance limitations.
- Quantitative Strength Testing to objectively measure strength of the knee stabilizers. This may include isokinetic testing, isometric testing with an isokinetic dynamometer, or handheld dynamometer, or determination of a 1- or 10-repetition maximum.

Goals

- No episodes of pain, swelling, and instability.
- Full ROM of the knee symmetrical to the noninvolved side
- Maximize strength, power and endurance. Achieve 90% quadriceps index.
- Optimize neuromuscular control.
- Begin agility, jumping (both legs), and hopping (single-leg) activities.

Protection

- A functional knee brace may be worn during functional training activities but is not required. Fitting of a functional knee brace is delayed until symmetrical thigh muscle bulk is achieved.

Management of Pain and Swelling

- Ice after activity is used to control pain and swelling if necessary.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Tibiofemoral and patellofemoral joint mobilization is used only if necessary to restore full ROM of the knee

Soft Tissue Techniques

- Only if necessary to restore normal mobility of the knee.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Stretching for the hamstrings, calf, rectus femoris, ITB, and hip flexors and adductors is continued as indicated based on assessment of musculotendinous length.
- Obtaining and maintaining full knee joint ROM remains important. Manual and self-administered stretching exercises as described above are continued if full ROM is not yet achieved.

Other Therapeutic Exercises

- Core, hip, and lower leg muscle strengthening as described above is continued and advanced as tolerated

Sensorimotor Exercises

- Continue advanced balance and perturbation exercises as described above.

Open and Closed Kinetic Chain Exercises

- OKC and CKC strengthening exercises are advanced as tolerated for further strengthening of the quadriceps and hamstrings.
- The range of OKC knee extension may be advanced to full range (90° to 0°) as tolerated by the patellofemoral joint.
- The range for CKC exercises may be increased from 0° to 90° as tolerated by the patellofemoral joint.
- More advanced CKC exercises include higher-level step-up/step-down activities, squats, and lunges.

Techniques to Increase Muscle Strength, Power, and Endurance

- Continued emphasis is on progressively increasing resistance with strength training exercises through full arc of motion as tolerated by patellofemoral joint using a daily adjustable progressive resistance exercise program 3 days per week.
- Quantitative quadriceps strength testing as described above should be continued. The minimum quadriceps index to initiate agility training and jumping (both legs simultaneously) is 85% and is 90% to initiate hopping (single leg) and cutting.

Neuromuscular Dynamic Stability Exercises

- Continue advanced balance and perturbation training exercises as described above.
- Continue strengthening of hip and core trunk muscles as necessary to ensure good trunk and hip control during movement.
- For all exercises, emphasize correct movement patterns. In particular, during weight-bearing exercises, ensure the patient performs the activity with good trunk and hip control. Provide cues as necessary to ensure that single-leg weight-bearing exercises are performed with good technique and avoidance of excessive hip adduction and internal rotation as evidenced by medial collapse/valgus of the knee.

Plyometrics

- Jumping and landing on both feet simultaneously may be started when the quadriceps index is greater than or equal to 85%, provided the patient can demonstrate good form with take-off and landing (no genu varum, hip adduction, or internal rotation during take-off and landing and weight forward on balls of feet and knees flexed when landing).
- Begin with single forward jumps taking-off and landing on both legs.
- When patient demonstrates good form and tolerance to forward jumps, patient can begin side to side jumping, jumping with rotation, and box jumps.
- As patient improves, he or she can progress from single jumps to consecutive jumps.
- Hopping on a single leg can be initiated when quadriceps index is greater than 90%, and the patient can

perform jumps on both legs with equal weight distribution and good form.
- Single-leg hopping follows same progression as jumping described above.
- Emphasize correct form including adequate knee flexion upon landing, no medial collapse of the knee (no hip adduction or internal rotation), and minimal trunk deviations.

Functional Exercises

- Submaximal agility drills may begin when the quadriceps index is greater than 85%, and the patient is tolerating running for 15 minutes with good form and the absence of symptoms.
- Agility drills include lateral shuffling, forward/backward shuttle runs, carioca, and ladder drills. Drills are initially performed submaximally at 50% effort and gradually progressed to 75% and 100% effort as tolerated by the patient.
- Ensure there are no compensation patterns when performing agility drills, particularly during deceleration phase.
- Cutting drills may be initiated when the quadriceps index is greater than or equal to 90%, and the patient is tolerating agility and jumping drills with without symptoms or compensation patterns.
  - Cutting drills begin with running "S" pattern
  - Progress to 45-degree cuts then to sharper cuts.
  - Pivoting and cut and spin drills should begin when patient is able to cut at sharp angles.
- Sprinting can begin when quadriceps index is greater than or equal to 90%.
  - Begin with transition from running to full sprint for short distances with gradual increase and decrease in speed to full spring.
  - Sprint distance progressed to 40 then 100 yards.

Sport-specific Exercises

- Sports-specific exercises include running, agility, jumping, hopping, and spring activities as described above.
- Return to practice is delayed until patient is able to perform full effort running, agility, jumping, hopping, and sprinting activities that are required for sport with good for without symptoms.

Milestones for Progression to the Next Phase

- No pain or swelling.
- Full ROM symmetrical to opposite knee.
- Quadriceps index greater than or equal to 90%
- Hop test scores greater than or equal to 90%. Hop tests include:
  - Single-leg hop for distance
  - Single-leg triple hop
  - Single-leg triple crossover hop
  - Timed 10-meter hop
- Tolerating full effort agility, jumping/hopping, cutting, and sprinting drills without symptoms or movement abnormalities.

Phase VI (weeks 32 to 52, or 8 to 12 months postoperatively)

Goals

- No pain or swelling.
- Full ROM symmetrical to contralateral knee.
- Quadriceps index equal to or greater than 90% of contralateral side.
- Hop test indices equal to or greater than 90% of contralateral side.
- Tolerating full effort agility, jumping/hopping, cutting, and sprinting drills without symptoms or movement abnormalities.
- Full participation in practice.
- Full return to prior level of sports activity.

Protection

- The patient can be fitted for a functional brace when thigh muscle girth is symmetrical (less than 1 cm side to side difference) to contralateral thigh.
- Functional brace is recommended for return to practice and games for at least first full season after surgery.

Techniques for Progressive Increase in Range of Motion

- Patient should have achieved full ROM by 3 months postoperatively.
- Manual therapy techniques as described in previous phases if full mobility is not yet achieved.
  Stretching/flexibility techniques for the musculotendinous unit as indicated by muscle length testing.
- Manual and self-administered stretching exercises as described above are continued if full ROM of the knee is not yet achieved.

Other Therapeutic Exercises

- Core, hip, and lower leg muscle strengthening as described above is continued and advanced as tolerated. Frequency may be decreased to once or twice per week for maintenance.

Sensorimotor Exercises

- Continue advanced balance and perturbation exercises as described above.

Open and Closed Kinetic Chain Exercises

- Continue full range OKC and CKC exercises to increase strength to increase or maintain strength to greater than or equal to the contralateral side. Once symmetrical strength is achieved, frequency may be decreased to 1 to 2 times per week for maintenance.

Techniques to Increase Muscle Strength, Power, and Endurance

- Continue with high-resistance strengthening exercises through full arc motion as tolerated by patellofemoral joint.

- Quantitative quadriceps strength testing as described above should be continued. Quadriceps index should be greater than or equal to 90%.
- Strength training may be decreased to 1 to 2 times per week for maintenance once 90% strength is achieved.

Neuromuscular Dynamic Stability Exercises

- Continue maintenance program of advanced balance and perturbation training exercises as well as continued strengthening of the hip and core trunk muscles to ensure good trunk and hip control and to minimize the risk of re-injury.
- Emphasize correct movement patterns for all exercises.

Plyometrics

- Jumping and hopping exercises should gradually be made more challenging by changing the height and/or distance of jumps and hops, speed of the drills, directions, and by combining multiple tasks.

Functional Exercises

- Continue agility, cutting, and sprinting drills.
- Incorporate drills within context of practice.
- Cutting and jumping drills should include anticipated and unanticipated movements.

Sport-specific Exercises

- Continue agility, jumping, hopping, cutting, and sprinting drills within context of practice.
- Practice should initially consist of unopposed drills followed by drills against opposition as player regains confidence and skill.
- Sport-specific activities may include:
  - Basketball: Almost all of sport-specific rehabilitation after 24 weeks should consist of plyometrics and agility drills.
  - Soccer: In the later stages of sport-specific rehabilitation, most of the drills should consist of cutting and progress to unanticipated cutting.
  - Football: Sports-specific rehabilitation drills are position-specific.
  - Softball: Practice swings at full speed and mimic sprinting down the first base line. Sport-specific rehabilitation defensive drills are infield or outfield specific.

Clinical Pearls

- Tendon graft healing takes place in 4 successive phases: initial necrosis, revascularization, cellular repopulation, and remodeling[22,23]. Revascularization ensures graft viability, which facilitates subsequent remodeling and increase in tensile strength[24]. If an athlete desires return to sports prior to 36 weeks, magnetic resonance imaging can be used to assess for graft healing[25-27]. Indications of a healing graft include increased water content of the graft, an indication of vascularity and graft tensile strength, and decreased graft signal intensity.
- Improved surgical techniques including anatomic placement of the ACL graft are associated with lower morbidity and improved recovery time. New surgical developments tend to make athletes desire earlier return to sports. For instance, following anatomic DB reconstruction using a quadriceps autograft, patients have been observed to advance to full range of motion with minimal pain and swelling and normal unassisted gait within 6 weeks postoperatively. Though the athlete may appear advanced clinically, the ACL graft may not be fully healed until months later. Thus, it is important for clinicians to emphasize careful and steady rehabilitation to prevent future injury by allowing adequate graft healing and remodeling.

Milestones for Progression to the Next Phase

- Completion of the full rehabilitation program.
- All rehabilitation goals of the previous phases have been met.
- Quadriceps index of at least 90%.
- Tolerance for sport-specific exercises.

Criteria for Return to Sport

General

- Achievement of passive and active extension symmetrical to the noninvolved knee.
- Flexion within 5 degrees of the noninvolved knee.
- Minimal pain and no increase in swelling with exercise.
- Quadriceps index greater than or equal to 90% of the contralateral knee.
- Hop test indices greater than or equal to 90% of contralateral knee.
- Tolerating full effort agility, jumping, hopping, cutting, and sprinting activities without asymmetries or symptoms.
- Full participation in practice.

Sport-specific

- Return-to-sports criteria varies based on the level and type of activity required for each individual sport (Box 32-2).
- Patients must achieve a quadriceps index of 90% or greater and satisfy the above criteria to progress to sports-specific tasks including cutting, jumping, and plyometric activities.
- Athletes who play highly competitive contact sports involving cutting and pivoting (football, soccer, basketball) must be able to withstand a series of sports-specific tests to ensure readiness for return to pre-injury levels of activity.
- Some athletes choose return to sports at a lower competitive level or return to a different sport with less

BOX 32-2 An Example of a Return to Sports Test[18]

- 10-repetition maximum single leg squat with external weight.
- Single broad jump, landing on one foot.
- Triple broad jump, landing on one foot.
- Single-leg forward hop.
- Single-leg crossover hop.
- Single-leg medial and lateral hop.
- Single-leg medial and lateral rotating hop.
- Single-leg vertical hop.
- Single-leg triple hop.
- Timed 6-meter hop.
- 10-yard lower extremity functional test.
- 10-yard pro-agility run.

functional demands. In such cases, rehabilitation requirements would be altered to meet the patients' functional needs and sports-specific demands.

After Return to Sport

Continuing Fitness or Rehabilitation Exercises

- Strengthening surrounding musculature (quadriceps) should always be a priority following ACL injury.
- ROM exercises and global flexibility should progress until active and passive ROM matches that of the uninjured limb.
- Development and maintenance of hip and core trunk muscle strength should always be a priority following ACL reconstruction.

Exercises and Other Techniques for Prevention of Recurrent Injury

- Prevention of recurrent ipsilateral or contralateral knee injury requires continued strengthening of the quadriceps and hamstrings as well as the hip and core trunk muscles.
- Balance training, plyometric, and agility training exercises similar to those included in ACL prevention programs.
- A recent review conducted by Wright et al. demonstrated that the rate of contralateral ACL tear is double the risk of ACL graft rupture in the ipsilateral knee after 5 years of follow-up.[18] Thus, it is important to rehabilitate both knees following ACL surgery for bilateral strength and to establish dynamic neuromuscular control.

Evidence

Harner CD, Irrgang JJ, Paul J, et al: Loss of motion after anterior cruciate ligament reconstruction. *Am J Sports Med* 20:499–506, 1992.

Retrospective review and follow-up examinations on 244 patients (minimum follow-up of 1 year) to assess risk factors and outcomes of patients who developed loss of motion after arthroscopic ACL reconstruction. (Level III evidence)

Kartus J, Magnusson L, Stener S, et al: Complications following arthroscopic anterior cruciate ligament reconstruction. A 2- to 5-year follow-up of 604 patients with special emphasis on anterior knee pain. *Knee Surg Sports Traumatol Arthrosc* 7:2–8, 1999.

The aim of this study was to assess knee function after arthroscopic ACL reconstruction and to analyze complications impeding rehabilitation, additional surgery until the final follow-up, and residual patellofemoral pain and donor-site problems. One or more complications impeding rehabilitation were recorded in 184 of 604 patients (30.5%). The most common was an extension deficit (>5 degrees) in 81 patients (13.4%). Patients with a full range of motion and a minimal loss (< or = 4 cm^2) of anterior knee sensitivity had significantly ($p < 0.01$) less subjective anterior knee pain than patients who did not fulfill these criteria. (Level II evidence).

Kato Y, Ingham SJ, Kramer S, et al: Effect of tunnel position for anatomic single-bundle ACL reconstruction on knee biomechanics in a porcine model. *Knee Surgery, Sports Traumatol Arthrosc* 18:2–10, 2010.

Ten porcine knees used for five different reconstruction techniques: three different anatomic SB [AM-AM (antero-medial), PL–PL (postero-lateral), and MID–MID] (n = 5 for each group), conventional SB (PL–high AM) (n = 5), and anatomic double-bundle (DB) (n = 5). ATT and in situ forces tested with robotic/universal force–moment sensor testing system. In situ forces were higher in anatomic ACLR, provided best stability and more closely restored normal knee kinematics.

van Grinsven S, van Cingel RE, Holla CJ, et al: Evidence-based rehabilitation following anterior cruciate ligament reconstruction. *Knee Surg Sports Traumatol Arthrosc* 18:1128–1144, 2010.

Systematic review to develop an optimal evidence-based rehabilitation protocol to enable unambiguous, practical, and useful treatment after ACL reconstruction. Thirty-two rehabilitation programs, randomized clinical trials, and reviews were included. The results indicate that an accelerated protocol without postoperative bracing, in which reduction of pain, swelling, and inflammation, regaining range of motion, strength, and neuromuscular control are the most important aims, have important advantages, and do not lead to stability problems. (Level II evidence)

Wright RW, Magnussen RA, Dunn WR, et al: Ipsilateral graft and contralateral ACL rupture at five years or more following ACL reconstruction: A systematic review. *J Bone Joint Surg Am* 93:1159–1165, 2011.

Systematic review of Level I and Level II prospective studies evaluating the long-term rate of ACL graft rupture and ACL rupture in the contralateral knee, following primary reconstructions. After 5 years follow-up, the risk of ACL tear in the contralateral knee (11.8%) is nearly double the risk of ACL graft rupture in the ipsilateral knee (5.8%). (Level II evidence)

Yagi M, Wong EK, Kanamori A, et al: Biomechanical analysis of an anatomic anterior cruciate ligament reconstruction. *Am J Sports Med* 30:660–666, 2002.

Controlled laboratory involving 10 cadaveric knees subjected to external loading conditions. Anterior tibial translation for

double-bundle anatomic reconstructions was significantly closer to that of the intact knee than was the single-bundle reconstruction, suggesting that anatomic reconstruction may produce a better biomechanical outcome, especially during rotatory loads. (Level II evidence)

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Multiple-Choice Questions

QUESTION 1. Which of the following exercises are focused on obtaining full extension in the immediate postoperative period (0 to 14 days)?

A. Multidirectional mobilization of the patella.
B. Active mobilization with "heel slides".
C. Aggressive manipulation through a range of motion identical to the contralateral knee.
D. Safe, prolonged stretching with a "prolonged hang" or "heel prop" exercises.

QUESTION 2. Crutches may be discontinued when the patient has reached which of the following rehabilitation milestones?

A. During the first postoperative week to encourage quadriceps strengthening.
B. Once a normal gait pattern is attained without extensor lag on straight leg raise.
C. Once 80 to 90 degrees of passive knee flexion has been obtained.
D. Not before a quadriceps index is >90%.

QUESTION 3. The beginning of in-line jogging may be initiated at:

A. Weeks 2 to 6, before hip and lumbopelvic stabilization.
B. Weeks 6 to 12, once the brace has been discontinued.
C. Weeks 12 to 20, if treadmill walking is tolerated with a quadriceps index of at least 70%.
D. Weeks 20 to 32, after the patient has demonstrated sufficient strength on consecutive hop tests.

QUESTION 4. Causes of a "bent knee gait" include all of the following EXCEPT:

A. Hamstring weakness.
B. Lack of passive extension.
C. Arthrofibrosis.
D. Postoperative pain.

QUESTION 5. Which of the following exercises focus on regaining balance proprioception?

A. Add variation in surface stability and vary visible input to agility training and sports-specific exercises.
B. Increase speed of in-line running by 10% to15% per week.
C. Addition of a functional brace at 36 weeks.
D. Closed kinetic chain exercises from 0 to 45 degrees of flexion.

Answer Key

QUESTION 1. Correct answer: **D** (see Phase I, Increase ROM)

QUESTION 2. Correct answer: **B** (see Phase II, Protection)

QUESTION 3. Correct answer: **C** (see Phase IV, Functional Exercise)

QUESTION 4. Correct answer: **A** (see Phase III, Clinical Pearls)

QUESTION 5. Correct answer: **A** (see Phase IV, Sensorimotor Exercises)

Chapter 33



Posterior Cruciate Ligament Injuries

INTRODUCTION

Robert F. LaPrade, MD, PhD, Casey M. Pierce, MD, and Scott A. Wilkins, DPT, OCS

Epidemiology

- Injuries to the posterior cruciate ligament (PCL) are rare compared with ACL injuries.
  - Comprise between 3% and 23% of knee injuries and usually occur in combination with other ligament injuries
  - Schulz et al. reported that 33% of PCL injuries are sports related.
  - These numbers are highly dependent on the patient population because PCL injuries are most frequently trauma associated rather than sports related.
  - The PCL has an intrinsic healing capacity not seen in the ACL, so chronic injuries can undergo some healing and can go undiagnosed for long periods of time.
- Low grade/minor tears can be asymptomatic.
  - NFL football player study found 2% of pre-draft players have PCL insufficiency.
- Isolated PCL injuries are less common and account for between 3% and 20% of PCL injuries.
  - PCL is stronger than the ACL in terms of tensile strength.

Age

- Mean age 27.5 ± 9.9 years[1]

Sex

- Almost 80% male likely because of a higher number of males active in contact/collision sports[1]

Sport

- Contact/collision sports, skiing, and soccer mostly but also football, hockey, and wrestling
  - 40% sports related

Position

- Soccer goalie, also players in football who get tackled (quarterback, running back, wide receiver)
- Mechanism of injury puts them at risk for the common flexed knee with anterior tibial blow mechanism

Pathophysiology

Intrinsic Factors

- Movement patterns that are common are falls on a flexed knee, which are commonly seen with cutting in football and planting for leverage in wrestling.
- Neuromuscular development, proper training, stretching, strengthening, and conditioning and proper technique when landing from a jump can contribute to preventing PCL injury.
- There is an increased risk seen with affected siblings, so there is a probable genetic component.
- Decreased risk with certain genetic mutations and polymorphisms in the COLIA1 gene
  - Specifically increased production of collagen type Iα 1 mRNA and proteins
    - Increases tensile strength of tendons
    - Also characteristic of fibrotic diseases and low bone mineral density (BMD)
- Increased risk with other polymorphisms of the COL1A1 that lead to increased risk of soft tissue rupture
- Age, flexibility, previous injury, overuse
- Unlike the ACL, the PCL has an intrinsic ability to heal and is stronger so it is less likely to be injured

Extrinsic Factors

- Footwear: With any sport footwear, it is critical to help prevent slipping and twisting injuries to the knees.

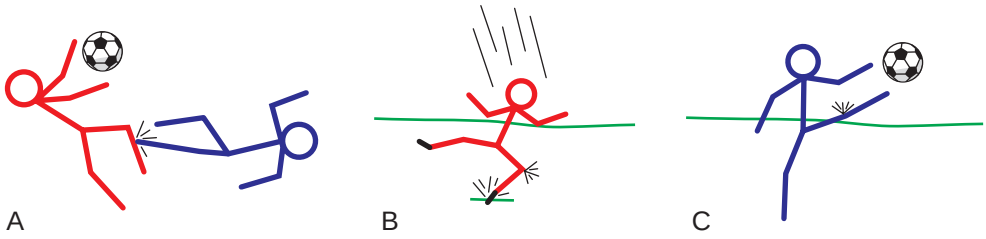

FIGURE 33-1. The three most common mechanisms of injury to the posterior cruciate ligament: direct anterior proximal tibial blow to a flexed knee (**A**), falling on a flexed knee with the foot plantarflexed (**B**), and sudden, powerful forced hyperextension (**C**).

- Environmental conditions that increase the likelihood of slipping or hyperextending the knee increase the risk of injury:
  - Wet or icy fields could contribute to this.
- Lifestyle
- Motor vehicle accidents are a common cause with the well-known "dashboard" injury (knee driven into dashboard on impact)
- Rigid structures on the playing field such as soccer, football, or hockey goal posts

Traumatic Factors

- Typical mechanism is a direct anterior proximal tibial blow to a flexed knee like a hockey goalie sliding into the goal post or soccer goalie sliding into another player (Figure 33-1*A*)
- Second most common is fall on the flexed knee with foot plantarflexed illustration (Figure 33-1*B*)
- Third most common is sudden, powerful forced hyperextension (Figure 33-1*C*)

Classic Pathological Findings

- Increased posterior translation on posterior stress x-rays (Figure 33-2)
- Increased posterior sag of the tibia
- Midsubstance ruptures
- Proximal or distal bony avulsions (Figure 33-3)
- On arthroscopy, the torn PCL may be visualized directly
  - In addition, the ACL appears slack when the PCL is torn; known as the "sloppy" or "slack" ACL sign (Figure 33-4*A*)
    - This is secondary to posterior tibial subluxation owing to the loss of support from a torn PCL and can be restored with an anterior translation force (Figure 33-4*B*)
    - The practitioner may also observe signs of damage secondary to the PCL injury such as altered tibial/femoral contact points, anterior horn meniscal tears, and degenerative changes

Clinical Presentation

History

- Typical history involves a direct blow to the anterior tibia with the knee flexed or a forced hyperextension
- Pain and swelling following the injury
  - Recurrent swelling or effusion
  - Less likely to complain of instability compared with ACL injuries
  - Instability with descending stairs, going down slopes or sudden decelerations, and also when on uneven ground.
  - Athletes may complain of generalized pain around the knee, and feel that "something is not right"

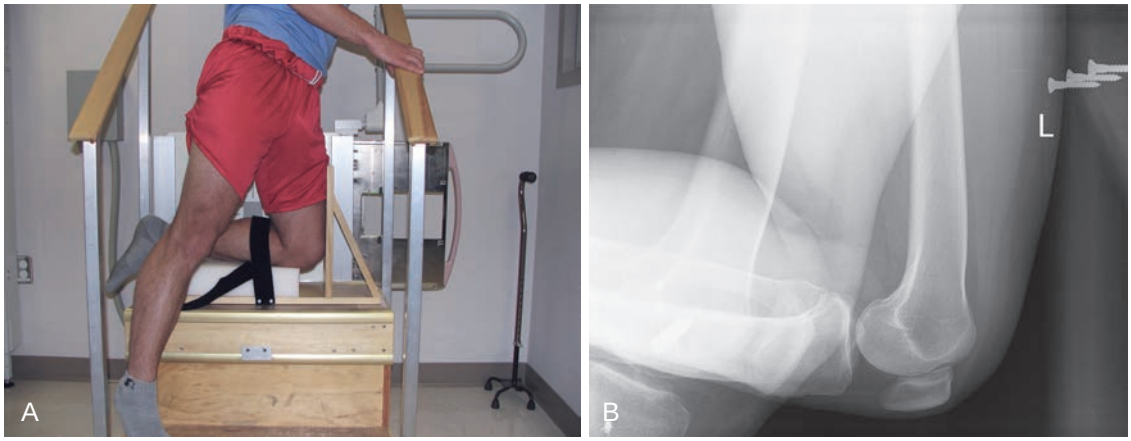

FIGURE 33-2. Posterior stress radiographs: setup (**A**) and an example radiograph (**B**).



FIGURE 33-3. Sagittal magnetic resonance image of a PCL tibial avulsion.

- Chronic injuries tend to complain of pain on walking for prolonged periods and when coming down stairs
- Low grade/minor tears can be relatively asymptomatic → football player study found 2% of pre-draft players have PCL insufficiency
- Torg et al. found that patients with isolated PCL injuries tend to remain asymptomatic compared to those who have combined injuries because of degenerative changes in the medial/lateral compartments.
- Patients may complain of numbness, tingling, or footdrop if they have a concurrent neurovascular injury.

Physical Examination

Abnormal Findings

- Gait pattern observation
  - Varus thrust gait could indicate a combined PCL/PLC (posterolateral corner) injury.
    - A varus thrust possibly combined with a hyperextended knee as the patient walks
  - An antalgic or quadriceps avoidance gait could indicate an ACL or combined ACL/PCL injury.
  - Studies have found quadriceps strength in chronic PCL-deficient patients to be compromised at higher knee flexion angles.
    - Patients tend to walk with a bent knee gait to avoid terminal hyperextension and external rotation of the tibia on the femur caused by posterior subluxation of the lateral tibial plateau.
- Classically mild joint effusion
- Misalignment of the limbs when standing and sitting with the knees flexed; important in chronic injuries
- Scars indicative of previous surgeries
- Palpation of the tibial plateau with the patient lying supine and having the knees flexed at 90°
  - Anterior border of the tibial plateau should sit 1 cm anterior to the medial femoral condyle
    - Grade I PCL injury → plateau still anterior
    - Grade II PCL injury → plateau now flush with medial condyle
    - Grade III PCL injury → plateau now posterior to condyle
- Sag test: Posterior sag of the subluxed tibia with patient's hips flexed to 45° and knees flexed to 90° while the legs are supported (Figure 33-5)
- Posterior sag disappears when quads flexed at 60° knee flexion and feet on table (quads active test)
- Posterior drawer test: Patient should be supine with the hips flexed to 45° and knees flexed to 90°, the examiner pushes the tibia backward (Figure 33-6)
  - Increased laxity will be observed with a PCL injury.
    - Increased posterior translation of the tibia under the femur
  - 3+ posterior drawer test should be considered a combined knee ligament injury until proved otherwise
- Positive posterior shift test: Flex the hip to near 90°, then extend the flexed knee; a posteriorly subluxated tibia will reduce, causing a clunk
- Positive reverse pivot shift test: Supine patient with knee flexed to 90°, externally rotate the foot, feel for the posteriorly subluxated lateral tibial plateau under the femoral condyle and observe for abrupt reduction of the tibia as the knee is extended (Figure 33-7)

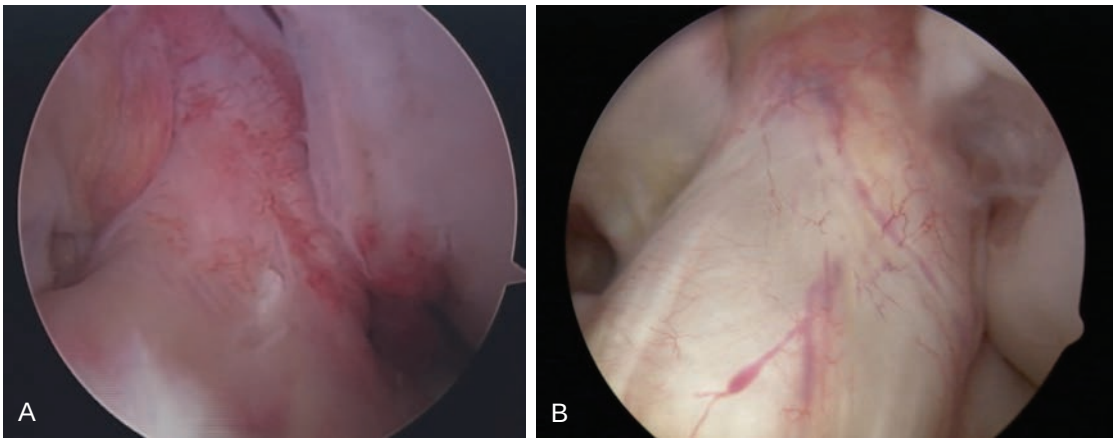

FIGURE 33-4. Arthroscopic PCL tear findings: ACL is "slack" or "sloppy" because of loss of support from the deficient PCL (**A**) and restored with an anterior translation force (**B**).



FIGURE 33-5. Sag test. Patient's hips flexed to 45° and knees flexed to 90° with the legs supported, the tibia will sag posteriorly with a PCL injury.



FIGURE 33-6. Posterior drawer test. Patient should be supine with the hips flexed to 45° and knees flexed to 90°.The examiner pushes the tibia backward. Increased laxity will be observed with a PCL injury.



FIGURE 33-7. Reverse pivot shift. Supine patient with knee flexed to 90°. Externally rotate the foot, feel for the posteriorly subluxated lateral tibial plateau under the femoral condyle, and observe for abrupt reduction of the tibia as the knee is extended.

- Caution: This can be positive in up to 35% of normal knees, so the examiner should check the normal contralateral knee.
- Positive dial test: Supine patient with knees at 90°, knees placed together and both feet externally rotated, positive if difference greater than or equal to 10° to 15° for combined PCL/PCL injury at 90° (Figure 33-8)
  - Repeat with patient prone and knees flexed at 30° and 90°
- Positive external rotation-recurvatum test: Patient supine, stabilize the thigh and lift the great toe, positive if increased recurvatum, varus, and external rotation (Figure 33-9)
  - Usually indicative of a combined posterolateral and ACL injury rather than an isolated PCL injury
- Inoue et al. found there were no difference in the electrical activity of the quadriceps and hamstrings in patients with chronic PCL deficiency compared with normal contralateral knee, but they did find earlier contraction of the gastrocnemius in PCL-deficient knees.
- Features of isolated PCL tears:
  - Abnormal posterior laxity (use less than 8 mm as a cutoff)
    - Laxity decreases with internal rotation of the tibia
  - Positive sag, quads active, and posterior drawer tests
- Features of combined PCL/posterolateral corner tears
  - Abnormal posterior laxity (cutoff is greater than 12 mm)
  - Positive recurvatum, reverse pivot shift, posterior shift, varus stress, posterolateral Lachman, pivot shift, posterolateral drawer, and/or dial tests
- Features of combined ACL/PCL tears
  - Positive Lachman and anterior/posterior drawer and pivot shift
  - Posterior tibial drop back beyond flat tibial step off (15–20 mm)
  - Increased varus/valgus laxity in full extension
  - Almost always found combined with posterolateral or posteromedial instability

Pertinent Normal Findings

- Isolated PCL injury
  - Negative/Normal tests: Valgus and varus stress, meniscus tear assessment, Lachman and posterolateral Lachman, pivot shift, posterolateral drawer, and dial test
- Normal anterior drawer and Lachman test (unless combined injury to ACL)
- No lateral/medial gapping, unless combined injury to PLC/MCL
- Often a negative meniscus assessment test
- Quadriceps and hamstring activity are normal in PCL-deficient knees
- No numbness or tingling which would indicate a more serious injury with a neurovascular injury

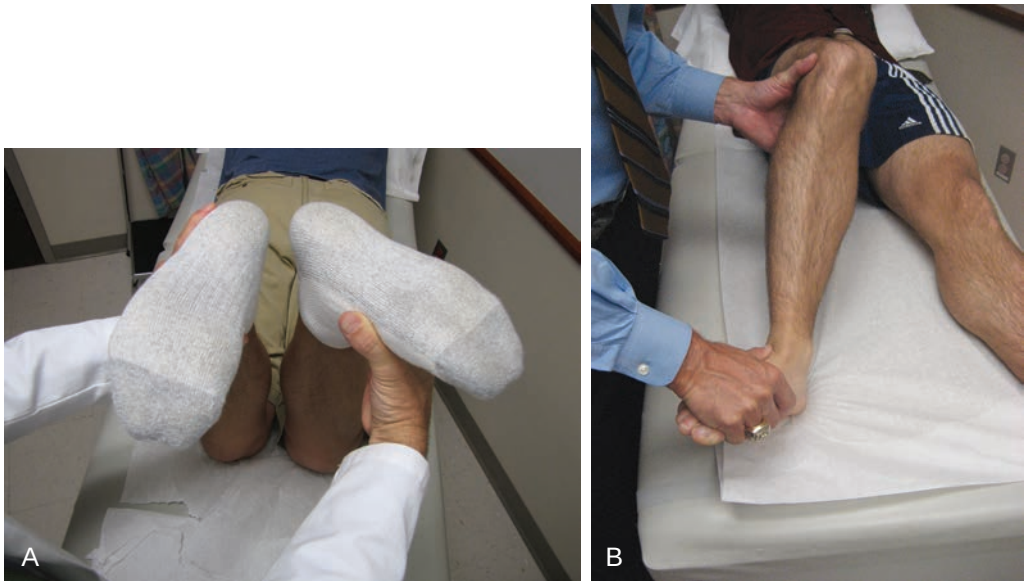

FIGURE 33-8. Dial test prone (**A**) and supine (**B**). Supine patient with knees at 90°, knees placed together and both feet externally rotated, positive if difference ≥10° to 15° for combined PCL/PCL injury at knees flexed to 90°.

Imaging

- Acute injury studies should include: AP, lateral and oblique radiographs, MRI, PCL stress radiographs
  - CT has little use unless the surgeon is trying to assess the size of an avulsion fracture for operative planning or suspects a tibial plateau fracture.
  - Posterior stress radiographs help demonstrate complete versus partial tears (see Figure 33-2)
    - Hewett et al.[2] studied normal knees and those with PCL injuries.
      - Normal knees have between 0 and 2 mm increased posterior translation
      - Partial tears 2 to 7 mm posterior translation
      - Complete tears 8 to 11 mm posterior translation
      - Combined injuries will have greater than 12 mm increased posterior translation
      - Patients must be relaxed while the radiographs are taken.
        - "Guarding" by activating the quads can lead to false measurements
    - Films should be examined closely for avulsion fractures and tibial plateau fractures.
      - Pelligrini-Stieda (avulsion leading to heterotopic calcification) lesion at the femoral origin of the MCL
      - Seen in chronic MCL injuries
    - Lateral projections are useful to identify bony avulsions of the tibial attachment of the PCL.
- Chronic injury studies should include: Weightbearing AP, lateral at 45° flexion, Rosenberg view (Figure 33-10) and standing long leg radiographs and MRI
  - Radiographs should be carefully examined for tibial PCL insertion avulsion fractures that have not healed, or healed in malunion.
    - In addition, the physician should look for calcified lesions like the Pelligrini-Stieda lesion at the



FIGURE 33-9. External rotation recurvatum test. With the patient supine, stabilize the thigh and lift the great toe. Suspect combined injury if increased recurvatum.

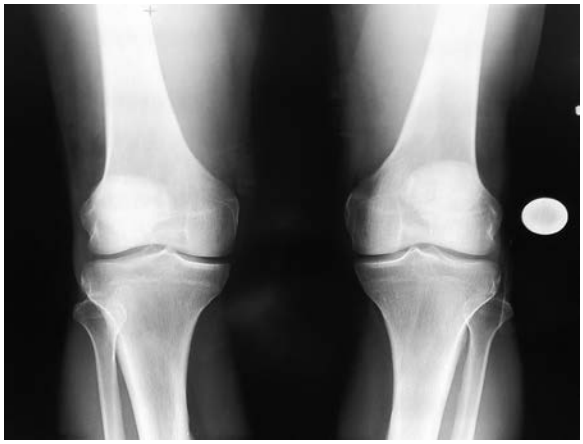

FIGURE 33-10. Rosenberg view radiograph.

femoral condyle, which would indicate a previous medial knee injury.
  - Standing long leg radiographs are used to assess joint alignment and help the practitioner decide the need for osteotomies before reconstruction of the damaged ligaments.
- Plain radiographs, including AP (weightbearing), lateral (at 45° flexion), oblique, sunrise, and Rosenberg views all may be useful.
- MRI → 97% sensitive for detecting acute PCL tears, but sometimes it can be difficult to tell if the tear is complete or partial. MRI can be inaccurate for chronic PCL injuries. This is where stress radiographs are useful.
  - Great for detecting combined injuries as well as assessing other ligaments/structures in the knee and subchondral bruising or damage
  - In chronic injuries, MRI of the PCL may appear normal as tears heal and scar, then the scar tissues can stretch out
  - Replaced the need for bone scans in patients with chronic PCL injuries suffering from pain and instability to look for early degenerative changes in the medial and patellofemoral compartments
    - Helps to influence surgical decision making

Differential Diagnosis

- PLC injury
  - Historical findings: Mechanism is typically hyperextension (contact or non-contact), direct trauma to the anteromedial knee or non-contact varus force to the knee
  - Physical findings: Pain, instability, swelling, positive posterolateral drawer sign/test, recurvatum test, varus stress tests at 0° and 30°, dial test, reverse pivot shift test, and figure 4 test. Also a varus thrust gait can be seen on gait analysis
  - ACL injury
  - Historical findings: Mechanism is typically valgus stress, or pop occurring while cutting, changing direction, landing (hyperextension pivot)
  - Physical findings: Pain, instability, swelling, positive Lachman sign/test
- MCL injury
  - Historical findings: Mechanism is valgus stress ± rotational stress
  - Physical findings: Pain and medial gapping with valgus stress testing; anteromedial drawer test
- Meniscal tear
  - Historical findings: Mechanism is typically a sudden twist on a weightbearing knee or repeated squatting
  - Physical findings: Intermittent pain at the joint line and possible joint locking, clicking, or catching. Meniscal tear assessment, Apley Test, posterior knee pain with knee flexion
- Tibial plateau fracture
  - Historical findings: Mechanism is typically a valgus force with axial loading, often from a fall or landing from height
  - Physical findings: Large effusion, palpable defect, varus or valgus instability, and severe pain

Treatment

An algorithm for deciding among surgical and nonsurgical treatment options is presented in Figure 33-11.

Nonoperative Management

- All modalities rely on physical therapy, and return to sporting activities is not typically allowed until full quadriceps strength has been restored and a firm end point on clinical exam is achieved (typically 6 to 8 months, but for elite athletes the timeframe could be as little as 6 to 8 weeks)
  - Slower rehabilitation protocols than those for ACL injuries

1. Immobilize the affected limb in extension for 2 to 4 weeks using a splint with a pad placed under the tibia to counter gravity (Figure 33-12)
   - Maintaining the tibia in the proper anatomical position is critical for maximizing healing potential.
   - Immobilizing in extension takes the tension off of the anterolateral bundle.
   - Physical therapy during the first 6 weeks focuses on reduction of inflammation (NSAIDs), maintaining ROM with prone passive flexion.
     - Patients should be doing straight leg raises, quadriceps sets, and partial weightbearing with crutches to maintain quadriceps strength.
   - Hamstring exercises should be avoided for at least 3 months.
   - Quadriceps strengthening is essential, can use PT or electrical stimulation
2. Jung et al.[3] put patients in a cylindrical cast for 6 weeks followed by a brace for 6 more weeks.
   - All 12 weeks utilized support against posterior tibial sag.
     - After 12 weeks physical therapy begins.
     - Straight leg raises and quad strengthening are recommended while casted.
   - After the cast is removed, patients start closed, kinetic exercises while preventing posterior displacement.
   - Flexion of up to 90° is allowed for the third week after cast removal and up to 120° by 6 to 12 weeks after cast removal.
3. Quadriceps strengthening with/without activity modification
4. Reduction of physical activity and/or MRI
5. Jack brace (Figure 33-13)
   - Allows full range of motion within the brace from 0° to 110° of flexion
   - Maintains anteriorly directed force on the posterior proximal tibia which prevents posterior sag and allows the PCL to heal in the proper position
   - Typically worn for 4 months
   - Only allowed to be taken off when the knee will be in full extension with the quads contracted (like standing in a shower) or prone full knee extension

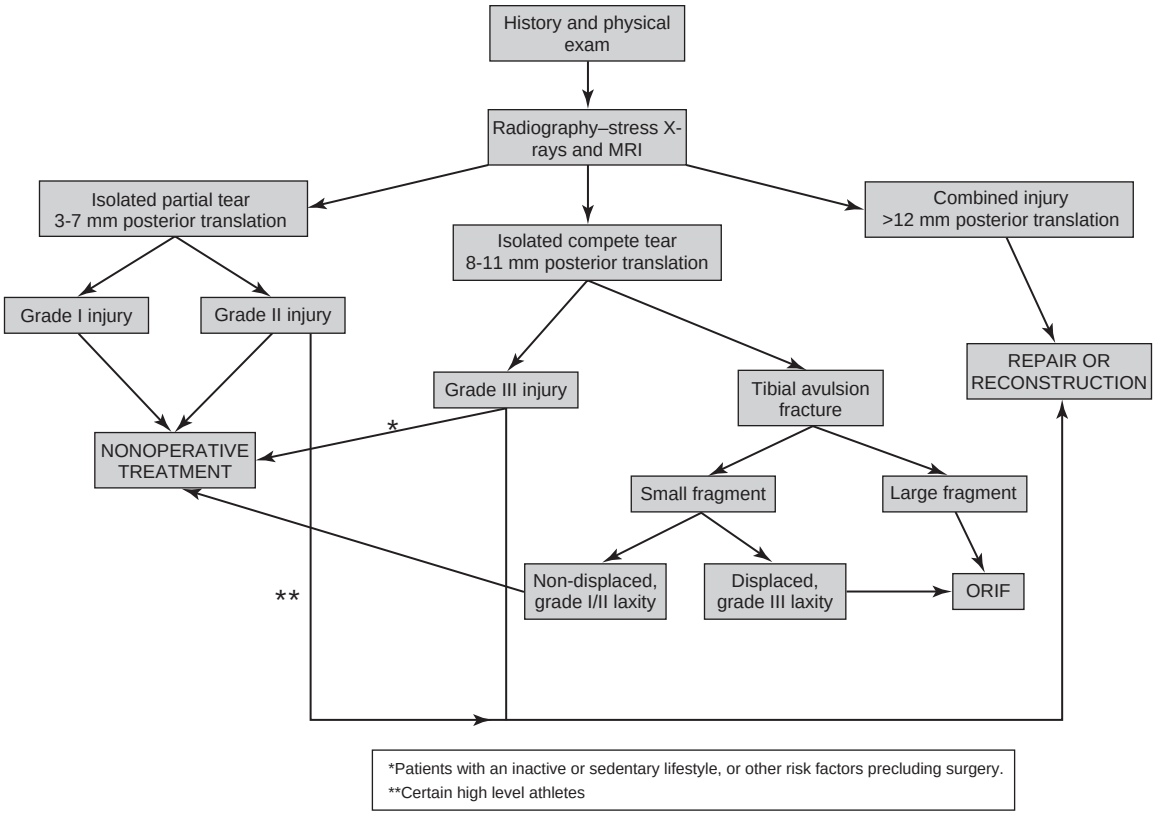

FIGURE 33-11. Flow chart of decision making for surgical versus nonsurgical treatment.

Guidelines for Choosing Among Nonoperative Treatments

- An optimal set of guidelines for nonoperative management of PCL injuries has not yet been defined or agreed upon.
- Combined PCL injuries are treated surgically.
- For nonsurgical treatment, patients should meet the criteria for isolated PCL injury:
  - PCL stress radiographs less than 8 mm
  - Less than 5° of abnormal rotary laxity at 30° knee flexion
  - No significant collateral injury causing varus/valgus laxity
- Isolated grade I or II PCL tears or a non-displaced PCL bony avulsion with a small fragment with grade I/II laxity can be treated with progressive weightbearing and rehabilitation focused on quadriceps strengthening.
  - Use of a Jack brace has been shown to provide good to excellent results in this patient population.
- Isolated grade III injuries can be immobilized in extension for 2 to 4 weeks followed by progressive weightbearing and therapy.
  - Therapy is focused on increasing ROM and quadriceps strengthening.
  - Elite athletes or those who fail conservative therapy should be considered for surgery.
- Grade III injuries in patients with an inactive or sedentary lifestyle: Typically these patients should not have surgery and should undergo appropriate nonoperative management, including quadriceps strengthening with or without activity modification.
- Patients with grade II injuries who develop recurrent pain and swelling should reduce physical activity until the pain and swelling subside.
  - May also require an MRI to gauge the status of the joint, articular cartilage, and meniscal cartilage
- Patients with chronic isolated or combined PCL injuries may require MRIs to gauge injury progression and dictate treatment modifications



FIGURE 33-12. Immobilizer brace for rehab patients.

Surgical Indications

Absolute

- PCL stress radiograph posterior translation greater than 12 mm
  - Indicates a combined ligament injury

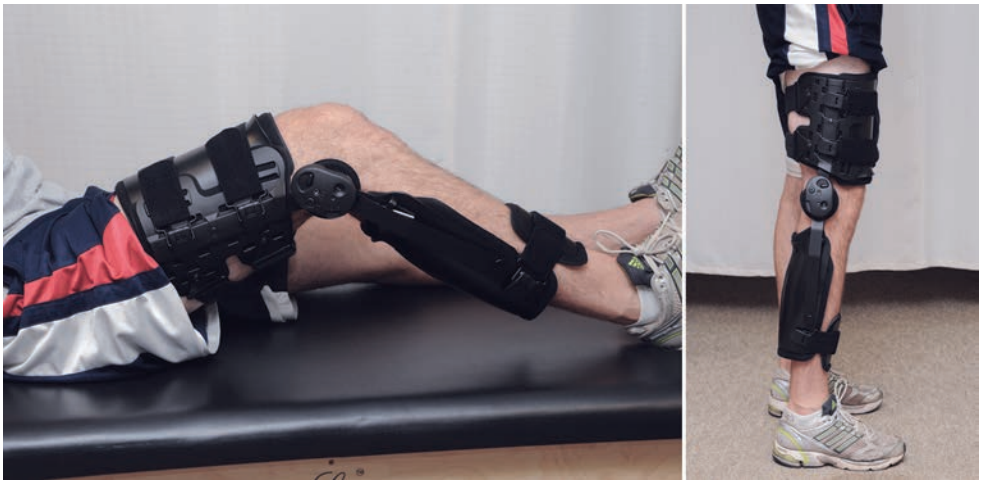

FIGURE 33-13. Jack PCL brace maintains anteriorly directed force on the posterior proximal tibia which prevents posterior sag and allows the PCL to heal in the proper position.

- Acute isolated PCL injury:
  - Grade III tears with plateau posterior to condyle
  - Bony avulsions that are displaced
  - Significant/symptomatic laxity (not confined to PCL only)
  - Associated meniscal injuries
- Especially medial meniscal root tears
- Acute combined PCL injuries:
  - Combined grade III PCL/PLC or PCL/PMC injuries should be treated surgically, typically will require reconstruction via a single or double bundle method
  - Multiligament repairs should be reconstructed concurrently and not as a staged procedure
- Chronic isolated PCL injury:
  - Symptomatic instability/pain
  - Early stages of arthrosis
- Large or displaced PCL tibial avulsions should be treated with operative fixation
- Symptomatic grade III tears
- Failure of conservative/nonoperative treatment

Relative

- Grade III tears with comorbidities
- Grade II tears in elite athletes to prevent medial and patellofemoral arthrosis and laxity following nonoperative treatment
- Small fragment bony avulsions with a high degree of laxity
  - Exceptions to surgery are patients with low physical demands or medical issues that would exclude operations or anesthesia

Aspects of History, Demographics, or Exam Findings That Affect Choice of Treatment

- Grade I and II injuries are not typically treated surgically, whereas most grade III injuries are reconstructed or repaired.
- Patient who will not comply with postsurgical protocol should not be treated surgically.
- Combined injuries found on exam are treated surgically.
  - Typically require reconstruction if chronic (greater than 3 weeks)
  - Not recommended to be done as a staged procedure
- Complete midsubstance tears can be reconstructed via a single bundle, double bundle, or tibial inlay technique.
- Large bony avulsion injuries or those that are displaced should be treated surgically (open reduction internal fixation).
- Studies have shown that PCL-deficient knees tend to have altered load bearing patterns and contact areas, especially in the patellofemoral and medial compartments, which could lead to degenerative joint disease and disability.
- Practitioners should be cautious when considering whether to treat patients with sedentary, inactive lifestyles surgically.
  - Patients will have to adhere to a strict postoperative physical therapy protocol to achieve optimal results.
  - Patients who are likely to be noncompliant should be screened accordingly.

Aspects of Clinical Decision Making When Surgery Is Indicated

- The time frame for surgery for acute combined PLC/PCL injuries should take place within 3 weeks of the initial injury to avoid fixed posterior subluxation and capsular scarring if possible.
  - Acute isolated injuries to the PCL that will require surgery are best reconstructed early.
- The location of the injury and the degree of laxity are major factors that play a role in determining the necessity of surgery.
  - Large bony avulsions and combined PCL/PLC injuries should be treated early if found.
- Patients with grade I and II injuries can be managed nonoperatively, but isolated grade III injuries are controversial.
  - Most surgeons believe that grade III injuries increase pressures in the medial compartment and can lead to early arthritis.

  - Younger patients with grade III tears are typically managed surgically to prevent the development of arthritis even though there has been no definitive study showing it to be beneficial.
- Almost all combined grade III tears are repaired by repair/reconstruction of the damaged PCL and reconstruction/repair of the other damaged structures depending on the severity and location of the injury.
- Some patients who require surgery present with a fixed posterior subluxation.
  - Typically seen in patients with a previous failed PCL reconstruction or patellar tendon harvest and a long history of PCL insufficiency
  - Patients with grades I and II fixed posterior subluxations should be treated with a functional PCL brace to reposition the tibia before surgery.
  - Patients with grade III fixed posterior subluxation may require more invasive procedures such as a posterior capsulotomy before having their PCL reconstructed to avoid stretching of the graft after surgery.
- Head injuries, vascular traumas, soft tissue status, and general medical comorbidities must be taken into account before deciding on the appropriate treatment

Evidence

Fanelli GC: Posterior cruciate ligament injuries in trauma patients. *Arthroscopy* 9:291–294, 1993.
Fanelli GC, Edson CJ: Posterior cruciate ligament injuries in trauma patients: Part II. *Arthroscopy* 11:526–529, 1995.

A two part prospective cohort analysis of the incidence of PCL injuries in patients presenting to a trauma center with acute knee hemarthrosis. The study found PCL injuries in 38% of cases with 56% being trauma related and 33% were sports related. (Level I evidence)

Jung YB, Tae SK, Lee YS, et al: Active non-operative treatment of acute isolated posterior cruciate ligament injury with cylinder cast immobilization. *Knee Surg Sports Traumatol Arthrosc* 16:729–733, 2008.

Prospective study of 17 acute and isolated PCL injuries with at least 2 years follow-up for each patient. Patients were put in full extension in a cylinder cast for 6 weeks followed by 6 weeks in an immobilizer brace with tibial supporter. The authors found improved anteroposterior stability and clinical results with some residual laxity. Concluded that conservative treatment making use of a cylinder cast and immobilizer brace could be a recommendable nonoperative treatment modality for isolated and acute PCL injuries. (Level III evidence)

Kennedy JC, Hawkins RJ, Willis RB, et al: Tension studies of human knee ligaments. Yield point, ultimate failure, and disruption of the cruciate and tibial collateral ligaments. *J Bone Joint Surg Am* 58(3):350–355, 1976.

Cadaver study to determine failure strengths of human FCL, ACL and PCL using an Instron Tension Analyzer. Found the PCL to be was significantly stronger than the FCL (LCL) and ACL, which were of equal strength. Discovered the ligaments were intact macroscopically but electron microscopy revealed disruption of the collagen fibrils at ultimate failure. This signifies that microscopic failure of the collagen fibrils in grossly intact ligaments may be a cause of clinical instability. (Cadaver study)

Khoschnau S, Melhus H, Jacobson A, et al: Type I collagen α1 Sp1 polymorphism and the risk of cruciate ligament ruptures or shoulder dislocations. *Am J Sports Med* 12(36):2432–2436, 2008.

Case control study that examined 358 patients with soft tissue injuries versus 325 random female controls using unconditional logistic regression to determine if persons with a mutation to the COL1A1 gene was less likely to suffer a soft tissue injury. The ss genotype was found to be less likely to sustain soft tissue injuries.(Level III evidence)

Lein OA, Aas EJ, Johansen S, et al: Clinical outcome after reconstruction for isolated posterior cruciate ligament injury. *Knee Surg Sports Traumatol Arthrosc* 18:1568–1572, 2010.

This prospective trial followed 43 patients to discover clinical outcomes following surgery with reconstruction for an isolated PCL injury. At 48 months, Lysholm knee scores, International Knee Documentation Committee 2000 (IKDC) scores, Cincinnati scores, Tegner scores, KOOS scores, VAS scores, stress radiographs, and functional tests showed good functional outcomes following reconstruction. (Level III evidence)

MacDonald P, Miniaci A, Fowler P, et al: A biomechanical analysis of joint contact forces in the posterior cruciate deficient knee. *Knee Surg, Sports Traumatol Arthroscop* 3:252–255, 1976.

A biomechanical study that compared nine fresh cadaveric knees from young donors as they were loaded at 0°, 30°, and 60° to 1.5 kN with low-pressure sensitive Prescale film inserted through arthrotomies into the medial and lateral compartments. Computerized analysis of the imprints on the film was then carried out and repeated after cutting the PCL. Results showed a statistically significant posterior subluxation of the tibia on the femur at 60° flexion leading to a significant increase in pressure at the medial compartment after cutting the PCL. These findings may explain long-term degenerative changes at the medial femoral condyle in PCL deficient knees. (Cadaveric study)

Parolie JM, Bergfeld JA: Long-term results of nonoperative treatment of isolated posterior cruciate ligament injuries in the athlete. *Am J Sports Med* 14(1):35–38, 1986.

Long-term study of 25 athletes who received nonoperative treatment of isolated PCL injuries with follow-up averaging 6 years. Patients were evaluated with a questionnaire and objectively with clinical examination, x-ray films, Cybex II dynamometer, and KT-1000 Knee Arthrometer. Found that 80% of the patients were satisfied with their knee with 84% returning to their previous sport. It was concluded that if athletes with isolated PCL injuries maintain muscle strength, the majority should return to sports without lingering disability. (Level IV evidence)

Schulz MS, Russe K, Weiler A, et al: Epidemiology of posterior cruciate ligament injuries. *Arch Orthop Trauma Surg* 123:186–191, 2003.

A retrospective analysis of 494 patients with PCL insufficiency using stress radiographs to quantify posterior tibial displacement to understand the epidemiology of PCL Injuries. The authors found that athletic injuries represented 40% of this cohort, with the majority of these resulting from contact sports. (Level II evidence)

Shelbourne KD, Jennings RW, Vahey TN: Magnetic resonance imaging of posterior cruciate ligament injuries: Assessment of healing. *Am J Knee Surg* 12(4):209–213, 1999.

This study followed 40 knees with acute PCL injuries during the initial 6 months to and approximately 3 years later to assess healing demonstrated on T2 MRI. Found that all of the low and mid-grade PCL injuries had healed with continuity, whereas 19 of 20 high-grade and combined injuries were showed healing, but were less likely to regain continuity. Concluded that most nonoperatively treated PCL tears can heal with continuity, even when accompanied by other ligament injuries. (Level III evidence)

Strobel MJ, Weiler A, Schulz M, et al: Fixed posterior subluxation in posterior cruciate ligament-deficient knees. *Am J Sports Med* 30(32):32–38, 2002.

This study examined found that 109 of 248 patients with PCL insufficiency suffered from fixed posterior subluxation of the tibia. Patients were treated with a posterior tibial support brace to reduce subluxation. The investigators found that the brace reduced subluxation well in patients with grades I and II subluxations, but not sufficiently in patients with grade III subluxation. They concluded that patients with grades I and II subluxations should be treated with a posterior support brace before PCL reconstructions, whereas those with grade III subluxation should receive more invasive treatments prior to reconstruction. (Level III evidence)

Winters K, Tregonning R: Reliability of magnetic resonance imaging of the traumatic knee as determined by arthroscopy. *N Z Med J* 118(1209):U1301, 2005.

A prospective study comparing the diagnostic results of MRI scans of 67 patients with knee injuries with subsequent arthroscopic diagnosis. The imaging studies provided a diagnostic accuracy of 96% for posterior cruciate ligament injuries with a sensitivity of 80% and specificity of 97%. It was concluded that MRI is a useful diagnostic tool for evaluating knee injuries. (Level II evidence)

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1. Schulz MS, Russe K, Weiler A, et al: Epidemiology of posterior cruciate ligament injuries. *Arch Orthop Trauma Surg* 123:186–191, 2003.
2. Hewett TE, Noyes FR, Lee MD: Diagnosis of complete and partial posterior cruciate ligament ruptures. Stress radiography compared with KT-1000 arthrometer and posterior drawer testing. Am J Sports Med 25(5):648–655, 1997.
3. Jung YB, Tae SK, Lee YS, et al: Active non-operative treatment of acute isolated posterior cruciate ligament injury with cylinder cast immobilization. *Knee Surg Sports Traumatol Arthrosc* 16:729–733, 2008.

Multiple Choice Questions

QUESTION 1. A 25-year-old male soccer player slid into the goalpost while making a save. He suffered a direct anterior blow to the proximal tibia of his flexed left leg. He presented to the hospital that night with pain and swelling of the left knee. He described a general feeling of "something not being right" and had difficulty walking down stairs. On clinical examination he was discovered to have a Grade III PCL tear. Which of the following is the most important aspect to evaluate in a patient presenting with an acute knee injury?

A. Posterior drawer test
B. MRI with axial cuts
C. Posterior knee stress radiographs
D. Neurovascular status

QUESTION 2. If a patient had suffered an isolated posterior cruciate ligament tear, which of the following abnormal motions would be seen on physical exam?

A. The tibia would move anteriorly in relation to the femur.
B. The knee would have lateral opening when a valgus stress is applied.
C. The tibia would move posteriorly in relation to the femur.
D. The knee would lock in extension.

QUESTION 3. Which of the following patients should not be considered for surgical repair or reconstruction of a PCL injury?

A. A 25-year-old elite athlete with a grade II PCL tear
B. A 19-year-old patient with an acute combined grade III PCL/PLC injury with hemarthrosis of the affected knee
C. A 35-year-old female with a large bony avulsion off the tibia
D. A 58-year-old obese, sedentary male with an isolated grade III tear of his PCL

QUESTION 4. During first 6 weeks of rehabilitation or nonoperative treatment of posterior cruciate ligament injuries, which of the following exercises should be avoided?

A. Isolated hamstring strengthening exercises
B. Straight leg raises
C. Electrical stimulation of the quadriceps muscles
D. Partial weightbearing on crutches

QUESTION 5. A 45-year-old male hockey player comes into the office complaining of generalized pain in his left knee after sliding into a goal post during a recreational hockey game 1 week ago. He has no numbness, tingling, or loss of sensation in the affected limb. After completing a complete physical exam, you suspect he has suffered an isolated PCL injury. If an MRI scan were unable to determine if the tear is partial or complete, which diagnostic modality would be most helpful in classifying his injury?

A. Tunnel view radiographs
B. Posterior stress radiographs
C. AP and lateral radiographs
D. CT imaging

Answer Key

QUESTION 1. Correct answer: **D** With acute knee injuries it is of vital important to determine a patient's neurovascular status. The examiner must make certain there has been no damage to arteries or nerves which would require immediate intervention to prevent permanent loss or disability. (see Clinical Presentation)

QUESTION 2. Correct answer: **C** The tibia would move posteriorly in relation to the femur. With isolated PCL injuries, the main posterior stabilizer preventing

posterior translation of the tibia is lost. In combined injuries you can see increased rotatory instability as well as medial/lateral gapping. Locking in extension/flexion is more typical of meniscal injuries and would not be expected in an isolated PCL injury. (see Clinical Presentation)

QUESTION 3. Correct answer: **D** Patients with a sedentary lifestyle, or those who are unlikely to comply with rehabilitation and postoperative protocols should not be considered for PCL reconstruction, even with grade III tears. Elite athletes with grade II tears can be considered for surgery to aid them in returning to the previous level of performance. Large bony avulsion fractures are candidates for surgery, whereas smaller avulsions can be managed conservatively. Acute combined PCL injuries are typically candidates for surgery within 3 weeks of the injury, even if hemarthrosis is present. (see Treatment)

QUESTION 4. Correct answer: **A** Isolated hamstring exercises create posterior forces on the tibia, which can stretch reconstruction grafts or reinjure partial tears. Patients should avoid isolated hamstring exercises for at least 8 weeks after injury or surgery to allow for adequate healing. Straight leg raises, electrical stimulation, and partial weightbearing on crutches are all strategic points in the initial phase of surgical rehab or conservative treatment. (see Treatment)

QUESTION 5. Correct answer: **B** Posterior stress radiographs are a helpful diagnostic tool to objectively assess PCL tears. Normal knees have between 0 and 2 mm increased posterior translation, partial tears 2 to 7 mm, complete tears 8 to 11 mm and combined injuries will have greater than 12 mm increased posterior translation. They can be very helpful when the clinical exam or an MRI is nondiagnostic. Tunnel view radiographs, AP, and lateral radiographs are all part of the imaging work-up for a suspected PCL injury, but are of no use when grading the tear. Computed tomography has little use with PCL injuries unless the surgeon is trying to assess the size of an avulsion fracture for operative planning or is looking for a tibial plateau fracture. (see Imaging)

NONOPERATIVE REHABILITATION OF POSTERIOR CRUCIATE LIGAMENT INJURIES

Robert F. LaPrade, MD, PhD, Casey M. Pierce, MD, and Scott A. Wilkins, DPT, OCS

GUIDING PRINCIPLES OF NONOPERATIVE REHABILITATION

- Protect healing ligament.
- Reduce swelling and pain.
- Restore functional strength and stability to the knee.
- Initiate early activation of the quadriceps to maintain stability.
- Limit risk or reinjury.
- Help the patient adapt to daily life after injury and safely return to sports.

Phase I (weeks 0 to 4)

Protection

- Nonweightbearing (NWB) to partial weightbearing for 2 weeks
- Axillary crutches until gait is normalized
- Knee immobilizer locked in 0° extension during gait for first 1 to 2 weeks (Figure 33-14*A*)
  - Pad behind tibia to avoid posterior tibial sag while at rest (Figure 33-14*B*).
  - Brace opened to 90° for sitting after 2 weeks.
  - Knee ROM should be performed only in the prone position for the first week (Figure 33-15).
    - Prevents hamstring activation and posterior sag caused by gravity
- If a combined PLC and PCL injury is diagnosed, the patient should be in a functional PCL brace to better support the posterior capsule.
- Range of motion during therapy exercises should be limited from 45° to 90° for the first 2 weeks.
  - This is based on biomechanical studies that show the varying loads on the PCL based on knee flexion angles and avoidance of sheer forces on the damaged PCL.

Management of Pain and Swelling

- Vasopneumatic compression
- Elevation
- Compression bandage
- Cryotherapy
  - Apply ice for 20 minutes following exercises/physical therapy
- PRICE technique → protect, rest, ice, compress, and elevate



FIGURE 33-14. Knee Immobilizer locked in 0° extension (**A**) and pad behind tibia to avoid posterior tibial sag while at rest (**B**).

- Medications
  - NSAIDs as needed
- 48 hours after the injury moist heat can be applied for 20 minutes at a time as needed

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Initially patients are immobilized to allow for early ligament healing to begin (see Figure 33-14).
- Protected prone ROM may begin right away depending on the grade of the injury or other associated injuries.
  - Posterior sag of the tibia must be protected at all times during this phase.
  - Once ROM is allowed, passive ROM is progressed slowly over the next 4 weeks from 0° to 120°.
  - Knee ROM should be performed passively in the prone position (see Figure 33-15).
    - Avoids activation of the hamstrings
    - Allows compression of the tibiofemoral joint preventing posterior translation of the tibia on the femur
    - Prevents posterior sag of the tibia on the femur
  - Passive knee flexion should be performed with a manual anteriorly directed translation force on the tibia over the femur throughout the range of motion.
- Anteriorly directed tibial translation mobilizations may be performed in chronic injuries that have a fixed posterior translation to restore normal joint position and tibiofemoral contact points.
- Patellar mobilizations can be performed during the immobilization period to avoid adhesions of the patellofemoral joint.



FIGURE 33-15. ROM exercises in the prone position with anteriorly directed tibial translation.



FIGURE 33-16. Stretching exercises for the hamstring (**A**), gastrocnemius (**B**), and quadriceps (**C**).

Soft Tissue Techniques

- Soft tissue mobilization, trigger point release, myofascial release, and retrograde edema mobilization may be performed on the muscles and fascia around the involved limb.
  - These techniques reduce fascia restrictions, control swelling, reduce pain, and facilitate muscle activation.
  - To limit stress to the healing ligament, care should be taken during soft tissue techniques to avoid direct posterior pressure on the tibia or varus/valgus positioning of the limb.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Stretching of the posterior thigh, hamstring and gastrocnemius muscles as tolerated without pain (Figure 33-16).
  - Especially warranted for those individuals demonstrating a flexed knee gait

Other Therapeutic Exercises

- Total leg strength (TLS)
  - Two sets of 10 to 15 repetitions for lower extremity strengthening exercises
  - Straight leg raise in supine with brace on and locked in extension (Figure 33-17)
  - Standing/side-lying hip abduction with brace on (Figure 33-18)



FIGURE 33-17. Supine straight leg raise with locked extension brace.



FIGURE 33-18. Side-lying hip adduction with the brace in place.

- Standing/prone hip extension with brace on (Figure 33-19)
- Standing heel raises once weightbearing is allowed (Figure 33-20)

- Total body strength (TBS)
  - Upper body strengthening and core strengthening may continue throughout this phase in a nonweightbearing position.
    - Care must be taken to avoid bracing or stabilizing with the involved limb during upper body and core strengthening.
    - The knee brace should be worn for safety.
  - Early TBS exercises
    - Two sets of 8 to 12 repetitions for upper extremity and core strengthening exercises
    - Posterior pelvic tilting with abdominal bracing (Figure 33-21*A*)
    - Abdominal bracing with leg lifting in supine and prone (Figure 33-21*B*)
    - Seated rows with the legs straight
    - Seated pull downs with the legs straight
  - Rotational stresses to the core may be applied manually by the therapist and initiated in supine during Phase I.



FIGURE 33-19. Standing hip extension with the brace in place.

TIMELINE 33-1: **Nonoperative Rehabilitation of a Posterior Cruciate Ligament Injury**

PHASE I (weeks 1 to 2 postinjury)

- PWB with crutches until end of week 2
- Brace limiting ROM 0°–90°
  - Padding placed behind posterior tibia to prevent sagging at rest
  - Capsule support if combined injury
- Transition to Jack PCL brace when quad control allows normal SLR
- PRICE protocol and proper stretching
- PT modalities
- Passive prone ROM-flexion 0°–90°
  - Patellar mobilizations and anterior tibial translation mobilizations
- EMS to quadriceps
- TBS/TAS/TLS activities as recommended and tolerated
- OKC and CKC exercises
  - Quad sets
  - Quad isometrics Straight leg raises
  - Hip abduction/adduction
  - Knee extensions 90°–60°
  - Leg presses 0°–70°
- Avoid isolated hamstring activating exercises
- TBS/TAS/TLS activities as recommended and tolerated
- Stability exercises progression to unstable surfaces by week 3
- Upper body bike
- Stationary bike and pool program during week 3
- Gait mechanics after week 2

PHASE II (weeks 5 to 8 postinjury)

- Weightbearing as tolerated
- JACK brace
- PRICE protocol and proper stretching
- PT modalities
- ROM—week 3: Performed passively in prone 0°–90°
- ROM—week 4: Performed passively in prone 0°–120°
- ROM—week 6: Performed passively in prone 0° to full PROM
- OKC and CKC exercises with progressing weight
  - Quad sets
  - Quad isometrics
  - Straight leg raises
  - Hip abduction/adduction exercises
  - Knee extensions 0°–70°
  - Leg presses 0°–70°
  - Mini-squats 0°–70°
  - Step ups
  - Toe calf raises
- Hamstring activation beginning week 6
- Range 0°–70° with low resistance only
- TBS/TAS/TLS activities as recommended and tolerated
- Pool running week 5
- Running progression may begin week 6
- Deceleration exercises



FIGURE 33-20. Standing heel raises: two legs (**A**) and one leg (**B**).

TIMELINE 33-1: **Nonoperative Rehabilitation of a Posterior Cruciate Ligament Injury** (Continued)

PHASE III (weeks 9 to 14 postinjury)	PHASE IV (weeks 15 to 20 postinjury)	PHASE V (weeks 21+ postinjury)

• PT modalities as needed JACK brace
• PROM—full
• PRICE protocol and proper stretching
• Soft tissue techniques and joint mobilizations as needed PT modalities
• TBS/TAS/TLS activities as recommended and tolerated
• Quadriceps strengthening—PREs
• TAS—upper body strengthening—PREs-performed in sitting
• Hip—PREs
• Core strengthening/stabilization exercises
• Balance and proprioception exercises
• Neuromuscular dynamic stability exercises with brace on
• Straight-ahead running as tolerated
• OKC and CKC exercises with progressing weight
  • Quad sets
  • Quad isometrics
  • Straight leg raises
  • Hip ab/adduction
  • Knee extensions 0°–90°
  • Leg presses 0°–70°
  • Mini-squats 0°–70°
  • Step ups
  • Toe calf raises
• CKC exercises to 70° flexion, progressing to 90° by week 8
• Continued deceleration training
• Initiate plyometrics and jump training exercises
• Running progression including light cutting and pivoting by week 12
• Sport specific agility and skill training
• Gradual return to practice and sport activities
	• Clinical exam and/or PCL stress radiographs to verify healing of PCL
	• PCL brace with sporting activities
	• PT modalities as needed
	• PROM—full
	• Tool assisted soft tissue techniques and joint mobilizations as needed
	• TBS/TAS/TLS activities as recommended and tolerated
	• Hip—PREs
	• TAS—upper body strengthening- PREs—performed in standing
	• Core strengthening/stabilization exercises progressed
	• OKC knee exercises for quadriceps and hamstrings
	• CKC exercises to 90° knee flexion
	• Balance and proprioception exercises
	• Neuromuscular dynamic stability exercises with brace on
	• Progress running program
	• Sport specific agility exercises
		• PROM—maintain full motion
		• Mobilizations as needed
		• TBS/TAS/TLS activities as recommended and tolerated
		• OKC exercises progressed
		• CKC exercises progresses
		• Neuromuscular dynamic stability exercises without brace
		• Plyometric/jump training progressed
		• Sport specific agility exercises
		• Core strengthening/stabilization exercises progressed
		• Noncontact return to play after 24
		• Full contact return to play when return to sports criterion met

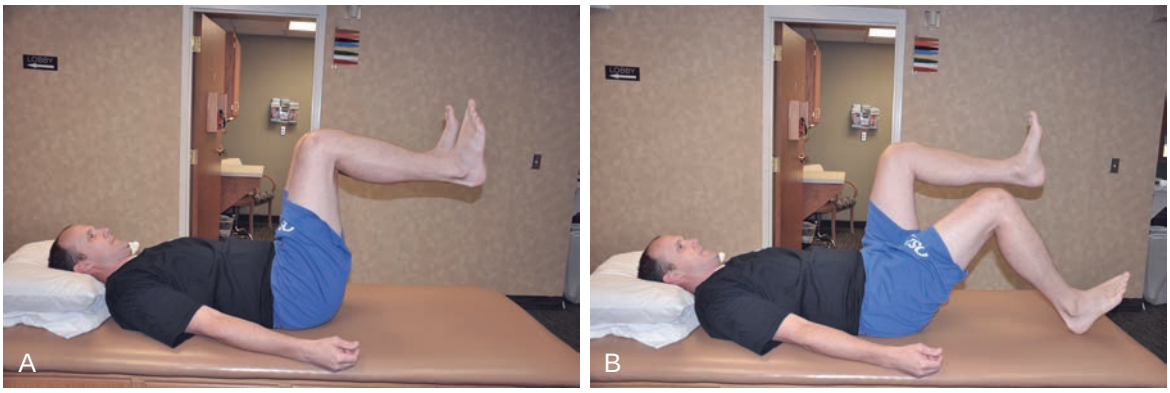

FIGURE 33-21. Posterior pelvic tilting with abdominal bracing (**A**) and with one leg lifting (**B**).

Activation of Primary Muscles Involved

- Quadriceps activation through quadriceps setting and progressing to straight leg raising without an extension lag
  - Two sets of 10 to 15 repetitions
  - This should be performed in the knee brace with pad behind tibia to avoid posterior tibia sag.
  - Patient may progress to straight leg raise without the brace once able to perform exercise without a lag sign
- Neuromuscular electrical stimulation may be applied to quadriceps to aid in early activation and prevent atrophy of immobilized muscles (Figure 33-22)
  - Also found to be useful when applied while the patient exercises

Sensorimotor Exercises

- Once weightbearing is allowed, patients may initiate standing weight shifts with their brace on.
  - May progress to exercises without the brace once the patient has demonstrated normal quadriceps activation, straight leg without lag sign, and can bear full weight without pain or giving way
- Single leg exercises help to restore balance
- Balance exercises are progressed from eyes open to eyes closed and from stable to unstable surfaces such as foam pads.
- The majority of proprioceptive training will begin during Phase II.

Open and Closed Kinetic Chain Exercises

- OKC exercises while in brace
  - Two sets of 10 to 15 repetitions for OKC exercises
  - Side-lying or standing hip abduction
  - Standing or prone hip extension
  - Supine straight leg raises
  - Ankle pumps
- Once knee ROM is allowed, OKC exercises can include:
  - Knee extension from 90° to 60° flexion to facilitate quadriceps strengthening (Figure 33-23)
    - Limit knee extension to decrease forces on the patellofemoral joint and sheer forces on the healing PCL



FIGURE 33-22. Electrical stimulation pad placement on the quadriceps.

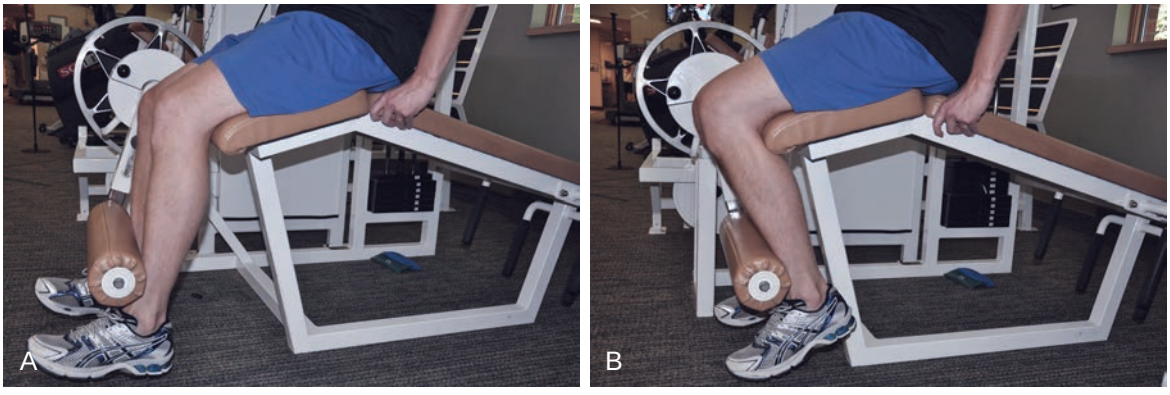

FIGURE 33-23. OKC knee extensions from 90° (**A**) to 60° (**B**).



FIGURE 33-24. Two legged wall slides from 0° to 70°.

- CKC exercises may begin after 2 to 3 weeks or once weightbearing is allowed
  - Limit knee extension between 70° and 30° window to limit forces on the patellofemoral joint and sheer forces on the healing PCL
  - Early exercises
    - Two sets of 10 to 15 repetitions for early exercises
    - Standing heel raises
    - Two-legged wall slides from 0° to 70° (Figure 33-24)
    - Leg press at 25% body weight (Figure 33-25)
  - 25% body weight is a starting point for CKC exercises that may be progressed according to patient tolerance and performance of exercise at an intensity of two sets of 10 to 15 repetitions
  - Limited to 45° knee flexion for the first week and progressed to 70° during week 2
    - Prevents posterior sheer forces on the PCL
  - Progress to mini squats at the counter from 0° to 70°



FIGURE 33-25. Leg presses at 45°.

Techniques to Increase Muscle Strength, Power, and Endurance

- OKC and CKC exercises can be progressed according to patient tolerance and endurance
  - Mixed CKC and OKC quadriceps will help build strength/power
  - Single leg resisted knee exercises can start after week 1
  - Exercises should be pain free
  - Exercises are discontinued if pain, acute effusion, catching, or giving way is present
- Early exercises should include high repetition and low weight resistance to target Type I endurance muscle fibers
  - An upper body bicycle can be helpful to maintain or improve cardiovascular endurance
- Strengthening exercises should be performed daily or every other day and monitored for signs of joint aggravation such as acute swelling/effusion and localized joint pain

Neuromuscular Dynamic Stability Exercises

- CKC neuromuscular stability exercises should be performed in the brace initially until normal quadriceps activation (as compared with the contralateral normal side) is achieved and the patient is able to walk without a limp.
  - Stability exercises should progress from stable to unstable surfaces such as foam, air bladders, or wobble boards (Figure 33-26).
    - Three to five sets of 30 second intervals for stability exercises
  - Patients may initially require upper extremity assistance to maintain balance.
  - As function and stability progress, perturbations may be applied in random order to further challenge the neuromuscular system.

Functional Exercises

- Step up exercises performed on a 6-inch step can begin when gait on flat ground is normalized (Figure 33-27).
  - Two sets of 10 to 15 repetitions for step up exercises
- Exercises should be performed with the brace on and can be progressed through increased step height and from stepping up to stepping down.
- Walking forward and backward with the help of a mirror will help to restore proper gait mechanics once full weightbearing is allowed

Milestones for Progression to the Next Phase

- Minimal or decreased knee swelling
- Ability to straight leg raise without extension lag
- Gait is normalized without crutch assistance
- Patient is able to walk up and down steps without limp
- Knee ROM to 120° flexion

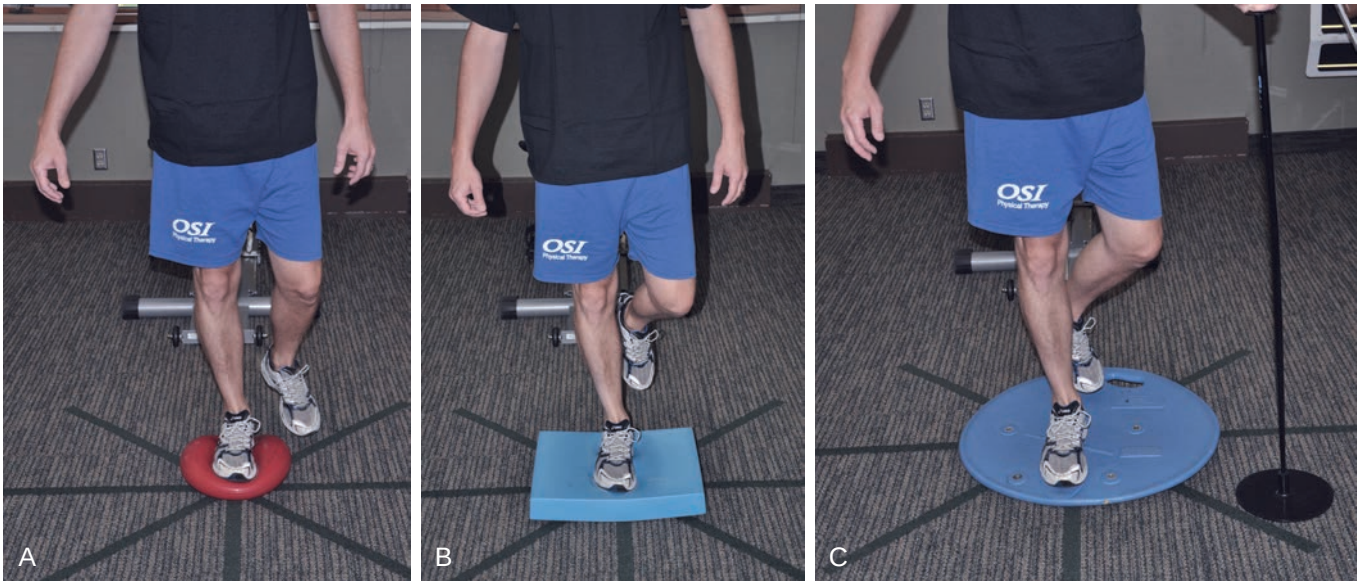

FIGURE 33-26. Stability exercises on an air bladder (**A**), foam (**B**), and wobble board (**C**).

Phase II (weeks 5 to 8)

Protection

- Transition to PCL support brace
  - Used for support during light activities and pain free return to sports activities
- Discontinue the use of crutches
  - Weightbearing as tolerated

Management of Pain and Swelling

- Similar to Phase I
- Vasopneumatic compression
- Elevation
- Compression wrap
- Cryotherapy
  - Apply ice for 20 minutes following exercises/physical therapy
- PRICE technique → protect, rest, ice, compress, and elevate
- Medications
  - NSAIDs as needed
- Moist heat can be applied for 20 minutes at a time as needed

Techniques for Progressive Increase in Range of Motion

- Progress toward full PROM starting at week 4 followed by full AROM once isolated hamstring contractions are allowed at 6 weeks.

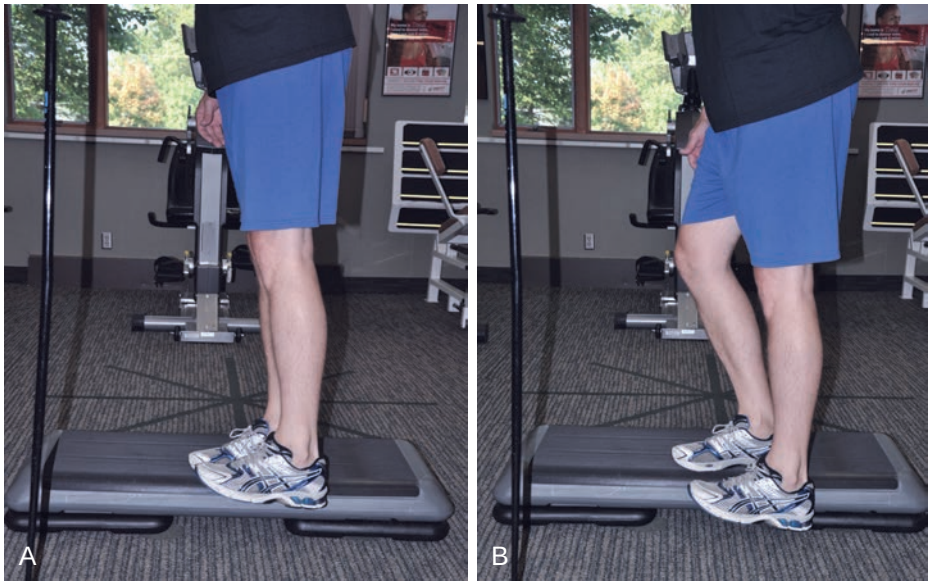

FIGURE 33-27. Step up exercises: start (**A**) and finish (**B**).

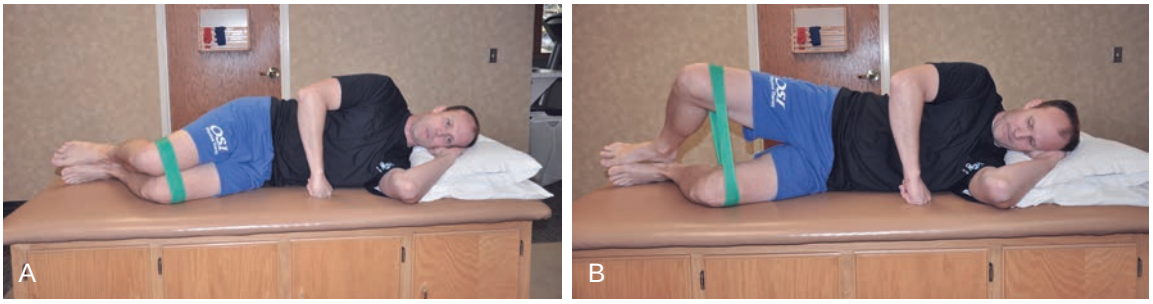

FIGURE 33-28. Side-lying external rotation (clamshell): start (**A**) and finish (**B**).

- Posterior sag of the tibia must continue to be avoided through an anteriorly directed force applied to the tibia during all ROM exercises and avoidance of isolated hamstring activation.

Manual Therapy Techniques

- Anterior tibial translation mobilizations and patellar mobilizations as needed to restore normal tibiofemoral contact points and prevent fixed posterior translation of the tibia
- Continued patellar mobilizations may be required as full knee flexion ROM is achieved

Soft Tissue Techniques

- Continue as necessary from Phase I.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Passive range of motion (PROM) performed in a prone position, or in a supine position with anteriorly directed force applied to the posterior tibia during flexion to achieve the goal of full PROM
- Hamstring and calf stretching as needed
- Begin prone quad stretching as full knee flexion ROM is achieved

Other Therapeutic Exercises

- Weight or resistance bands may be added proximal to the tibia as strength allows
- TLS should be performed to fatigue every other day
- TLS exercises should continue to include:
  - Quadriceps sets
  - Supine straight leg raises into hip flexion
  - Side-lying hip abduction
  - Prone hip extension
  - Side-lying hip "clamshell" external rotation (Figure 33-28), and standing single leg heel raises
  - Each exercise should be performed three times per day to fatigue
- Stationary biking for ROM may begin once 105° of knee flexion is achieved (Figure 33-29)
  - Seat height should be set so that the lower leg should have the knee slightly flexed at bottom dead center of the pedal stroke
  - The foot should be placed slightly forward on the pedal (without toe clips) to minimize hamstring activity
  - Start with no resistance
  - Progress from 5 minutes to 20 minutes as strength permits



FIGURE 33-29. Proper leg placement on a stationary bike. To avoid activation of the hamstrings, the patient should ride the bike with the seat set to allow the knee to flex slightly (**A**) and the feet slightly forward on the pedals (**B**).

- Core stability exercises may now incorporate the use of the lower body for stabilization:
  - Two sets of 10 to 15 repetitions for core stability exercises
    - Isometric hold exercises such as planks may be performed in two to three sets of 30- to 60-second hold intervals
  - Standing isometric side planks and side-lying planks
  - Bridging progression
  - Swiss ball work
- Patients should avoid kneeling on the affected limb.
  - Quadruped strengthening exercises are avoided.
- Isolated hamstring activation is not allowed; therefore, stability exercises such as 90/90 bridging or heel digs must also be avoided.
- TBS exercises can include upper body strengthening in weightbearing with brace on for protection.
  - Patients should maintain an athletic stance with equal weight distribution throughout the lower extremities during upper body exercises.
  - Resistance should be limited to levels conducive to proper form throughout the upper and lower body.

Activation of Primary Muscles Involved

- Quadriceps
- Gluteal muscles
- Gastrocnemius

Sensorimotor Exercises

- Weight shifting and single leg stance exercises can be progressed from flat ground to unstable surfaces such as foam pads, half-foam roller, rocker boards, and air bladders
  - Two to three sets of 30- to 60-second hold intervals for sensorimotor exercises
- Emphasis is placed on maintaining neutral knee alignment and athletic stance during balance exercises
- Exercises should be performed with brace on for additional safety
- Balance exercises can be further progressed by closing the eyes or applying manual perturbations
- Single leg exercises should be increased

Open and Closed Kinetic Chain Exercises

- Open kinetic chain knee extension for quadriceps strengthening may begin at the end of week 2 and continue throughout rehabilitation, ranging from 70° to 30° of extension, in a sitting position
- Open kinetic chain knee flexion and isolated hamstring activation is not allowed until after week 6
  - When starting leg curls/isotonic hamstring curls, range only from 0° to 70° and begin with very light resistance
- Supine straight leg raise, side-lying hip abduction, prone hip extension, side-lying hip external rotation (clamshell) OKC strengthening should continue throughout Phase II
- CKC exercises can be increased from Phase I (two sets of 8 to 12 repetitions)
  - Leg press 0° to 70° increasing to 60% to 80% body weight
  - Squats to 70° knee flexion
  - Single leg squats to 70° flexion
  - Forward and backward lunges (Figure 33-30)
  - Resisted toe calf raises
  - Step ups and step downs
  - Single leg wall slides to 70° knee flexion



FIGURE 33-30. Forward/Backward lunges.

Techniques to Increase Muscle Strength, Power, and Endurance

- Exercises for endurance can be initiated as ROM and discomfort allow
  - 20- to 30-minute intervals three to five days per week at 65% to 70% of age predicted maximum heart rate
    - Begin initially with 10 minute bouts three times per day until 20 to 30 minutes of exercises is tolerated for endurance exercises
  - Resisted cycling is progressed as endurance allows
    - Patients should maintain greater than 80 RPMs and quadriceps should feel fatigued after cycling, not completely exhausted
  - Elliptical
  - Stairmaster
  - Pool running/pool program

Neuromuscular Dynamic Stability Exercises

- Two sets of 8 to 12 repetitions for neuromuscular dynamic stability exercises
- Deceleration drills to teach proper landing technique should begin during Phase II
  - Double leg landings
    - Make sure the patient holds the landing position for 3 to 5 seconds



FIGURE 33-31. Squat jumps progression.

- Squats on a tilt board or balance ball
- One-legged balance throws
- Balance lunges on a tilt board
  - Can increase difficulty by adding perturbations

Plyometrics

- Two sets of 8 to 12 repetitions per exercise for plyometric exercises
- Deceleration/landing exercises should be mastered prior to moving on to plyometric exercises:
  - Side to side jumps
  - Jumping jacks
  - Squat jumps (Figure 33-31)

Functional Exercises

- Before progressing to running the patient must be able to walk aggressively at approximately 4.2 to 5.2 MPH without pain
  - Progression of marching skipping, high knees, and bounding performed at three sets of 30-second intervals until 450 foot contacts are achieved would be equivalent to two thirds of a mile
- Running progression should start during week 6
  - Marching → skipping → high knees → alternate leg bounding
- Squatting is progressed to a depth of 70° knee flexion
  - Patients should be told to avoid excessive forward lean during squats because this increases hamstring activation relative to the quadriceps
- Single leg squats to a depth of 70° are initiated with the patient's back against a ball propped on the wall
  - It is important to maintain neutral knee alignment, avoiding knee valgus or varus during squats

Sport-Specific Exercises

- Straight line running may begin at approximately 6 to 8 weeks if swelling is eliminated, gait is normalized, there is a negative posterior sag sign, patient is pain free with up and down steps and squatting exercises
  - Patients should run with brace on
  - Treadmill running is preferred initially to control the consistency of running surface and allow for immediate discontinuation of exercise if pain symptoms arise
  - Running can be advanced to outdoor running as endurance and strength allows
  - Distance may be progressed by 15% per week
    - If patient experiences symptoms of pain, swelling, or shifting in the knee the distance is reduced to the previous weeks distance for 2 weeks before advancing again
    - Repeat until goal running distance is achieved
- Patients can start to gradually return to sports activities around weeks 8 to 9 if they have met the following criteria:
  - Painless full ROM
  - No change in laxity
  - Adequate return of quadriceps strength has returned
  - At least 85% to 90% compared with that of contralateral normal leg
    - Measured by OKC and CKC knee extension exercises as well as compared by measurement around the thigh to compare muscle bulk versus the contralateral normal leg

Milestones for Progression to the Next Phase

- Full non-painful PROM by the end of week 6
- Improved lower extremity strength
  - Measured against the patients starting points when rehabilitation first began
- Single leg squat to 70° and held for 5 seconds
  - A 5-second hold allows for local fatigue of fast twitch muscle fibers and minimize contact forces around the knee.
- Flat ground running without asymmetry
- Negative posterior sag sign
  - Patient supine, knees flexed at 90°
  - Practitioner supports the legs and ankles and looks for the tibia to "sag" posteriorly
    - Posterior sag indicates PCL insufficiency
      - Positive sag sign could indicate a more severe PCL injury than first suspected and the patient may require repeat examination by the clinician/surgeon or further time spent on the exercises in the current phase
- Negative quads active test
  - Patient supine, knees flexed at 90°
  - Practitioner supports the patient's thigh to monitor muscle tone and stabilizes the foot with the other hand
  - Patient attempts to slide their foot down the table
    - A PCL deficient knee's tibia will move anteriorly
    - A normal knee's tibia will move minimally

Phase III (weeks 9 to 14)

Protection

- PCL support brace to prevent posterior tibia translation

Management of Pain and Swelling

- Similar to Phase II:
  - Vasopneumatic compression
  - Elevation
  - Compression wrap
  - Cryotherapy as needed
    - Should focus on icing after exercises for at least 20 minutes
  - Moist heat as needed

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Full passive range of motion

Soft Tissue Techniques

- Continue those from Phase I/II as needed

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Active range of motion (AROM) and active assisted range of motion (AAROM) continues toward full flexion, if not already achieved
- Stationary biking for ROM may begin once 105° of knee flexion is achieved
  - Seat height should be set so that the lower leg should have the knee slightly flexed
  - The foot should be placed slightly forward on the pedal (without toe clips) to minimize hamstring activity
  - Begin with zero resistance
  - Progress from 5 minutes to 20 minutes as strength permits

Other Therapeutic Exercises

- Total leg strength (TLS)
- Two sets of 8 to 12 repetitions for lower extremity strengthening
- Continue quadriceps sets
- Straight leg raises into hip flexion, extension, abduction
  - Resistance bands or weight should be added proximal to the knee joint as strength allows
- Open kinetic chain knee extension from 70° to 30° in sitting position
- Calf raises with the knee straight
  - Sets done slow and fast (each)
- Double leg squats to 90 degrees flexion
- Single leg squats (from 0° to 70°)
- Leg presses
  - Light weights (start off at 25% of body weight and maximize to 60% to 80%)
    - Start at 25% body weight and progress as tolerated with two sets of 8 to 12 repetitions for strengthening
    - Limit to 60% to 80% to prevent over exertion, improper form and potential injury
  - Maximum of 0° to 70° of knee flexion

Activation of Primary Muscles Involved

- Quadriceps
- Gluteals
- Gastrocnemius
- Hamstrings

Sensorimotor Exercises

- Weight shifts on involved limb
  - Three to five sets of 30 to 60 seconds for weight shift exercises
  - Eyes open and eyes closed
  - Progress to single leg stance, eyes open, on a firm surface
  - Increase difficulty by closing eyes and adding changing to an unstable surface (i.e., cushion, foam half-roller, air bladder, wobble board, or BOSU ball)

Open and Closed Kinetic Chain Exercises

- Two sets of 8 to 12 repetitions for OKC and CKC exercises
- OKC exercises
  - After 8 weeks, if posterior sag sign and posterior drawer are negative, patients may begin active hamstring strengthening
    - Hamstring strengthening should be initiated in CKC hamstring dominate exercises such as "good morning" exercises (Figure 33-32) and may progress to more isolated hamstring activation such as supine heel digs or eccentric rollouts on a Swiss ball (Figure 33-33)
    - As hamstring strength develops and no signs of increasing posterior instability appear, patients may progress to OKC hamstring strengthening against resistance



FIGURE 33-32. CKC hamstring exercises.

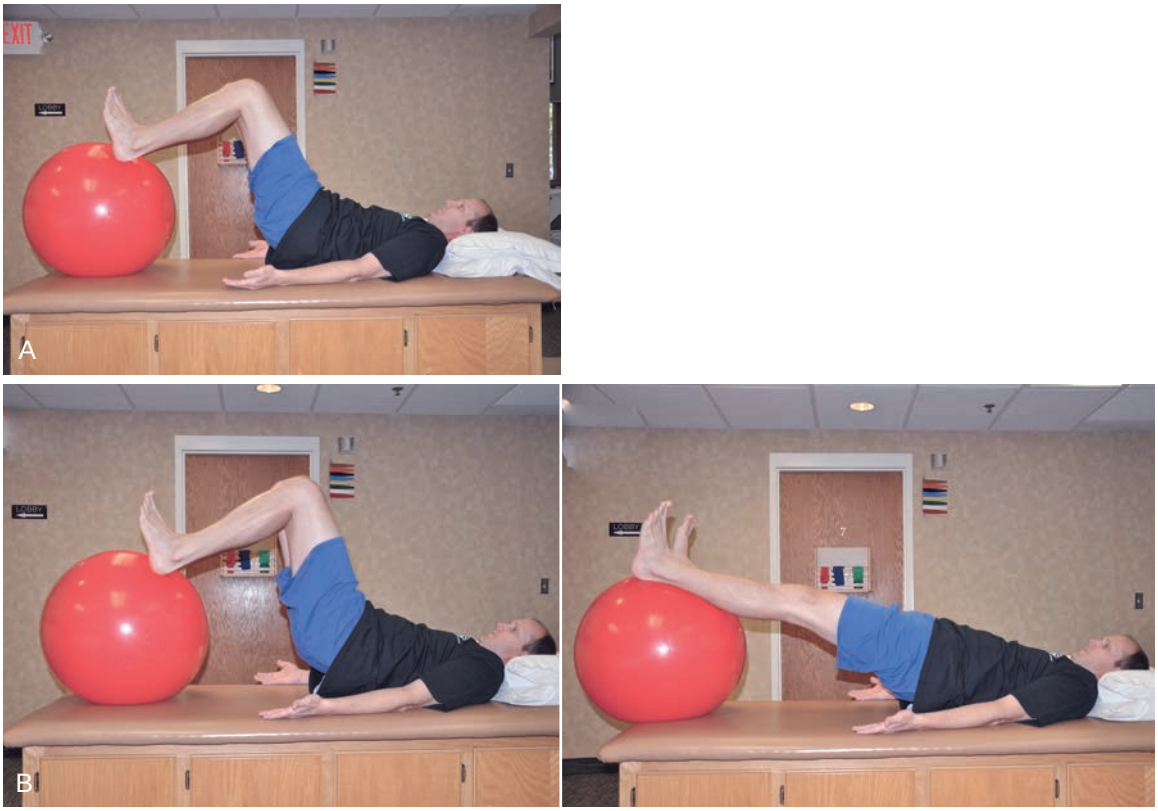

FIGURE 33-33. Supine heel digs (**A**) and eccentric rollouts (**B**) on a Swiss ball.

  - Patients should be directed to maintain neutral foot alignment throughout the ROM
- CKC exercises
  - Functional squats with resistance to 90° knee flexion
  - Single leg squat with dumbbell resistance to 70° knee flexion
  - Leg press to 90° flexion with two legs
  - Single leg eccentric leg press to 70° knee flexion
  - Standing single leg heel raises with dumbbell resistance
  - Lateral and backward walking with band resistance (Figure 33-34)

Techniques to Increase Muscle Strength, Power, and Endurance

- Stationary biking may be progressed as strength and endurance allow.
  - Low impact activities such as cycling may be increased as tolerated from 30 to 60 minutes.



FIGURE 33-34. Lateral (**A**) and backward (**B**) walking band resistance.

- Maintain approximately 80 rotations per minute as endurance allows.
- Begin straight ahead jogging after running progression completed.
  - Straight line running every other day for 30 minutes starting with 5 minutes fast walking and 1 minute jog repeated five times
  - Progress running by decreasing walk time by 1 minute and adding 1 minute to jog interval every other day

Neuromuscular Dynamic Stability Exercises

- Three to five sets of 30- to 60-second intervals for neuromuscular dynamic stability exercises
- Neuromuscular dynamic stability exercises are progressed on a continuum of difficulty depending on the patient's ability
- Exercises are advanced from double to single leg stance, from stable to unstable surfaces, and from predictable to unpredictable perturbations
- Perturbations may be manually applied or through the use of weighted balls

Plyometrics

- Deceleration and balance exercises should be mastered by now
  - Determined by ability to complete exercises while maintaining balance and proper posture/form
- Jump training may begin after 8 weeks
  - Training should emphasize controlled take off and landings without knee valgus or medial hip rotation
  - Jump training is cautiously progressed starting with two-legged jump ups onto a 6-inch box toward two-legged broad jumps and eventually single leg hop for distance
- Running at increasing speeds and sprints may begin at 9 to 10 weeks

Functional Exercises

- Functional step up exercises can be progressed to 12-inch step with dumbbell resistance
  - Step up exercises performed at two sets of 8 to 12 repetitions
  - Step ups should be performed forward, laterally, and with crossover step to further challenge the function of the lower extremity
- Jogging straight forward
  - Running may continue every other day for 30 minutes with no more than 10% increase in time per week
- Running progression
  - Marching → skipping → high knees → alternate leg bounding
    - Plyometric running progression can be performed at three sets of 30 seconds
    - Now include pivoting and cutting toward week 12



FIGURE 33-35. Grapevine step exercises. Begin with feet center, right foot steps over, then step behind the right foot with the left foot. Cross the left leg behind the right leg, and place the left foot behind and slightly to the right of the right foot. Left foot should be pointing toward the right heel, but not directly behind it. Take a step to the right with the right foot, bringing your feet together again. Continue the exercise by moving to the left.

Sport-Specific Exercises

- Sport-specific skill or agility training should begin
- Perform sport specific exercises three sets of 30-second intervals
  - 90 seconds rest between sets and 3 minutes rest between exercises
- Agility exercises may be initiated and progressed from straight line movements such as lateral shuffle, forward and backward sprints, and grapevine step exercises (Figure 33-35) to more advanced movements such as figure-eight running, short distance forward and backward sprint with 45 degree quick change in direction, and ladder drills
  - Grapevine is a step-over exercise seen in Figure 33-22
- Gradual return to sports practice
  - Build up to full return to practice

Milestones for Progression to Advanced Sport-Specific Training and Conditioning

- Full active ROM
- No evidence of instability or giving way
- Less than 80% difference in lower extremity strength
  - Measured by OKC and CKC knee extension exercises (quadriceps) as well as compared by measurement around the thigh to compare muscle bulk versus the contralateral normal leg
- Less than 85% difference in single leg hop for distance

Phase IV (weeks 15 to 20)

Protection

- Functional brace with sports

Management of Pain and Swelling

- Vasopneumatic compression
- Elevation
- Compression wrap
- Electrical stimulation
- Cryotherapy as needed

Techniques for Progressive Increase in Range of Motion

- Full AROM is expected

Manual Therapy Techniques

- Anterior tibial translation mobilizations and patellar mobilizations as needed to restore normal tibiofemoral contact points and decrease fixed posterior translation of the tibia if indicated.

Soft Tissue Techniques

- More aggressive tool assisted soft tissue mobilization may be required to elongate tissue and free up motion if normal ROM and flexibility around the joint is not yet achieved

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Contract/relax PNF stretching to quadriceps, gastrocnemius, hamstrings, hip flexors as indicated for normal symmetrical flexibility

Other Therapeutic Exercises

- Total leg strength (TLS)
  - Continue PREs for hip, knee, and ankle strength with added resistance
    - Two to three sets of 60% to 80%, one repetition, maximum three to four days per week
- Total body strength (TBS)
  - All upper body strengthening allowed in standing position
  - High level core exercises, Swiss ball exercises, and circuit training for upper and lower body conditioning
    - Two to three sets of 65% to 70% of one repetition maximum performed three to four days per week

Activation of Primary Muscles Involved

- Quadriceps, hamstrings, gastrocnemius

Open and Closed Kinetic Chain Exercises

- Two sets of 8 to 12 repetitions for OKC and CKC exercises
- OKC strengthening
  - Isolated hamstring strengthening, knee extension strengthening, hip strengthening all planes
- CKC strengthening
  - Resisted double leg squats to 90°
  - Resisted single leg squats to 70°
  - Resisted forward/reverse/lateral lunging

Techniques to Increase Muscle Strength, Power, and Endurance

- Resisted cycling at 80 to 100 RPMs, progressing as endurance allows
- Running program—increasing distance 15% per week or as symptoms allow

Neuromuscular Dynamic Stability Exercises

- Three to five sets of 30- to 60-second intervals for neuromuscular dynamic stability exercises
- Single leg stance windmill exercises (Figure 33-36)

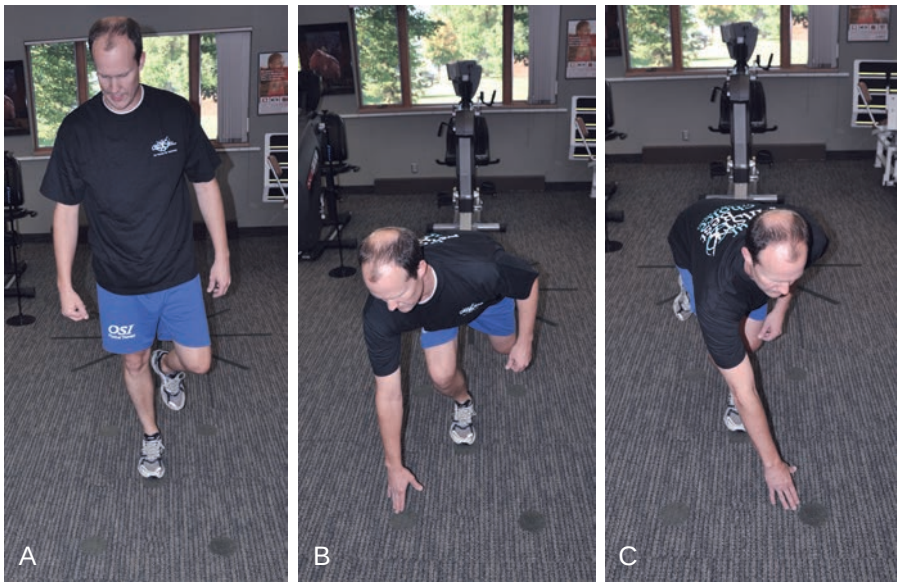

FIGURE 33-36. Single leg stance windmill exercise. Start (**A**), finishing to the right (**B**), and finishing to the left (**B**).



FIGURE 33-37. Power cleans progression

- Single leg stance on BOSU ball with medicine ball toss
- Single leg stance with manual perturbations
- Resisted walking with sport cord
- Lateral shuffle
- Grapevine running

Plyometrics

- Three sets of 30-second intervals for plyometric exercises
  - 90-second rest between sets and 3 minutes rest between exercise
- Two-leg broad jump
- One-leg broad jump
- One-leg triple jump
- One-leg crossover jump
- Two-leg drop jumps
- One-leg drop jumps
- High knee skipping

Sport-Specific Exercises

- Two sets of 8 to 12 repetitions for sport specific exercises
  - 30- to 60-second intervals for cutting and running activities
- Power cleans (Figure 33-37)
- Resisted running
- Figure-eight running
- 45° and 90° cutting
- Non-contact practice of sport

Guidelines to Progress to Advanced Sport-Specific Training and Conditioning

- Normal clinical examination—full active ROM, progressed to running
- Normal functional testing—hop tests, agility runs, gait testing
  - Completion of single leg hop for distance, triple cross over hop, and 6-meter hop testing performed at 90% of uninvolved limb (limb symmetry Index of 90%)
- No pain, swelling, or tenderness after training
- No increase in posterior laxity
  - Negative posterior sag sign
- No evidence/complaints of instability or giving way
- Quad strength in the injured leg is 85% to 90% or more than that of the uninjured leg
  - Measured by OKC and CKC knee extension exercises as well as compared by measurement around the thigh to compare muscle bulk versus the contralateral normal leg
- No signs of medial or patellofemoral joint space degeneration
- Greater than 90% functional strength achieved with return to sports testing
  - Completion of single leg hop for distance, triple cross over hop, and 6-meter hop testing performed at 90% of uninvolved limb (limb symmetry index of 90%)

Criteria for Abandoning Nonoperative Treatment and Proceeding to Surgery or More Intensive Intervention

- Pain or degeneration of the medial or patellofemoral joint spaces
- Evidence/complaints of instability or giving way
  - Objectively grade instability with PCL stress radiographs
- Persistent pain with return to activity
- Inability to meet Phase I criteria
- Evidence of concomitant ligament, meniscal, or articular cartilage injury

Tips and Guidelines for Transitioning to Performance Enhancement

- Patients who have met the criteria for transition to advanced sport-specific performance enhancement training are progressed cautiously and monitored for recurrent symptoms throughout training.
  - Patients should not push training through pain or swelling.
- Both active and passive knee stability is challenged through sport-specific drills.
- Emphasis is placed on proper form and technique during all drills to reinforce proper lower extremity mechanics as well as protect from re-injury.
- Initial contact/tackling drills are initiated with use of pads and tackling dummies and progressed to live tackling drills.
- Continued stretching and maintenance of muscle strength are important to prevent re-injury.

Performance Enhancement and Beyond Rehabilitation: Training/ Trainer and Optimization of Athletic Performance

- Designed to bring athletic performance above and beyond entry level
- The goal is to return athletes to their sport at a performance level equal to or better than the level at the time of injury.
- Performance enhancement places extra focus on the injured limb and identifies other deficits that may have developed because of immobilization and deconditioning.

Specific Criteria for Return to Sports Participation: Tests and Measurements

- Full AROM
- Normal quad strength
  - Measured by OKC and CKC knee extension exercises as well as compared by measurement around the thigh to compare muscle bulk versus the contralateral normal leg
- No evidence of instability or giving way
- Greater than 90% function on return to sports testing
  - Completion of single leg hop for distance, triple cross-over hop, and 6-meter hop testing performed at 90% of uninvolved limb (limb symmetry index of 90%)
- The athlete should understand the need for continued conditioning to prevent reinjury
- The athlete should be psychologically ready to return to sport and not be timid with the limb and fearful of reinjury
  - Test using the Tampa Bay Kinesophobia index or Fear Avoidance Belief Questionnaire (FABQ)

Evidence

Cross MJ, Powell JF: Long-term follow-up of posterior cruciate ligament rupture: A study of 116 cases. *Am J Sports Med* 12:292–297, 1984.

Case series that followed 116 PCL injuries, 55 were caused by sports injuries. An excellent or good result was obtained in 47 sports-injured patients. Found that patients with a posterior cruciate rupture can have a good result when treated conservatively (nonsurgically) if they maintain their strength and conditioning, especially concerning the quadriceps muscles. (Level IV evidence)

Escamilla RF, Fleisig GS, Zheng N, et al: Biomechanics of the knee during closed kinetic chain and open kinetic chain exercises. *Med Sci Sports Exerc* 30:556, 1998.

The study used 10 subjects who performed three repetitions of each exercise. Kinematic, kinetic, and electromyographic data were recorded using video cameras, force transducers, and EMG. Internal muscle forces and tension in the cruciate ligaments were estimated using a muscle model during CKC and OKC exercises. They found that tension in the PCL was highest in CKC exercises with knee flexion and that squats generated nearly two times as much hamstring activity compared to the leg presses and knee extensions. (Level IV evidence)

Harner CD, Xerogeanes JW, Livesay GA, et al: The human posterior cruciate ligament complex: an interdisciplinary study: Ligament morphology and biomechanical evaluation. *Am J Sports Med* 23:736–745, 1995.

This study used 14 human cadaver knees to examine the biomechanical properties of the femur-posterior cruciate ligament-tibia complex. The anterolateral bundle was found to have a significantly greater linear stiffness and ultimate load than both the posteromedial bundle and meniscofemoral ligaments. (Cadaveric study)

Ittivej K, Prompaet S, Rojanasthein S: Factors influencing the treatment of posterior cruciate ligament injury. *J Med Assoc Thai* 5:84–88, 2005.

Prospective study that followed 91 patients through a 1-year rehabilitation process following PCL injury. Patients were treated nonoperatively with a three-phase rehabilitation process. Authors found that the only factor correlating to failed nonsurgical rehabilitation was the degree of posterior laxity. Concluded that patients with greater than 10 mm of laxity should be treated surgically. (Level II evidence)

Jacobi M, Reischl N, Wahl P, et al: Acute isolated injury of the posterior cruciate ligament treated by a dynamic anterior drawer brace. *J Bone Joint Surg Br* 92-B:1381–1384, 2010.

Treated 21 patients with an isolated tear of the PCL for 4 months nonoperatively using a functional brace. Initial and follow-up stability was tested by Rolimeter arthrometry and radiography and clinical outcomes were measured using the Lysholm score, Tegner score, and International Knee Documentation Committee scoring system at 1 and 2 years. Found that the applied treatment produced a good or excellent functional result in all patients. Concluded the PCL has an intrinsic healing ability and will heal with less attenuation if the tibia is reduced to the proper anatomic position. (Level IV evidence)

Lutz GS, Palmitier RA, Chao YS: Comparison of tibiofemoral joint forces during open kinetic chain and closed kinetic chain exercises. *J Bone Joint Surg* 75A:732–739, 1993.

The study examined five healthy subjects to analyze forces at the tibiofemoral joint during open and closed-kinetic-chain exercises during maximum isometric contractions at 30°, 60°, and 90° of knee flexion. Electromyographic activity of the quadriceps and hamstrings, load and torque-cell data were recorded to calculate tibiofemoral shear and compression forces. Results indicated that CKC exercise produced significantly less posterior shear force at all angles when compared with the open kinetic chain extension exercise and that CKC exercise produced significantly greater compression forces and increased co-contraction of the muscles at the same angles that the OKC exercises produced the highest shear forces and lowest muscular co-contraction. (Level IV evidence)

Nadler S, Malanga G, DePrince M, et al: The relationship between lower extremity injury, low back pain, and hip muscle strength in male and female collegiate athletes. *Clin J Sport Med* 10:89–97, 2000.

Cohort study of 210 college athletes that measured average and maximum hip abduction and extension strength using a specially designed dynamometer anchoring station. Found a significant difference in side-to-side symmetry of maximum hip extension strength in female subjects who reported previous lower extremity injuries. This study supports the necessity of rehabbing and improving hip musculature strength to aid in return to sports after knee injuries. (Level III evidence)

Wilk KE, Escamilla RF, Fleisig GS, et al: A comparison of tibiofemoral joint forces and electromyographic activity during open and closed kinetic chain exercises. *Am J Sports Med* 24:518–527, 1996.

Study of 10 males performing four isotonic repetitions to investigate tibiofemoral compressive forces, anteroposterior shear forces, extension torque, and electromyographic activity of the quadriceps, hamstring, and gastrocnemius muscles during OKC knee extensions and CKC leg presses and squats. The findings showed significant differences in tibiofemoral forces and muscle activity between the CKC and OKC exercises. (Level IV evidence)

Multiple Choice Questions

QUESTION 1. During the initial phases of nonsurgical rehabilitation of a posterior cruciate ligament injury, it is important to avoid isolated activation of which muscle group to avoid stressing the injured ligament.

A. Gastrocnemius
B. Quadriceps
C. Hamstrings
D. Sartorius

QUESTION 2. Patients with a posterior cruciate ligament injury may begin plyometric training during which phase of rehabilitation, and only after mastering what other type of exercises?

A. Phase I, wall squats to 90°
B. Phase II, deceleration exercises
C. Phase III, straight forward running
D. Plyometrics are never allowed during rehabilitation of a PCL injury

QUESTION 3. When a patient who is undergoing active rehabilitation from a posterior cruciate ligament injury begins riding a stationary bike during Phase III, which of the following conditions should apply?

A. Stationary biking may begin once 105° of knee flexion is achieved
B. The seat height should be set so that the knee is slightly flexed
C. The feet should be placed slightly forward on the pedals
D. All of the above

QUESTION 4. When rehabilitating a patient with a combined PCL/PLC injury, which of the following is a strategic difference compared to the rehabilitation of a patient with an isolated PCL injury.

A. A patient with a combined PCL/PLC injury should initially be placed in a functional PCL brace.
B. The patient with a combined PCL/PLC injury does not require any posterior tibial support.
C. Patients with combined injuries do not need to avoid hamstring activating exercises during the initial phase of rehabilitation.
D. There are no differences in the rehabilitation of combined versus isolated injuries.

Answer Key

QUESTION 1. Correct answer: **C** With a damaged posterior cruciate ligament, it is important to avoid isolated activation of the hamstring muscles, which can increase posterior sheer forces on the damaged PCL until at least 6 weeks after the injury. The quadriceps are the single most important muscle to be strengthened and maintained during therapy because they are critical to joint stabilization. Strengthening of the gastrocnemius has no detrimental effect on a healing PCL, and the sartorius is not involved. (see Phase I)

QUESTION 2. Correct answer: **B** With an injured posterior cruciate ligament, patients cannot undertake plyometric exercises until Phase II at the earliest. Regardless of their progression, patients should be required to master deceleration exercises and proper landing technique before beginning plyometric exercises. Phase I does not include plyometrics, and patients should not be doing wall squats during Phase I. By Phase III patients should already have started plyometrics. (see Phase II)

QUESTION 3. Correct answer: **D** When patients begin riding the stationary bike during rehabilitation, they should have attained at least a 105° range of motion in the affected knee. To avoid activation of the hamstrings, the patient should ride the bike with the seat set to allow the knee to flex slightly and the feet slightly forward on the pedals. (see Phase III)

QUESTION 4. Correct answer: **A** The patient should be placed in a functional PCL brace. If a combined PLC and PCL injury is diagnosed the patient should be in a functional PCL brace to better support the posterior capsule. Patients with combined injuries still require posterior tibial support because they have a PCL deficiency. Patient with combined injuries still must avoid hamstring exercises early in rehabilitation to avoid posterior sheer forces on their damaged PCL. Grade III PCL/PLC injuries require surgery to repair or anatomically reconstruct the damaged structures, whereas partial tears to the PLC should be evaluated by a specialist to determine the proper course of action. (see Phase I)

POSTOPERATIVE REHABILITATION AFTER POSTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

Ernest M. Muntean, PT, MS, OCS, ATC, and Jon K. Sekiya, MD

Indications for Surgical Treatment

- Failure of nonoperative management including an aggressive quadriceps strengthening program
- Functional instability with sports or activities of daily living despite adequate rehabilitation
- PCL bony avulsion injuries may be fixed acutely before attempting non-operative management
- Multiple ligament injured knees (PCL along with ACL/lateral or medial sided injuries) are often fixed before an attempt at conservative management due to the significant instability and high rate of failure with non-operative management
- Isolated PCL injuries are often treated nonoperatively in both athletes and the non-athletic population owing to often satisfactory clinical outcomes in this injury pattern. However, a high index of suspicion should be held for concomitant posterolateral or posteromedial injuries[1-3] when significant posterior laxity exists greater than 10 mm. In addition, patients should be cautioned that a PCL-deficient knee is at risk for premature medial and patellofemoral compartment osteoarthritis despite reasonable functional stability

Brief Summary of Surgical Treatment

Major Surgical Steps

- Examine under anesthesia to document laxity pattern/compare with contralateral knee.
- Perform diagnostic arthroscopy to document all pathology, including a medial and lateral drive through sign to evaluate medial/lateral instability.
- Make a posteromedial arthroscopic portal to assist with tibial insertion site preparation.
- Perform tibial socket (for arthroscopic inlay) or transtibial tunnel for a PCL graft.
- Perform outside in or inside out double bundle PCL femoral tunnels in the anatomical insertion sites of the anterolateral (AL) and posteromedial (PM) bundles of the femoral PCL.
- Prepare a bifid Achilles allograft (preferred) or bifid autograft quadriceps tendon graft.
- Pass the graft and fix on tibial side.
- Reduce the knee joint and fix the femoral side.

Factors That May Affect Rehabilitation

Anesthetic

- Femoral nerve blocks can assist with postoperative pain relief. If doing a concomitant lateral-sided injury, avoid sciatic blocks until postoperative assessment can be made of peroneal nerve function.

Surgical

- Arthroscopic inlay PCL reconstruction can have the advantages of a minimally invasive arthroscopic approach with the advantages of the inlay technique that decreases the killer turn, which may have implications with postoperative range of motion.[4,5]
- Double bundle reconstructions have the advantage of a more anatomical restoration of PCL function.[6]
- Bi-cruciate PCL and ACL injuries are a more unstable injury pattern and thus need more protection during postoperative rehabilitation.
- Collateral ligament reconstruction (medial- or lateral-sided injuries) create an even more unstable pattern in which varus and valgus forces must be protected postoperatively.[7]

GUIDING PRINCIPLES OF NONOPERATIVE REHABILITATION

- The clinician should understand the surgical procedure performed.
- The clinician should understand the anatomy and function of the PCL in providing knee tri-plane stability.
- The clinician should understand basic tissue healing.
- The clinician must understand the postoperative goals and precautions to provide for safe and effective progression to maximize athlete outcomes.

Phase I (days 0 to 14): Immediate Postoperative Period[1]

Goals

- Protect the PCL graft.
- Decrease pain and swelling.
- Improve quadriceps neuromuscular control.
- Increase ROM to 0° to 90°.
- Instruct in daily independent home exercise program (HEP).

Protection

- Knee is kept in ROM brace locked in extension at all times except for shower (including sleep, exercises, *no exceptions*).

[1]*Prehabilitation, if appropriate, is described in the Nonoperative Rehabilitation section of this chapter.*

- Axillary crutches used to initiate 30% PWB of involved lower extremity with brace locked in extension.

Management of Pain and Swelling

- Treatment for pain
  - Oral pain medications
  - Continuous cryotherapy
  - Electrotherapy—TENS, interferential, pre-modulated
- Treatment for swelling
  - Elevation of lower extremity above the heart
    - Compression
    - Stockings
    - ACE wrap
  - Compliance with weightbearing instructions

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Precaution: Limit ROM to 0° to 90°
- Knee flexion: ROM should be passive to avoid isolated hamstring activation to prevent posterior tibial translation of the tibia on the femur, which may produce excessive tension of the graft.
- Patellar mobilizations

Soft Tissue Techniques

- Effleurage for swelling reduction.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Passive stretching of the calf, hamstring, and hip flexor bilaterally
- Continuous passive motion for at least 1 hour per day at 0° to 90°.

Other Therapeutic Exercises

- Athletes are encouraged to participate in upper body cardiovascular conditioning exercises when able to do so comfortably and safely as determined by the clinician.
  - Upper body ergometer (UBE)

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Quadriceps re-education with use of NMES
  - High-volt
  - Russian
- Quadriceps setting exercises
- Biofeedback

Clinical Pearl

To assist with volitional activation of the quadriceps muscle group, have the athlete contract this musculature while the e-stim is in the on-cycle while relaxing during the off-cycle. Progress to an active straight leg raise (SLR) during the on-cycle once the athlete demonstrates improved quad control.

Open and Closed Kinetic Chain Exercises

- Four-way SLR
  - Abduction and adduction are contraindicated with athletes who have had a concurrent ACL or collateral reconstruction/repair.
- Resisted ankle pumps.

Milestones for Progression to the Next Phase

- Full knee extension ROM
- Improving quadriceps control
- Decreasing swelling
- Patient compliance with daily HEP, PWB, and brace/crutch use

TIMELINE 33-2: **Postoperative Rehabilitation After Posterior Cruciate Ligament Injury**

PHASE I (postoperative weeks 0 to 4)	PHASE II (postoperative weeks 4 to 8)	PHASE III (postoperative weeks 8 to 16)
• Knee brace locked in full extension • No active hamstring contraction for heel slides • 30% PWB with axillary crutches in brace • PT modalities for pain/swelling control and quad re-education • PROM—0–90° • TBS/TAS/TLS activities as recommended and tolerated • OKC—band calf pumps • OKC—SLRs	• Continue knee brace locked in extension • No active hamstring contraction for heel slides • Progress ambulation to FWB in brace • PT modalities for pain/swelling control and quad re-education • PROM to full • TBS/TAS/TLS activities as recommended and tolerated • Initiate retro-biking at week 6 • Initiate balance/proprioceptive training with weight shifting exercise • OKC—band calf pumps • OKC—SLR for hip in standing	• Knee brace unlocked for ambulation • Initiate active assisted heel slides • DC crutches when gait in normalized • PT modalities as needed for pain/swelling and quad re-education • AROM—full • Initiate hamstring setting exercise • TBS/TAS/TLS activities as recommended and tolerated • Progress balance with upper extremity reaches • OKC—long arc quad exercise 45°–90° without resistance • CKC—mini squats with <45° of knee flexion • CKC—calf raises • CKC—step ups/downs • Neuromuscular—PWB BAPS level 1, wobbleboard

Phase II (postoperative weeks 4 to 8)

Goals

- Increase ROM to full
- Decrease pain and swelling
- Normalize quadriceps control
- Return to FWB ambulation
- Increase lower extremity strength

Protection

- Continue use of brace without ROM restrictions.
- Wean to a single crutch in the opposite upper extremity at four weeks if athlete demonstrates:
  - Full knee extension ROM
  - Normal quadriceps control: Athlete able to perform a SLR without an extension lag

Management of Pain and Swelling

- Treatment for pain
  - Oral pain medications
  - Cryotherapy
  - Electrotherapy: TENS, interferential, pre-modulated
- Treatment for swelling
  - Elevation of lower extremity above the heart
  - Compression:
    - Stockings
    - ACE wrap

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- ROM can progress to full.
- Knee flexion ROM should be passive to avoid isolated hamstring activation to prevent posterior tibial translation of the tibia on the femur, which may produce excessive tension of the graft.
- Patellar mobilizations.

Soft Tissue Techniques

- Effleurage for swelling reduction.
- Cross-friction massage to mobilize scar tissue.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Progress multi-plane stretching of the calf, hamstring, and hip flexor bilaterally to standing, such as true stretch.
- Stationary cycling can be initiated at 6 weeks
  - No resistance
  - Seat elevated to limit knee flexion ROM
  - *No toe straps* to limit hamstring activation

Clinical Pearl

> Have the athlete perform retro- or backward cycling initially. The change in direction will facilitate more quadriceps activation while limiting hamstring activation.

Other Therapeutic Exercises

- Continue use of upper body ergometer for cardiovascular conditioning.
- Initiate partial Turkish get-ups with kettlebell for core strengthening (Figure 33-38).

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Continue quad re-education with NMES
- Quadriceps sets

TIMELINE 33-2: Postoperative Rehabilitation After Posterior Cruciate Ligament Injury (Continued)

PHASE IV (postoperative weeks 16 to 20)	PHASE V (postoperative weeks 20 to 26)	PHASE VI (postoperative weeks 26 to 32)
• TBS/TAS/TLS activities as recommended and tolerated • PT modalities as needed for pain/swelling • CKC—leg press 0°–60° • CKC—hip abd/add machine • CKC—multi-plane lunges • CKC—hamstring curls • Neuromuscular—PWB BAPS level 2, wobbleboard, balance reach exercises • Initiate light throwing activities • Leg press test >75%	• TBS/TAS/TLS activities as recommended and tolerated • CKC—leg press 0°–90° • CKC—mini squats on unstable/unlevel surface • CKC—multi-plane lunges with dumbbells • CKC—step downs with progressive height • Neuromuscular—add resistance to balance reach exercise • Jump rope training • Initiate slow jogging	• TBS/TAS/TLS activities as recommended and tolerated • CKC—progression of resistances • Plyometrics—box jump • Progress jogging to running • Agilities—initiate cariocas, cutting, and pivoting • Initiate sports specific activities

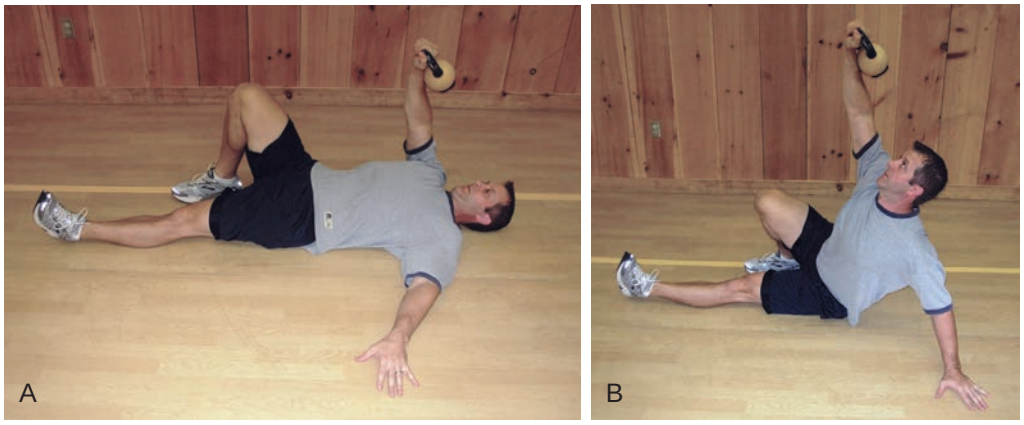

FIGURE 33-38. Partial Turkish get-up with kettlebell.

Sensorimotor Exercises

- Initiate lower body lateral weight shifting exercises—forward, retro, and lateral.[8]

Open and Closed Kinetic Chain Exercises

- Continue four-way straight leg raises.
- Four-way standing hip exercise
- Full long arc quads exercise without resistance

Techniques to Increase Muscle Strength, Power, and Endurance

- Initiate upper body strengthening.

Milestones for Progression to the Next Phase

- Normalized quadriceps control
- Minimal to no swelling
- Full knee extension ROM

Phase III (postoperative weeks 8 to 16)

Goals

- Progression of lower body strengthening
- FWB ambulation in brace without compensations
- No swelling
- Improved balance and proprioception

Protection

- Knee brace can be unlocked at all times
- Must remain in place at ALL times, including sleep and exercises
- Discontinue use of crutches once the athlete has normal quadriceps control, minimal to no swelling, full knee extension ROM, and minimal to no gait deviations

Management of Pain and Swelling

- Treatment for pain
  - Oral pain medications
  - Cryotherapy
  - Electrotherapy: TENS, interferential, pre-modulated
- Treatment for swelling
  - Continue ice, elevation, and compression

Techniques for Progressive Increase in Range of Motion

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Progress multi-plane stretching of the calf, hamstring, and hip flexor bilaterally to standing, for example, True Stretch (Figure 33-39).

Other Therapeutic Exercises

- Athlete may begin to use a stationary bike at this time without the use of toe straps.



FIGURE 33-39. True stretch calf/hip flexor stretch.



FIGURE 33-40. Rope undulation training—alternating arms.

- Progress cardiovascular conditioning with use of treadmill, Elliptical trainer, stationary bike, or stair climber.
- Initiate rope undulation training (Figure 33-40).

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Initiate active assisted heel slides.
- Initiate hamstring sets in the long seated position.
- Retro-exercises for progression of quadriceps/calf activation and strengthening. Examples are retro-step ups, retro stair climber, and treadmill.

Sensorimotor Exercises

- Balance reach exercises in multiple planes. Athlete balances on the involved extremity and reaches with the uninvolved extremity to predetermined directions at the treating clinician's discretion.[9]
- Initiate PWB BAPS at level 1 performed while standing.

Clinical Pearl

Have the athlete perform the BAPS exercise by having him/her rotate the board one revolution clockwise followed by one revolution counterclockwise for completing one repetition. This minimizes the influence of momentum to assist the athlete.

Open and Closed Kinetic Chain Exercises

- Long arc quad (LAQ) exercise without resistance limited to 45° to 90° arc of motion.
- Weightbearing exercises including: standing calf raises, mini squats not to exceed 45° of knee flexion, and stepups/downs.
- Initiate CKC exercises:
  - Calf raises. Initially with bodyweight only and progressively adding resistance with dumbbells or calf raise machine.
  - Mini squats limited to 45° of knee flexion.

Clinical Pearl

Once the athlete is comfortable performing the mini squat exercise, then add the use of dumbbells to perform overhead presses to increase upper body and core strength. These presses can be performed with both arms together or in an alternating fashion.

Techniques to Increase Muscle Strength, Power, and Endurance

- Leg press machine. Begin with both extremities and use low resistance and high repetitions progressing to higher resistances and also to involved extremity only. Knee flexion angle not to exceed 45°.[10]

Neuromuscular Dynamic Stability Exercises

- Balance reach with upper extremity reaches. Patient balances on the involved lower extremity, reaching with both upper extremities anteriorly and/or overhead posteriorly and vertical heights (e.g., shoulder, knee) (Figure 33-41).

Milestones for Progression to the Next Phase

- Full ROM
- Normal gait pattern
- No swelling
- Excellent quad control



FIGURE 33-41. Single leg balance, bilateral upper extremity anterior to waist reach.

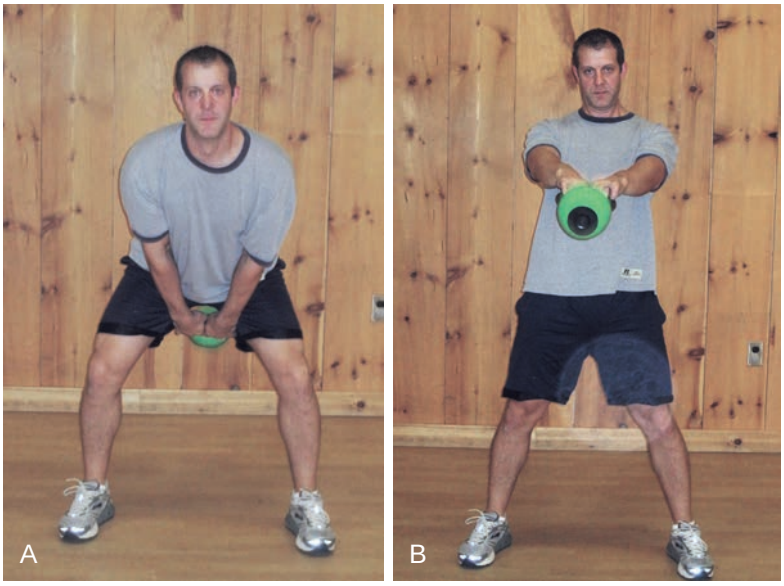

FIGURE 33-42. Kettlebell swing with both arms.

Phase IV (postoperative weeks 16 to 20)

Goals

- Progress strengthening in 0° to 60° ROM.
- Discontinue use of protective brace.
- Progress cardiovascular conditioning with use of lower body.
- Successfully pass a leg press test (greater than 75% of uninvolved extremity).

Management of Pain and Swelling

- Continue ice, elevation, and compression as necessary.

Techniques for Progressive Increase in Range of Motion

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Continue multi-plane stretching of the calf, hamstring, and hip flexor bilaterally to standing, for example, true stretch.

Other Therapeutic Exercises

- Initiate fast walking on the treadmill.
- Pool exercises to progress conditioning. Kicks should be kept in the sagittal plane to protect the reconstructed graft, therefore avoid frog kicking motion for breast stroke.
- Initiate kettlebell swings (Figure 33-42).
- Progression of rope undulation training:
  - Performing squats in symmetrical stance
  - Performing squats in a tandem stance
  - Single leg squat

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Initiate isolated, resisted hamstring curls with low resistance and high repetitions.
  - Seated
  - Prone

Sensorimotor Exercises

- Initiate balance reach exercise with the opposite lower extremity (Figure 33-43).

Open and Closed Kinetic Chain Exercises

- Mini squats can be progressed to single leg. Additionally dumbbells can be used for upper body matrix presses (Figure 33-44).[11]



FIGURE 33-43. Balance opposite lower extremity anterior reach.

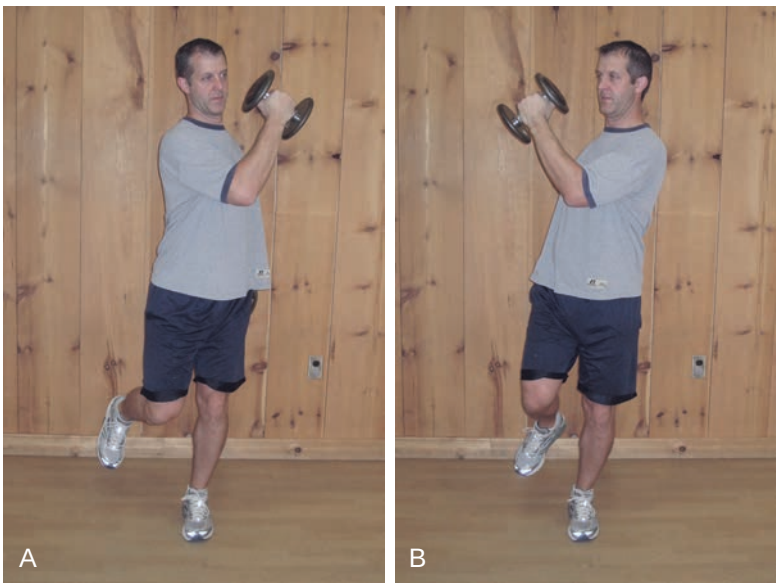

FIGURE 33-44. Single leg squat with alternating dumbbell uppercuts.

Techniques to Increase Muscle Strength, Power, and Endurance

- Progression of leg press resistance. Available knee flexion angle can be safely progressed to 60°.
- Initiate seated hip abduction and adduction machines.

Neuromuscular Dynamic Stability Exercises

- Progress balance reach exercises with the upper extremities to include added resistance from bands, dumbbells, Bodyblade, and so on.
- Progress BAPS exercises to level 2. Additionally progress weightbearing to full as patient is able to safely perform this exercise.

Functional Exercises

- Initiate involved lower extremity sagittal plane lunges. Athlete may need upper body support initially for safety and progressed to unsupported when safe.

Clinical Pearl

Depth of lunges should be self-selected by the athlete initially to avoid undesired compensatory patterns. The depth of the lunge should be progressed to not more than 60° of knee flexion once the athlete can safely perform without compensations in the early ranges.

Sport-Specific Exercises

- Throwing can be initiated for throwing athletes. This should be kept to relatively shorter distances for the primary purpose of restoring normal throwing mechanics.

Milestones for Progression to the Next Phase

- Leg press test: Athlete must successfully complete at least 75% repetitions of involved extremity versus the uninvolved extremity at 100% bodyweight.

Phase V (postoperative weeks 20 to 26)

Goals

- Initiate slow jogging
- Progress lower body strengthening
- Progress agility exercises

Management of Pain and Swelling

- Continue ice, elevation, and compression.

Techniques for Progressive Increase in Range of Motion

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Continue multi-plane stretching of the calf, hamstring, and hip flexor bilaterally to standing, for example, true stretch.

Other Therapeutic Exercises

- Progress intensity and frequency of aerobic, kettlebell, and rope undulation cardiovascular training.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Progress resisted hamstring curls with progressively increased resistance and decreased repetitions.

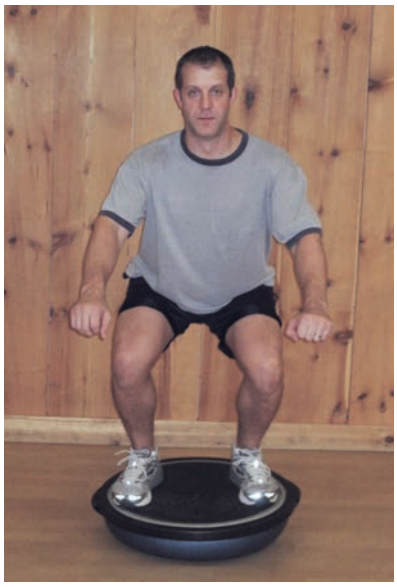

FIGURE 33-45. Mini squats performed on a BOSU.

Sensorimotor Exercises

- Progress balance lower extremity reach exercises with use of dumbbells, Bodyblade, and so on.

Open and Closed Kinetic Chain Exercises

- Progress mini squats by moving to an unstable or unleveled surface (Figure 33-45).

Techniques to Increase Muscle Strength, Power, and Endurance

- Progress resistance of leg press exercises.

Neuromuscular Dynamic Stability Exercises

- Progress exercises from Phase IV
- Initiate standard jump rope training exercises

Functional Exercises

- Progress lunges to include both frontal and transverse planes. Dumbbells may be used with the lunge exercise to facilitate upper body and core strengthening (Figure 33-46).

Sport-Specific Exercises

- Initiate light jogging activities on level ground or treadmill. Cutting, jumping, or pivoting should be avoided.

Milestones for Progression to the Next Phase

- Athlete should be able to run short distances without compensations.

Phase VI (postoperative 26 to 32)

Goals

- Initiate plyometric training exercises
- Initiate sports specific activities
- Progress lower body strengthening

Management of Pain and Swelling

- Continue ice, elevation, and compression.

Techniques for Progressive Increase in Range of Motion

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Continue multi-plane stretching of the calf, hamstring, and hip flexor bilaterally to standing, for example, true stretch.

Other Therapeutic Exercises

- Progress Phase V activities.

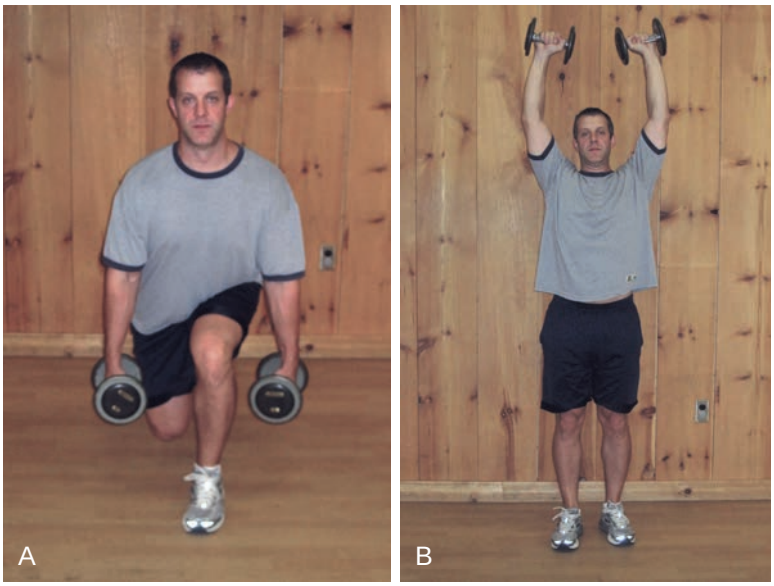

FIGURE 33-46. Lunge with dumbbell reach and press.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Progress resisted hamstring curls with increasing resistances.

Sensorimotor Exercises

- Progress balance lower extremity reach exercises.

Open and Closed Kinetic Chain Exercises

- Progress mini squats by moving to an unstable or unleveled surface.

Techniques to Increase Muscle Strength, Power, and Endurance

- Progress resistance of leg press exercises.

Neuromuscular Dynamic Stability Exercises

- Progress exercises from Phase V.
- Progress jump rope training to line jumps: anterior/posterior and lateral.

Plyometrics

- Initiate plyometric jumping activities. It is important to begin with light jumping from a low height. Careful observation is required to assess for asymmetry of movement and for compensations. When the athlete can safely perform these activities, then it is appropriate to progress the height and the intensity of the jumping.

Functional Exercises

- Progress lunges to include both frontal and transverse planes. Dumbbells may be used with the lunge exercise to facilitate upper body and core strengthening.

Sport-Specific Exercises

- Progress speed of running activities.
- Initiate multi-plane agility training (e.g., retro running, cutting, crossovers, cariocas)

Milestones for Progression to the Next Phase

- Minimum of 90% strength with involved lower extremity as compared with the uninvolved lower extremity with the leg press test.
- Sprinting drills without compensations.
- Ability to perform agilities without compensations.

Criteria for Return to Sport

General

- Quadriceps and hamstring strength at least 90% of uninvolved lower extremity.
- One-leg hop test and vertical jump at least 90% of uninvolved lower extremity.
- Jog, full speed run, shuttle run, and figure-eight running without compensations.
- Squat and rise from a full squat without pain or compensations.
- No swelling or quadriceps atrophy.
- Satisfactory clinical examination.

Sport-Specific

- It is important to identify athletes who may satisfy the criteria for return to support, however demonstrate asymmetries or adverse compensations while performing sport-specific drills. These athletes may need further neuromuscular training to facilitate safe, effective participation.
- The medical staff (MD, PT, ATC) must properly evaluate the athlete in the context of his or her sport as well as the specific position within that sport. This needs to be done on an individual basis because it is difficult to generalize these physical demands among a diverse athletic population. Sport-specific demands vary because of environment (turf, grass, other), contact versus noncontact (e.g., opponent, equipment), and physiological factors (e.g., slow endurance–type activity, ballistic activity).
- The clinician should understand that this protocol assumes that there has been no surgical reconstruction of the other major stabilizing structures of the knee, such as anterior cruciate ligament (ACL), lateral collateral ligament (LCL), or medial collateral ligament (MCL). Further protective time frames and precautions are necessary for optimal functional outcomes of rehabilitation.
  - PCL + ACL reconstruction: Modification of time frames with additional precautions
    - Phase IV is extended to 4 to 6 months.
    - Phase V is extended to 6 to 9 months.
    - Phase VI is extended to 9 to 12 months.
    - Protective brace is used for the first 5 months of rehabilitation.
  - PCL + collateral (MCL and/or LCL) reconstruction: Modification of time frames with additional precautions
    - Phases are the same as PCL + ACL time frames.
    - Protective brace is utilized for the first 6 months of rehabilitation.
    - Frontal and transverse plane exercises not initiated until Phase V. This is delayed for the purpose of protecting the collateral ligament reconstruction.

After Return to Sport

Continuing Fitness or Rehabilitation Exercises

- Continue the previously outlined total arm and body conditioning activities.

Evidence

Bowman K, Sekiya JK: Anatomy and biomechanics of the posterior cruciate ligament, medial and lateral sides of the knee. *Sports Med Arthrosc Rev* 18(4):222–229, 2010.

Article discusses the function of the PCL, medial and lateral sides of the knee in providing posterior as well as valgus, varus, and rotational stability. (Level of evidence = N/A)

Earl JE, Hertel J: Lower-extremity muscle activation during the star excursion balance tests. *J Sport Rehabil* 10:93–104, 2001.

Quadriceps training via the Star Excursion Balance Tests with an anterior reach facilitated the greatest VMO and VL activity versus the hamstring muscle group. (Level IV evidence)

Lephart SM, Pincivero DM, Giraldo JL, et al: The role of proprioception in the management and rehabilitation of athletic injuries. *Am J Sports Med* 25(1):130–137, 1997.

This article examines the diminished effect of joint proprioception resulting from ligamentous injury and surgical interventions. The authors state that rehabilitation programs should include a proprioceptive component to promote functional joint stability. (Level V evidence)

Powers CM: The influence of abnormal hip mechanics on knee injury: A biomechanical perspective. *JOSPT* 40(2):42–51, 2010.

The author presents a biomechanical argument to include pelvic and hip stability, as well as dynamic hip joint control into the rehabilitation of knee injuries. (Level V evidence)

Salata MJ, Sekiya JK: Arthroscopic PCL tibial inlay: Surgical technique that may influence rehabilitation. *Sports Health* 3:52–58, 2011.

This article suggests that there are unique features of an arthroscopic, double bundle PCL reconstruction that allow a more aggressive postoperative rehabilitation approach. (Level V evidence)

Sekiya JK, Haemmerle MJ, Stabile KJ, et al: Biomechanical analysis of a combined double bundle posterior cruciate ligament and posterolateral corner knee reconstruction. *Am J Sports Med* 33(3):360–369, 2005.

You need to address the posterolateral corner if injured when reconstructing the PCL to restore normal knee kinematics and stability. (Level of evidence = N/A)

Sekiya JK, Whiddon DR, Zehms CT, et al: A clinically relevant assessment of PCL and posterolateral corner injuries: Evaluation of isolated and combined deficiency. *J Bone Joint Surg Am* 90(8):1621–1627, 2008.

The posterolateral corner contributes to significant posterior stability in the PCL deficient knee and should be suspected in patients with significant posterior laxity. A high index of suspicion should always be present when examining PCL injuries. (Level of evidence = N/A)

Tibor LM, Marchant MH, Sekiya JK, et al: Management of medial sided knee injuries, Part 2: Posteriomedial corner. *Am J Sports Med* 39:1332–1340, 2011.

This article reviews the relevant literature on the PMC, discusses reasons for selective operative management, and illustrates reconstructive strategies for PMC injuries occurring as part of a medial-sided or multi-ligament injury to the knee. (Level of evidence = N/A)

Whiddon DR, Zehms CT, Sekiya JK, et al: Comparisons of a double bundle arthroscopic inlay and open inlay posterior cruciate ligament reconstruction using clinically relevant tools: A cadaveric study. *Arthroscopy* 24(4):472–480, 2008.

The double bundle inlay PCL reconstruction provides comparable stability to the open inlay technique. (Level of evidence = N/A)

Whiddon DR, Zehms CT, Sekiya JK, et al: Double compared with single-bundle open inlay posterior cruciate ligament reconstruction in a cadaver model. *J Bone Joint Surg Am* 90:1820–1829, 2008.

This cadaver study demonstrates that the double-bundle surgical reconstruction offers measurable benefits in terms of rotational stability and posterior translation of an untreated posterolateral corner injury. (Level of evidence = N/A)

Wilk KE, Escamilla RF, Fleisig GS, et al: A comparison of tibiofemoral joint forces and electromyographic activity during open and closed kinetic chain exercises. *Am J Sports Med* 24(4):518–527, 1996.

This study demonstrated that the posterior directed shear force of the knee was greatest between 85° and 105° of knee flexion in a closed chain environment. (Level IV evidence)

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Multiple Choice Questions

QUESTION 1. Immediately postoperatively, active contraction of the _____ must be avoided to prevent _____ translation of the tibia on the femur, which may produce excessive tensioning of the graft.

A. Quadriceps; anterior
B. Hamstrings; anterior
C. Quadriceps; posterior
D. Hamstrings; posterior

QUESTION 2. Which of these exercises would be contraindicated for an athlete who had a surgical reconstruction of both his PCL and LCL immediately postoperatively?

A. SLR—flexion
B. SLR—abduction
C. SLR—extension
D. All the above

QUESTION 3. When is it safe to initiate the seated hip abduction machine for an athlete with a PCL/LCL reconstruction?

A. Month 6–8
B. Month 5–6
C. Month 4–5
D. Month 2–4

QUESTION 4. Light jogging is to initiate during which time period?

A. Month 2–4
B. Month 4–5
C. Month 5–6
D. Month 6–8

QUESTION 5. During the first month postoperatively, the knee brace can be unlocked for:

A. Showering
B. Driving
C. Riding the stationary bike
D. Walking

Answer Key

QUESTION 1. Correct answer: **D** (see Month 0 to 1)

QUESTION 2. Correct answer: **B** (see Month 0 to 1)

QUESTION 3. Correct answer: **B** (see Month 5 to 6)

QUESTION 4. Correct answer: **C** (see Month 5 to 6)

QUESTION 5. Correct answer: **A** (see Month 0 to 1)

BEYOND BASIC REHABILITATION: RETURN TO FOOTBALL AFTER POSTERIOR CRUCIATE LIGAMENT INJURY

Robert F. LaPrade, MD, PhD, Casey M. Pierce, MD, and Scott Wilkins, DPT, OCS

Introduction

ASPECTS OF FOOTBALL THAT REQUIRE SPECIAL ATTENTION IN REHABILITATION

- High impact nature
- Variability of playing position
- Relatively limited number of season games

- PCL injuries are most often the result of trauma and high-impact sports injuries such as those occurring in football
  - Injuries to the knee are 13 times more likely during a season game compared with a practice.
- The most common athletic-related injury is falling onto a flexed knee with the ankle plantarflexed.
  - This injury may be seen in a blocking lineman who slips and falls directly onto a flexed knee.
- A direct blow to the anterior tibia with the knee in a flexed position is the second most common mechanism.
  - May occur from being tackled while playing positions such as wide receiver, running back, or quarterback
- The injury may be more common than we think because an average of four to six NFL players in each draft class (of approximately 200 players) are found to have chronically PCL-deficient knees
  - Incidence around 2% for isolated injuries and slightly higher for combined injuries

Literature

- A study by Parolie and Bergfeld[1] investigated patients who were treated conservatively for PCL injuries, including 12 NFL football players.
  - 67% returned to play in the NFL
  - Quadriceps strength was critical to obtaining good outcomes

Phase I: Advanced Strength and Conditioning Programs

Periodization

- In Phase I, a linear periodization model is used to progress the athlete through three areas of training
  - Training focus changes from anatomical adaptations and endurance enhancement to muscle hypertrophy

and eventually progresses to strength and power enhancement
- Phase I linear periodization consists of short weekly microcycles with exercise progression occurring at weekly intervals.

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- Training continuum: Training in Phase I is progressed on a continuum via increases in volume of exercise and/or intensity as well as reduction of rest intervals.
- Flexibility/joint mobility for joint stability: Daily stretching for shortened muscles and normalized joint mobility is performed throughout Phase I and can be incorporated into daily cool down regimen.
  - Joint mobilization may be included to restore normal tibiofemoral contact points in a PCL-injured knee.
- Training with optimum posture. Optimum posture is emphasized throughout the exercise routine to reduce risk of injury and limit compensation strategies for the involved limb.
  - All exercises must be performed with optimum posture at current intensity and volume before progression is allowed.
  - Substitutions such as excessive forward lean during squatting activities will over-recruit the hamstrings and place increased stress on the healing ligament (Figure 33-47)
- Sensorimotor and balance training is incorporated into rest periods to further train the proprioception system and to maximize use of rest intervals.
- Core training is maintained and progressed throughout Phase I with emphasis on neutral spine postures and maximization of both lower and upper extremity movement and strength around a neutral spine posture.
  - Performed daily and avoids use of the involved limb for bracing during the acute healing phase
- Cardiorespiratory training is advanced not only through the endurance phase of training, but is also included as a daily exercise throughout all phases.
  - Cardiovascular exercise is used to maintain aerobic capacity during rehabilitation and minimize the effects of detraining following injury.

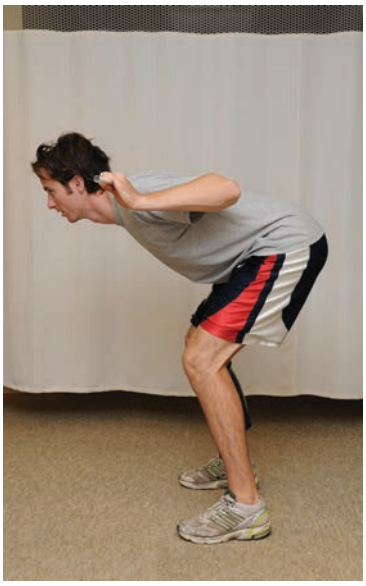

FIGURE 33-47. Improper forward lean during squats stressing the hamstring.

Training Principles Used in the Design of the Program

- The principle of progression is used to advance Phase I exercises through a linear advancement of intensity, volume, and reduction of rest intervals.
- The principle of overload is used to improve endurance, stimulate hypertrophy, and ultimately increase strength and power output of muscles.

Application of Acute Training Variables

- Repetitions: 10 to 14 repetitions in the endurance phase, 8 to 12 repetitions in the hypertrophy phase, and four to six repetitions in the power/strength phase
- Sets: three to four each
- Rest interval: 30 seconds between exercises and 60 seconds between sets initially
- Intensity: low intensity with high repetitions in endurance phase and increasing linearly as repetitions decrease through the hypertrophy and into the power phase

TIMELINE 33-3: **Return to Football After Posterior Cruciate Ligament Injury**

PHASE I (weeks 1 to 3)	PHASE II (weeks 4 to 9)	PHASE III (weeks 10 to 12)
• PCL Jack brace • PT modalities as needed for pain control • Stretching and ROM exercises • TLS-OKC knee extension, four-plane straight-leg raise, calf raises, leg press, lunges, two- and one-leg squats, and resisted walking/running • TBS-Pull ups, seated rows, neutral spine core exercises in prone and supine, treadmill running • Core strengthening/stabilization exercises • Balance and proprioception exercises	• PCL Jack brace • PT modalities as needed for pain control • TLS: resisted lateral and backward band walking, band resisted hip lateral rotation in side-lying, front squats, power cleans, box jumps, and resisted running in all planes • TBS: hang snatch, pull ups, bent over barbell rows, neutral spine core strengthening in supine/prone/quadruped, plank holds in all planes, treadmill running • Core strengthening/stabilization exercises • Balance and proprioception exercises	• PCL Jack brace • PT modalities as needed for pain control • TLS: broad Jumps, tuck jumps, drop jumps • TBS: Shuttle run, three-cone drill, high knee skipping and sprinting, reactionary drills, bear crawls, blocking drills • Core strengthening/stabilization exercises • Balance and proprioception exercises progressed • Noncontact return to play after 10 weeks • Full-contact return to play when return to sports criteria met

- Repetition tempo: exercises are performed in an explosive manner, controlling the eccentric portion and exploding throughout the concentric phase as fast as possible
- Training frequency: 3 days per week with cardiovascular, core, stretching, and joint mobilization exercises occurring during warm up, cool down, and off days
- Specific exercises used in the training (Figure 33-48):
  - Straight leg raises (Figure 33-48*A*)
  - OKC knee extension (Figure 33-48*B*)
  - Squats two legs (Figure 33-48*C*) and 1 leg (Figure 33-48*D*)
  - Lunges (Figure 33-48*E*)
  - Bench press (Figure 33-48*F*)
  - Pullups (Figure 33-48*G*)
  - Leg press (Figure 33-48*H*)
  - Rows (Figure 33-48*I*)
  - Calf raises (Figure 33-48*J*)
  - Resisted walking/running (Figure 33-48*K*)

Application of Chronic Training Variables

- Patient form with all exercises is monitored for compensation strategies caused by prior training errors or recent injury
  - Exercise intensity and volume is adjusted to allow for perfect form throughout training

Phase II: Performance Enhancement Training Techniques

Periodization

- An undulating periodization design is used for Phase II.
  - This model will incorporate more explosive and multijoint movements to maximize and progress the endurance, hypertrophy, and strength developed in Phase I, as well as further challenge the body through variability of exercise and functional motions.
- A 6- to 8-week mesocycle is used during Phase II with exercises progressed on weekly microcycles and advanced in difficulty every 6 to 8 weeks until the goals required to advance to Phase III are achieved.

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- Training with optimum posture
- Sensorimotor and balance training
- Core training
- Cardiorespiratory training
- Multi-planar training activities
- Training for optimum muscle balance
- Training for optimum muscle functional strength
- Training for optimum muscle functional power
- Neuromuscular dynamic stability exercises
- Training for speed, agility, quickness (SAQ)
- Plyometric training
- Functional training

Olympic Lifts Used in the Training Program

- Power clean (Figure 33-49*A*)
- Hang snatch (Figure 33-49*B*)

Training Principles Used in the Design of the Program

- The principle of overload continues to be applied in Phase II because the goal is to adequately overload the involved muscles followed by sufficient rest to further maximize power output through explosive functional and sport-related exercises.
- The principle of variation is used to vary demands on the body by undulating between a set of exercises performed on alternate days stimulating increases in strength and explosive power while allowing adequate rest.
- The principle of individualization is used to tailor the exercises to the specific deficits developed from the initial injury.
  - Following PCL injury, rehabilitation patients will demonstrate quadriceps weakness and atrophy as well as hamstring weakness secondary to forced disuse during the protection phase of rehabilitation.
    - These deficits may continue into return to sport training.
    - Patients may also demonstrate chronic deficits such as hip and core weakness, which must be addressed to further reduce risk of future knee injuries.

Application of Acute Training Variables

- Repetitions: three to six
- Sets: three to five
- Rest interval: 1 to 3 minutes between exercises and sets
- Intensity: High
- Repetition tempo: 311 (3-second eccentric phase, 1-second pause at end of motion, and 1-second explosive motion through the concentric phase)
- Training frequency: 3 days per week with cardiovascular, stretching, joint mobility, and core exercises performed on off-days as well as incorporated into warm up and cool down phase of training days. Exercises are divided into groups such as Group A and Group B. Exercise groups are performed on alternate training days. For example, Exercise group A will be performed on Monday and Friday. Exercise group B is performed on Wednesday. The order is switched the next week to avoid doing the same exercise group to training days in a row.
- Specific exercises used in the training (Figure 33-50)
  - Front squats (Figure 33-50*A*)
  - Power clean
  - Box jumps (Figure 33-50*B*)
  - 12- to 14-inch box stepups (Figure 33-50*C*)
  - Bent over barbell rows (Figure 33-50*D*)
  - Pull ups
  - Hang snatch
  - Resisted band walking



FIGURE 33-48. Specific exercises used during training: straight leg raises (**A**), OKC knee extension (**B**), two-leg squats (**C**), one-leg squats (**D**), lunges (**E**), bench press (**F**), pull ups (**G**), leg press (**H**),



FIGURE 33-48, cont'd rows (**I**), calf raises (**J**), and resisted running (**K**).



FIGURE 33-49. Olympic lifts used: power clean (**A**) and hang snatch (**B**).

- Band resisted hip external rotation in side-lying position (Figure 33-50*E*)
- Resisted running in all planes

Application of Chronic Training Variables

- Posture and form during exercise is monitored throughout the phase.
  - Jump and landing mechanics are evaluated to identify habitual patterns that may lead to excessive stress to the knee and healing ligament.

Phase III: Sport-Specific Training

Periodization

- Macrocycles: Macrocycle periodization is used in the last phase.
  - The goal is to peak the athlete's performance and perform return to sports testing corresponding with return to the next game when the injury occurs in season.
- Microcycles: Microcycle periodization uses a weekly cycle with the athlete progressing each week with peak performance testing each week to establish an estimated return to play.
  - Football games are played on a weekly basis; therefore the goal is to reach peak performance and return



FIGURE 33-50. Specific exercises used during training: front squats (**A**), box jumps (**B**), 12- to 14-inch box step ups finish by driving the knee up (**C**), bent over rows (**D**), and band resisted hip external rotation in side-lying position (**E**).

to play status at the end of the week (Friday), allowing for adequate rest before play on Saturday or Sunday.

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- Sensorimotor and balance training
- Core training
- Cardiorespiratory training
- Multi-planar training activities
- Training for optimum muscle balance
- Training for optimum muscle functional strength
- Training for optimum muscle functional power
- Neuromuscular dynamic stability exercises
- Training for speed, agility, quickness (SAQ)
- Plyometric training
- Functional training
- Sport-specific training

Olympic Lifts Used in the Training Program

- Power clean (see Figure 33-49*A*)
- Hang snatch (see Figure 33-49*B*)

Training Principles Used in the Design of the Program

- The principle of individualization is used in Phase III as exercises are tailored to the demands of football play and more specifically the demands of the athletes position
- The principles of specificity: Specific adaptation to imposed demands (SAID) is applied through simulation of specific high-risk scenarios seen during game play
  - Blocking drills for lineman and simulated contact with tackling dummies for ball carriers as well as high-speed cutting and sprinting

Application of Acute Training Variables

- Repetitions: six to eight
- Sets: one to two
- Rest interval: 30 seconds between sets, 60 seconds between exercises
- Intensity: High
- Repetition tempo: Fast with explosive movements, 1- to 3-second pause on stop landings
- Training frequency: 3 days per week
- Training duration: 2 to 4 weeks
- Specific exercises used in the training:
  - Drop jumps (Figure 33-51*A*)
  - Tuck jumps (Figure 33-51*A,B*)
  - Broad jumps one leg (Figure 33-51*C*) and two leg (Figure 33-51*D*)
  - Three-cone drill (Figure 33-51*E*)
  - High knee sprinting/skipping (Figure 33-51*F*)

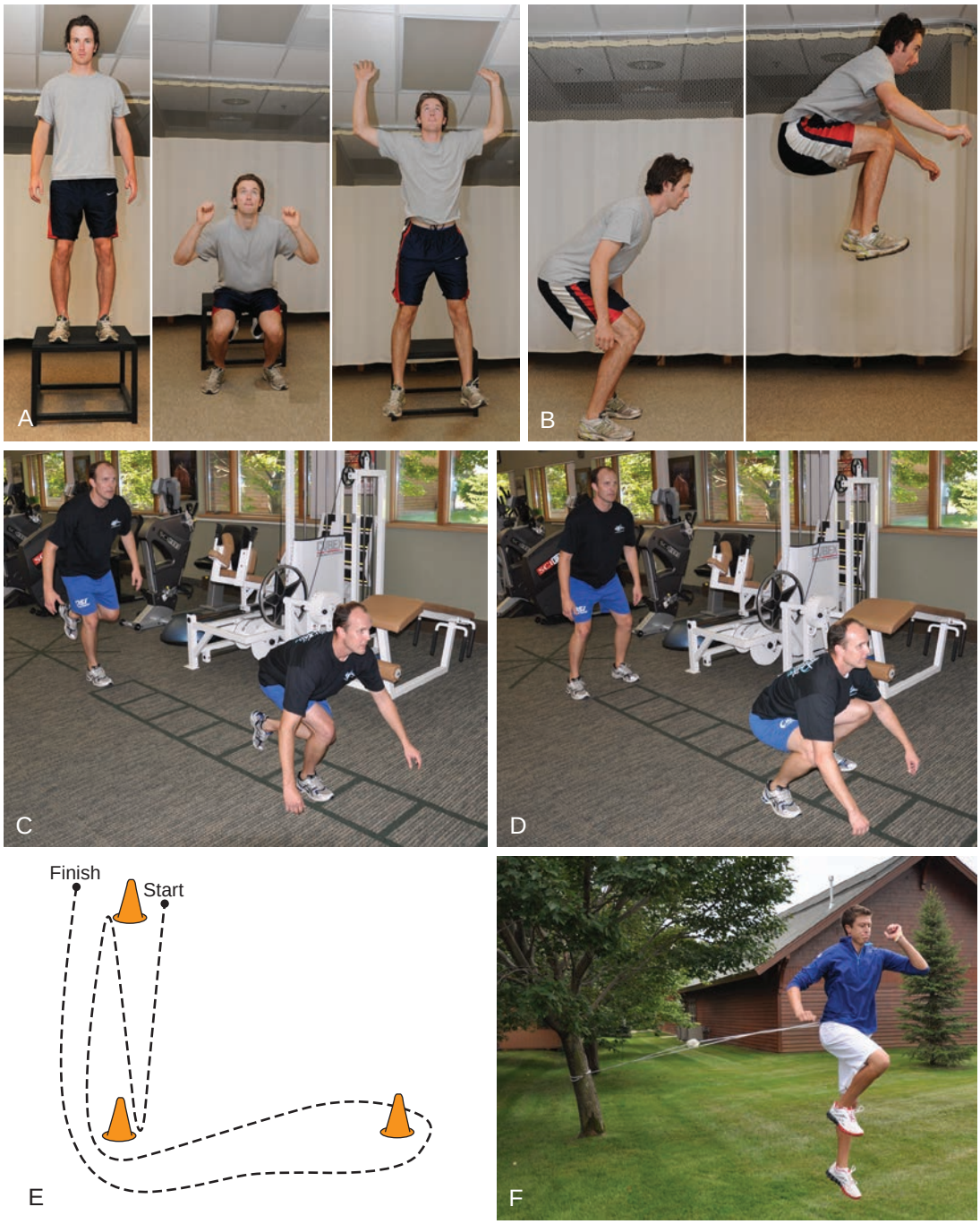

FIGURE 33-51. Specific exercise used in training: drop jumps (**A**), tuck jumps (**B**), broad jumps one leg (**C**), broad jumps two legs (**D**), three-cone drill (**E**), high knee skipping (**F**),

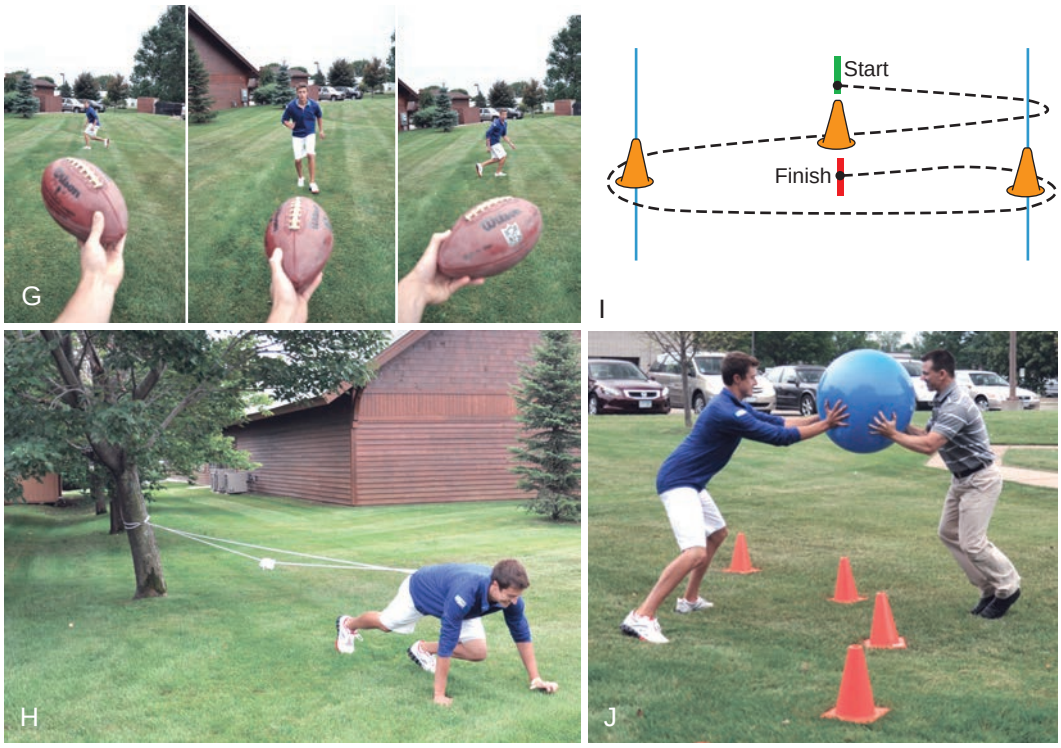

FIGURE 33-51, cont'd reactionary sprinting drills to visual/audible command (**G**), bear crawls for linemen (**H**), shuttle run (**I**), and lateral shuffle blocking drills for offensive linemen (**J**).

- Reactionary sprinting drills to visual and audible commands (line backers, defensive backs, wide receivers) (Figure 33-51*G*)
- Bear crawls (defensive linemen, offensive linemen) (Figure 33-51*H*)
- Shuttle run (Figure 33-51*J*)
- Lateral shuffle blocking drills (offensive linemen)

Application of Chronic Training Variables

- Focus in Phase III is placed on optimal takeoff and landing mechanics, proper lower extremity alignment during all jumping, cutting, and sport simulated drills
  - Proper lower extremity alignment is emphasized to reduce risk of injury, decrease loads on the involved knee, and maximize force production

Sports Performance Testing

General Information

- General history: A general background on the athletes playing position, skill level (first, second, or third string), and primary complaints is obtained.
  - Athletes with low-grade PCL injuries may complain less about instability or giving way and more likely describe a feeling of something being wrong.
  - Additionally, patients may complain of swelling in the knee following a traumatic episode involving falling onto a flexed knee or a direct blow to the tibia.
- Subjective questionnaires: IKDC Subjective Knee Evaluation Form
- Medical history: Athletes should be questioned regarding past medical history to ascertain any alternate diagnosis or conditions that may contribute the current complaints or complicate the healing time frame.
- Sports injury history: Sports injury history must be reviewed to establish the chronicity of the current condition
  - Athletes may present with more instability than expected from the mechanism of injury indicated that the current injury may be an acute injury imposed on chronic condition
  - Potential chronic conditions will have less chance of healing than an acute condition
    - A history of previous ligamentous or meniscal injuries may compound the observed instability and slow healing (e.g., an associated posterior lateral corner injury may result in failed conservative treatment for an acute PCL injury).
- Surgical history: A comprehensive surgical history must be obtained.
  - Athletes with previous ligamentous reconstructions or meniscal debridement may demonstrate residual laxity.
- Chronic conditions/medication: Chronic medical conditions as well as a current medication list (both prescription and over the counter) must be obtained and reviewed for potential conditions or medications that may slow healing.

Objective Tests

- Physiological assessments: Knee range of motion, manual muscle testing to associated hip musculature, assessment of gait pattern
  - Performed before and after Phase I
- Body composition tests: Circumference measurements to document quadriceps atrophy
  - Comparison made to uninvolved limb
  - Performed before phase I and after Phase II
- Static/dynamic postural assessments: posterior drawer testing
  - Performed before phase I and after each Phase II
  - Objectively better with PCL stress radiographs
- Dynamic muscle performance testing: Isokinetic testing for quadriceps and hamstrings strength
  - Hamstring to quadriceps ratio of the involved limb and comparison of quadriceps strength in the uninvolved limb
  - Performed before transition from phase II to Phase III
- Movement performance testing: One leg triple hop, crossover hop, and 6-meter hop testing
  - Comparison made to the uninvolved limb
  - Performed at end of Phase III
- Sport-specific testing: Simulated blocking drills, three-cone drill, cutting with visual and verbal curing for change in direction, shuttle run
  - Performed at end of Phase III

Specific Criteria for Progression to the Next Stage to Determine Readiness for Football

- Athletes must demonstrate 5/5 knee extension strength on manual muscle test, full active knee range of motion, and normalized gait to progress from stage I to stage II
- Athletes must demonstrate normal single leg squat to 60°, normal single leg hop, less than 15% deficit in quadriceps strength with isokinetic testing at 300° and 180° per second to progress from stage II to stage III
  - Negative posterior drawer sign as well

Specific Criteria for Release to Unsupervised Complete Participation in Football

- Athletes must demonstrate normal drop jump mechanics from a 12-inch box, no greater than 10% deficit in the involved lower extremity with one leg triple hop, one leg crossover hop, and one leg 6-meter hop test.
- There must be no complaints or evidence of instability or giving way with daily or sport simulated activities, and no evidence of knee joint effusion.

Recommended Ongoing Exercises

- Athletes must maintain an adequate quadriceps strengthening program throughout their career and should remain vigilant in routine jumping/landing drills

Evidence

Dick R, Ferrara MS, Agel J, et al: Descriptive Epidemiology of Collegiate Men's Football Injuries: National Collegiate Athletic Association Injury Surveillance System, 1988–1989 Through 2003–2004. *J Athl Train* 42(2):221–233, 2007.

A review of 16 years of injury data for men's collegiate football to identify ways to prevent injuries in athletes. The results show game injury rates were more than nine times higher than practice injury rate. The knees specific injury rate was 13.4 times higher in games as compared with practice. (Level IV evidence)

Fowler PJ, Messieh SS: Isolated posterior cruciate ligament injuries in athletes. *Am J Sports Med* 15(6):553–557, 1987.

Prospective study of isolated posterior cruciate injuries seen in 13 athletes diagnosed clinically and confirmed by arthroscopy. Patients were treated nonoperatively on a physiotherapy routine and followed for an average of 2.6 years. All patients were able to return to their previous activity and experienced no limitations with their injured knees. Concluded acceptable functional stability does not require an intact PCL and nonoperative treatment could be an acceptable short alternative to surgical reconstruction. (Level III evidence)

Jacobi M, Reischl N, Wahl P, et al: Acute isolated injury of the posterior cruciate ligament treated by a dynamic anterior drawer brace. *J Bone Joint Surg Br* 92-B:1381–1384, 2010.

Treated 21 patients with an isolated tear of the PCL for 4 months nonoperatively using a functional brace. Initial and follow-up stability was tested by Rolimeter arthrometry and radiography and clinical outcomes were measured using the Lysholm score, Tegner score, and International Knee Documentation Committee scoring system at 1 and 2 years. Found that the applied treatment produced a good or excellent functional result in all patients. Concluded the PCL has an intrinsic healing ability and will heal with less attenuation if the tibia is reduced to the proper anatomical position. (Level IV evidence)

Parolie JM, Bergfeld JA: Long-term results of nonoperative treatment of isolated posterior cruciate ligament injuries in the athlete. *Am J Sports Med* 14(1):35–38, 1986.

Long-term study of 25 athletes who received nonoperative treatment of isolated PCL injuries with follow-up averaging 6 years. Patients were evaluated with a questionnaire and objectively with clinical examination, x-ray films, Cybex II dynamometer, and KT-1000 knee arthrometer. Found that 80% of the patients were satisfied with their knee with 84% returning to their previous sport. Concluded that if athletes with isolated PCL injuries maintain muscle strength, the majority should return to sports without lingering disability. (Level IV evidence)

Patel DV, Allen AA, Warren RF, et al: The nonoperative treatment of acute, isolated (partial or complete) posterior cruciate ligament-deficient knees: An intermediate follow-up study. *HSSJ* 3:137–146, 2007.

Retrospective cohort study that identified 57 patients with an acute, isolated PCL tear that were treated nonoperatively. Clinical, radiographic, and functional assessments were performed with an average follow-up of 6.9 years. The authors concluded that most patients with acute, isolated PCL injuries do well with nonoperative treatment during intermediate follow-up. (Level III evidence)

Shelbourne KD, Davis TJ, Patel DV: The natural history of acute, isolated, non-operatively treated posterior cruciate ligament injuries. A prospective study. *Am J Sports Med* 27(3):276–283, 1999.

Prospective study of 133 patients with acute, isolated, non-operatively treated PCL-deficient knees. Mean follow-up after initial diagnosis of PCL injury was 5.4 years. the authors concluded that most cases of patients with acute, isolated PCL injuries can obtain satisfactory knee function when managed by nonoperative care. (Level III evidence).

REFERENCE

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Multiple Choice Questions

QUESTION 1. When rehabbing a football player with a posterior cruciate ligament injury, what should the training focus on during Phase I to reduce the risk of injuries and prevent stress on the healing ligament?

A. Proper form/posture during exercises
B. Maximum resistance
C. Endurance enhancement
D. Flexibility

QUESTION 2. Which of the following principles are used during Phase II of rehabilitation for a football player with a PCL injury?

A. Overload
B. Variation
C. Individualization
D. All of the above

QUESTION 3. Which of the following criteria must be met to progress an athlete from stage I to stage II during rehabilitation?

A. Full passive ROM
B. 5/5 knee extension strength
C. Quadriceps strength greater than 80% of the unaffected side
D. All of the above

QUESTION 4. Which of the following criteria must be met to progress an athlete from stage II to stage II during rehabilitation?

A. Normal single leg squat to 60°
B. Normal single leg hop
C. A and B
D. None of the above

QUESTION 5. What criteria should be met to release an athlete to full participation in football activities without further supervision?

A. No evidence of instability or giving way with sports-simulated activities
B. No evidence of instability or giving way with normal daily activities
C. No greater than 10% deficit in the involved lower extremity with one-leg triple hop
D. All of the above

Answer Key

QUESTION 1. Correct answer: **A** Proper form during therapy is critical to reduce injury risk and prevent substitution during exercises that can recruit the hamstrings and place undue stress on the healing PCL. Proper form and posture should be emphasized throughout each exercise and monitored carefully during training. Maximum resistance should not be undertaken until the athlete is well on the way to recovery and bears no value to preventing injury. Endurance training is important to prevent muscle atrophy and may play a role in injury prevention, but is not as important as proper form/posture. Flexibility training can prevent muscle shortening and help restore normal joint mechanics and is always important to prevent injury, but during therapy proper form and posture are more important. (see Phase I)

QUESTION 2. Correct answer: **D** Each of the principles listed in the preceding is used during Phase II of rehabilitation. Phase I focuses on progression and overload, whereas Phase III uses individualization and specificity. (see Phase II)

QUESTION 3. Correct answer: **B** To advance from stage I to stage II the patient should demonstrate full active range of motion, a normalized gait, and 5/5 knee extension strength. Quadriceps strength and passive range of motion are not criteria to progress from stage I to II. (see Sports Performance Testing)

QUESTION 4. Correct answer: **C** Athletes must demonstrate normal single leg squat to 60°, normal single leg hop, and less than 15% deficit in quadriceps strength with isokinetic testing at 300° and 180° per second to progress from stage II to III. In addition, athletes should have a negative posterior drawer test. (see Sports Performance Testing)

QUESTION 5. Correct answer: **D** Athletes must demonstrate normal drop jump mechanics from a 12-inch box, no greater than 10% deficit in the involved lower extremity with one leg triple hop, one leg crossover hop, and one leg 6-meter hop test. There must be no complaints or evidence of instability or giving way with daily or sports-simulated activities, and no evidence of knee joint effusion to be released from the care of a physical therapist. (see Sports Performance Testing)

BEYOND BASIC REHABILITATION: RETURN TO JOGGING AFTER MULTILIGAMENT KNEE RECONSTRUCTION

Nathan L. Cafferky, MD, Gregory C. Fanelli, MD, and Craig J. Edson, MS, PT, ATC

Introduction

ASPECTS OF JOGGING THAT REQUIRE SPECIAL ATTENTION IN REHABILITATION

- Muscle strength
  - Adequate ability to contract with sufficient force to range the knee joint
- Coordination
  - The ability to allow for smooth contraction and relaxation of the antagonistic muscle groups of the leg to allow for fluid motion
- Range of motion
  - Ability to allow for sufficient physiologic motion through the knee joint
- Ligamentous stability
  - The ability of the knee joint to resist internal and external forces of derangement
- Proprioception
  - The ability for the patient to appreciate the location of knee joint in space

Multiligament Knee Injuries: Key Aspects

- Jogging
  - The ability to jog is a major stepping stone in returning to athletics after a ligamentous knee injury and subsequent surgery.
  - Popularized by Arthur Lydiard in the 1960s and 1970s[1]
  - Definition
    - Running at a slow and leisurely pace
- Multiligamentous knee injuries are the result of knee dislocations or subluxations
  - Two distinct categories
    - High-energy injuries
      - Related to motor vehicle accidents
      - Falls from height
    - Low-energy injuries
      - Typically associated with athletic injuries.
        - Football
        - Soccer
        - Snow skiing
  - Associated injuries
    - A careful initial evaluation of the extremity of the injured patient is of critical importance since the incidence of neurovascular damage is directly proportional to the energy of injury.
  - Further differentiation of multiligamentous knee injuries can be categorized into different directions in which the tibia is dislocated or subluxed in relation to the femur. Although reports vary, anterior and posterior dislocations appear to be the most common.[2,3]
    - Anterior
      - Result from hyperextension injuries
    - Posterior
      - Result from when an anterior-to-posterior force is directed against the proximal tibia with the knee at 90° of flexion[4]
    - Lateral
      - Result from medial-to-lateral (varus) force
    - Medial
      - Result from a lateral-to-medial (valgus) force
    - Rotational
      - Result from pivot injuries
  - Incidence
    - Knee dislocations are rare
      - One review article stated their institution had 14 knee dislocations out of 2 million admissions over a 50-year period.[5]
    - However, it is felt that the true incidence of knee dislocations is under reported because it is believed that a large portion of knee dislocations spontaneously reduce.[6] It has been speculated that it may be as high as 50%.
  - Initial treatment
    - High index of suspicion is required based on the events surrounding the accident
    - Consists of reduction and stabilization of the knee joint
    - Considered an orthopaedic emergency
    - Extensive evaluation consisting of performing a thorough history and physical, radiographic analysis such as x-rays and MRI studies, and even vascular studies when indicated
  - Surgical reconstruction using allograft, autograft or a combination of both can be used[6]
    - Adequate time should be given to allow for the incorporation of ligamentous grafts. Thus, a slow and methodical approach to rehabilitation allows the patient the ability to return to the activity of jogging and in the end, their respective sport.

Return to Jogging After Multiligamentous Knee Reconstruction: Literature

- Rehabilitation after multiligamentous (ACL, PCL, MCL) knee reconstruction
  - The rehabilitation of a multiligamentous knee following surgical reconstruction can be separated out into four distinct phases.
  - Each phase has distinct goals and exercise programs associated with it (Table 33-1).

Table 33-1 Multiple Ligament Reconstruction Rehabilitation

	Goals	Program
Phase I: 0–6 weeks	Maximum protection of grafts Maintain patella mobility Minimize quadriceps atrophy Maintain full passive extension—locked long-leg hinged ROM brace Control pain and swelling	Nonweightbearing ambulation with crutches Brace locked in extension 24 h/day Cryotherapy Quad sets—enhance with low-intensity electrical stimulation or biofeedback Patella mobilization Low-intensity gastrocsoleus and hamstring stretching
Phase II: 6–10 weeks	Initiate weightbearing for articular cartilage nourishment Increase knee flexion gradually to 90°–100° Improve quadriceps tone and strength Improve proprioception Avoid isolated quadriceps and hamstring contractions	Begin partial weightbearing • Grossly 20% body weight and increase by 20% per week over the next 5 weeks to full weightbearing by the end of postoperative week number 10. Open brace to full flexion and discontinue brace for sleeping. Prone hangs Passive flexion exercises High-intensity electrical stimulation with knee at 60°–70° (optional) Initiate closed-chain strengthening once full weightbearing and quadriceps strength of 3+/5 or greater Advance proprioception Fit for functional brace after 10 weeks. Discontinue ROM brace.
Phase III: 10 weeks–6 months	Progress closed-chain strengthening Initiate open-chain quadriceps strengthening by end of month 4. Initiate straight-line jogging at end of month 5. Increase knee flexion to at least 120° by end of month 6. Improve cardiovascular endurance.	Progressive resistive closed-chain exercises avoiding flexion beyond 70° Isolated quadriceps strengthening at end of month 4 Single-leg proprioception on unsteady surface Aggressive flexion exercises if necessary Consider manipulation under anesthesia if ROM is <90° by end of month 4 Hip passive resistance exercises Straight-line jogging at end of month 5 Initiate low-intensity plyometrics at end of month 6
Phase IV: 6–12 months	Maximum flexion 10°–15° degree terminal flexion loss is common Quadriceps strength 90% or greater of nonsurgical leg Progress to sport-specific activities Return to sports between month 9 and 12	Progression of strengthening, conditioning, and agility exercises to achieve goals Progressive plyometric proprioceptive program ("jump program") Return to sports if the following criteria are met: • Minimal or no pain and swelling • Completion of all functional tests within 10% of the uninvolved side • Ability to spring without any gait alteration • Compliance with functional bracing

Reproduced with Permission from Edson CJ, Fanelli GC, Beck JD: Rehabilitation after multiple-ligament reconstruction of the knee. *Sports Med Arthrosc Rev* 19:162–166, 2011.

- A carefully orchestrated approach to rehabilitation among the orthopedic surgeon, the physical therapist, and most importantly the patient is paramount for the patient to reach his or her expected goals.
- It requires a precarious balance between restoring range of motion and function to the knee without compromising the static stability and integrity of the grafted tissues.[7]
- Although rehabilitation protocols may vary from surgeon to surgeon, it is evident that rehabilitation needs to be more conservative in this population than for those with an isolated ligament injury, such as an isolated ACL injury.[8]
- Rehabilitation can be slow and challenging for most patients, and realistically can take up to a year before unrestricted activity is permitted.
  - Deciding to allow a patient to return to jogging and sports is complex, and is discussed throughout the chapter.

Phase I (weeks 0 to 6): Immobilization and Nonweightbearing

- Phase I represents the patient's acute postoperative recovery phase.
  - Goals for Phase I:
    - Maximize protection of the grafts
    - Maintain patella mobility
    - Minimize quadriceps atrophy
    - Maintain full passive extension
    - Control pain and swelling
- Immediately following surgical reconstruction, the operative knee is placed into a long-leg hinged range of motion (ROM) brace locked in extension for 5 weeks.
  - The patient must wear this brace for 24 hours per day, with the exception of showering.

- The importance of locking the knee in full extension during this phase cannot be overestimated.
  - Full extension minimizes forces across the PCL.[9]
  - Prevents the development of early flexion contraction[7]
  - Healing of the PCL graft
  - Restoring static stability of the knee[10]
- Another strategic component to Phase I is that the patient is also instructed to maintain nonweightbearing (NWB) ambulation with crutches for the full 6 weeks.
  - However, the patient is permitted to stand statically in place and weight-bear across the knee while wearing the long-leg hinged ROM brace locked in extension.
  - This decreases the patient's chance of falls, as he or she has better static balance when standing on both legs.[7]
  - Also, occasional weightbearing is felt to stimulate ACL and PCL bone tunnel healing and graft incorporation, as well as promote the production of synovial fluid, which is also important for graft healing.
- The risk of Phase I is the development of quadriceps atrophy and inhibition as well as stiffness of the knee.
  - Although knee stiffness has been found to occur, early ROM of the knee has been found to be more detrimental to attaining static stability of the knee.
    - Thus leading to the maintenance of the long-leg hinged ROM brace locked in extension
    - The few patients who do develop knee stiffness can undergo a manipulation of the knee under anesthesia or arthroscopic lysis of adhesions once static stability of the knee is reached and maintained.[11]
  - Quadriceps atrophy and inhibition, on the other hand, is the most important factor to prevent, and may be the most challenging aspect of the patient's rehabilitation.
  - It has been shown that quadriceps weakness is more than just a result of disuse, but rather the result of reflex inhibition.
  - Reflex inhibition is a complex response to distorted afferent and efferent stimuli.
    - It is theorized that arthrogenic muscle inhibition is caused by reflex activity in which altered afferent signals originating from the injured and operative knee lead to diminished efferent motor drive of the quadriceps; thus causing muscular atrophy.[12]
- Exercises are recommended once the surgical bandages are removed to combat muscular atrophy.
  - The exercises include:
    - Self-patella mobilization and massage
      - Gentle self-manipulation of patella with quadriceps massage
    - Cryotherapy
    - Application of ice to operative knee to minimize inflammation
    - Electrical stimulation of quadriceps muscle
    - Transcutaneous electrical nerve stimulation and/or neuromuscular stimulation
    - Quadriceps sets and ankle pumps
    - Multiple repetitions of gentle isometric contractions of the quadriceps muscle with active dorsiflexion and plantar flexion of ankle joint
    - Low-intensity gastrocsoleus and hamstring stretching[7,12]
    - Gentle passive stretching of the gastrocsoleus and hamstring muscles
  - This program is initiated to help:
    - Minimize swelling
    - Prevent quadriceps atrophy
    - Improve blood flow to the quadriceps
- Only after having successfully achieved and maintained the goals for Phase I can the patient move on to Phase II of the rehabilitation program.

Phase II (weeks 6 to 10): Initiation of Weightbearing and Range of Motion

- Phase II represents the start of the patient's formal rehabilitation. At this point, the restrictions previously placed are liberalized. The patient is allowed to begin weightbearing ambulation, and the ROM brace is unlocked to allow for full flexion.
  - Goals for Phase II
    - Initiate weightbearing for articular cartilage nourishment.
    - Increase knee flexion gradually to 90° to 100°.
    - Improve quadriceps tone and strength.
    - Initiate proprioception training.
    - Avoid isolated quadriceps and hamstring contractions.
- Partial weightbearing with crutches is initiated.
  - Crutches and protective weightbearing minimizes the patient's risk of falling because of significant quadriceps atrophy. The patient is instructed to begin using 20% of his or her body weight to introduce weightbearing forces across the surgical graft and aid with articular cartilage nourishment.
    - The purpose of starting weightbearing at 20% of the body weight is to emphasize to the patient of the importance of maintaining partial weightbearing, and to give the individual a numerical limit that he or she should not exceed.
    - 20% of the patient's body weight can be calculated using a scale. The patient can then obtain a mental note for how much weight 20% feels like.
    - Example: 20% of 150 lb is 30 lb. The patient can apply 30 lb to the operative leg, thus giving the patient a sense of how much force he or she is allowed to apply to the surgical graft.
- It is important that passive flexion exercises in protection be started during this phase, completely avoiding isolated hamstring and quadriceps strengthening.
  - Attempted forced flexion by either the patient or therapist at this phase of rehabilitation may compromise the ligamentous grafts, which are still undergoing incorporation during this phase.

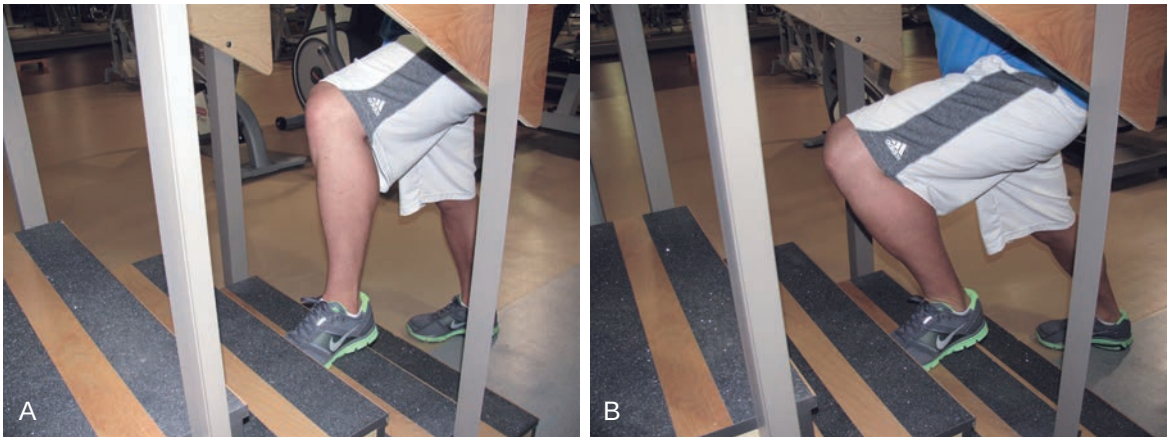


FIGURE 33-52. A,B, The stair stretch. The operative knee is placed on a step, and is then gently "rocked" forward until a comfortable stretch is felt by the patient.

- There have been reported incidences in which patients' grafts have torn just by being too aggressive during this phase of healing.[7]
- Passive knee flexion exercises exist that allow for improving ROM. Although many exercises exist, two such exercises include stair stretching (Figure 33-52) and passive-assisted heel slides (Figure 33-53).
  - Stair stretching is performed by having the patient place the involved knee on a stair and gently rocking forward. Passive knee flexion is achieved.
  - Passive-assisted heel slides can also be performed by using the nonsurgical leg to flex and extend the operative knee while the surgical knee maintains good alignment. Flexion is achieved until a stretch is felt, and then the knee is extended using the uninvolved leg.
- However, the initiation of flexion exercises can diminish a patient's ability to extend his or her operative knee. Thus, additional focus on extension during this phase is appropriate.
  - Prone hangs provide an excellent way for gravity to passively extend the knee.
    - The patient is placed in the prone position. With their body and thighs support, gravity is allowed to passively extend the knee. This further promotes passive range of motion to the surgical graft, thus minimizing the risk of graft compromise.
- Range of motion and weightbearing both progress gradually throughout this phase.
  - Range of motion
    - 90° of passive flexion is the goal that the patient should strive for at the end of week 10
  - Weightbearing
    - Increase weightbearing by 20% each week, until full weightbearing is achieved.[8]
  - Again, it is important to stress to the patient that this is a slow gradual process that should take 4 to 5 weeks.
- At the end of Phase II, once full weightbearing and quadriceps strength of 3+/5 is achieved, closed kinetic chain exercise programs, and proprioception training can be initiated.
  - Closed kinetic chain exercise programs (Figure 33-54).
    - Closed kinetic chain exercises progress the forces applied across the surgical graft in a controlled fashion. The operative extremity is kept in contact with an immobile surface throughout the entire exercise. Proper technique is emphasized, and

TIMELINE 33-4: **Return to Jogging After Multiligament Knee Reconstruction**

PHASE I (weeks 0 to 6)		PHASE II (weeks 6 to 10)
Weeks 0 to 2	**Weeks 2 to 6**	
• Long leg hinged ROM brace locked in extension • Surgical dressing maintained • NWB on operative extremity • Crutch ambulation	• Long leg hinged ROM brace locked in extension • NWB on operative extremity • Crutch ambulation • Surgical dressing removed • Patella massage/mobilization • Cryotherapy • Quadriceps sets • Ankle pumps • Low intensity gastrocsoleus and hamstring stretching	• Long leg hinged ROM brace unlocked • Allow for full flexion • WBAT on operative extremity • Starting at 20% body weight, advancing by 20% weekly • Continue crutch ambulation until WBAT is 100% • Crutch ambulation • Passive ROM exercises to 90°–100° • Stair stretching and passive-assisted heel slides • Initiate closed kinetic chain exercises • Electrical stimulation of quad muscle with knee at 60°–70° flexion

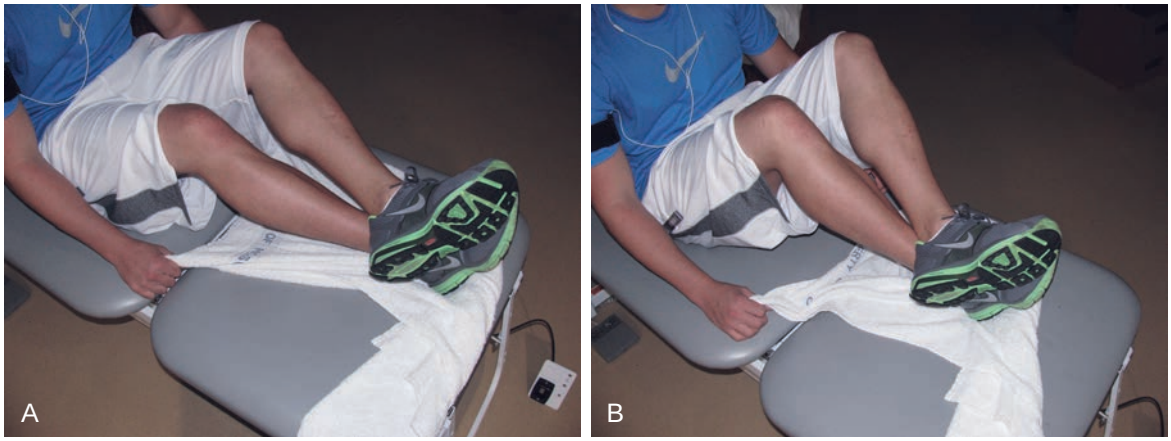


FIGURE 33-53. A,B, Passive heel slides. Many different techniques exist. The one depicted here occurs when the nonsurgical leg is used to flex and extend the operative knee while the surgical knee maintains good alignment.



FIGURE 33-54. Closed kinetic chain exercises. Squats are an excellent example of closed kinetic chain exercises. By placing a ball in between the patient's knees, adequate posture and biomechanics are enforced and maintained.

repetitions vary on the patient's ability and comfort level. Two such exercises are:
  - Lunges
    - With the operative knee placed in a forward position from the patient's body, the operative knee is flexed to 90° and then extended. The nonoperative knee is placed posteriorly, and allowed to flex to a point of comfort.
  - Squats
    - Legs are placed shoulder width apart. The patient is allowed to squat, similar to sitting down in a chair, and flex knees until 90° of flexion is achieved. Then the patient stands back up. This can also be performed by using a squat machine.
- Proprioception training (Figure 33-55)
  - Proprioception training provides neurological and biomechanical feedback to the patient to regain muscular coordination and control of the operative limb. It also re-establishes a sense of the operative limb in space.
    - Balance board
      - Double- and single-legged balance board training can be performed depending on the

TIMELINE 33-4: **Return to Jogging After Multiligament Knee Reconstruction** (Continued)

PHASE III (weeks 10 to 26)	PHASE IV (weeks 26 to 52)
• Change to multi-stability functional knee brace • Progressive resistive closed kinetic chain exercises • Avoid flexion knee beyond 70° • Single-leg proprioception exercises • Increase ROM/flexion exercises • Goal is 100°–110° by third month If ROM <90° by fourth month, will require manipulation under anesthesia • Goal is 120° by sixth month • Isolated quadriceps strengthening at end of fourth month • Hip passive resistance exercises • Stationary bicycle exercises • Straight-line jogging at end of fifth month • Initiate low-intensity plyometrics at end of sixth month	• Continue multi-stability functional knee brace • Progression of strengthening, conditioning, and agility exercises • Progressive plyometric proprioceptive program ("jump program") • Maximum flexion 10°–15° terminal flexion loss is common Quadriceps strength 90% or greater of nonsurgical leg • Return to sports between month 9 and 12 • Return to sports if the following criteria are met: • Minimal or no pain and swelling • Completion of all functional tests within 10% of the uninvolved side • Ability to spring without any gait alteration • Compliance with functional bracing

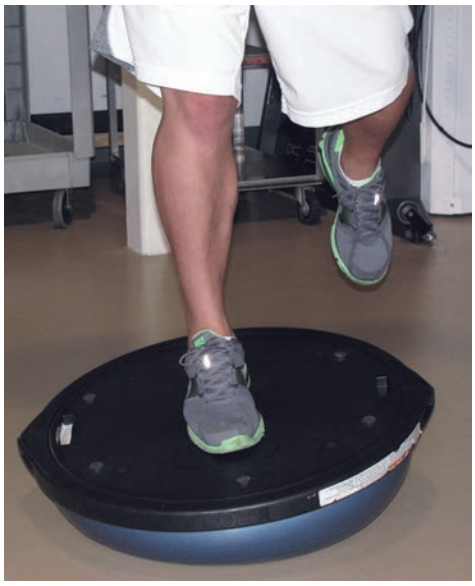


FIGURE 33-55. Balance board. Excellent way to enhance proprioception in the operative knee. The operative leg is used on the balance board. This is worked on until the patient is able to maintain his or her own balance without the use handrails.

patient's ability and comfort level. Using a platform with a round under-surface, the patient attempts to improve his or her ability to stabilize himself or herself and thus improve overall balance.

- If the patient has successfully achieved and maintained the goals for Phase II, he or she is allowed to progress to Phase III of the rehabilitation program.
  - When the patient is able to weight bear as tolerated on the operative leg, has regained 3+/5 strength in the quadriceps, and is able to perform closed kinetic chain and proprioception exercises without much discomfort, he or she is allowed to advance to Phase III.
  - At this point, the long-leg locking ROM brace can be discontinued, and the patient is fitted with a functional knee brace.
  - The functional knee brace should be multi-stability–specific so it prevents anteriorly and posteriorly directed forces on the tibia while also supporting the medial and lateral structures.
  - This brace should be worn throughout the remainder of the patient's rehabilitation.
  - This occurs typically by postoperative week 10.

Phase III (weeks 10 to 26): Increasing Range of Motion and Improving Muscle Conditioning

- Phase III represents the progression to more advanced strengthening and conditioning programs.
  - Goals for Phase III
    - Increase knee flexion.
    - Progress closed-chain strengthening.
    - Initiate open-chain quadriceps strengthening and straight-line jogging.
    - Improve cardiovascular endurance.
    - Continue proprioception conditioning.
- Studies have shown that both the ACL and PCL have mechanoreceptors that communicate directly with the central nervous system.[13,14]
  - The tearing of these ligaments and subsequent reconstruction leads to knee joint dysfunction, thus leading to joint laxity and muscular dysfunction.
  - Consequently it is imperative to train the surrounding knee musculature and mechanoreceptors so that joint proprioception is restored during gait and daily activities.
  - Exercises used during this period of rehabilitation focus on sensorimotor and balance training, and training toward optimum muscle functional strength.
    - This can be accomplished by having the patient continue to wear his or her multi-stability–specific knee brace and perform:
      - Continued proprioception training.
    - Balance board (see Figure 33-55) is an excellent way for the recovering athlete to focus on improving his or her overall balance through the knee joint, by re-training the knee mechanoreceptors.
      - Progressive closed-chain strengthening exercises.
        - Closed kinetic chain exercises not only improve muscle function and strength, but are also an excellent way to aid in the recovery of proprioception.
- Closed kinetic chain exercises have been shown to have decreased shear forces across the tibiofemoral joint, as compared with open kinetic chain exercises because of the axial orientation of the applied force and muscular co-contraction.[15]
  - This idea has been brought into question by the Beynnon et al.,[16] who found that closed kinetic chain exercises produce similar strain patterns as unweighted open chain exercises. However, Beynnon also found that performing weight resisted open chain exercises significantly increases the strain across the surgical graft, whereas adding resistance to closed chain exercises does not significantly increase the strain pattern across the surgical graft.
    - Open chain exercises are performed in which the foot of the operative leg is free in space, such as hamstring curls or leg extensions.
      - It is important to begin closed chain exercises with only using the patient's body weight, because the patient's quadriceps muscles may not be at full strength yet.
        - As previously stated, lunges and squats are excellent examples of these types of exercises.
  - It is imperative that the patient focus on good structural posture, and limit active knee flexion to 60° during this period of rehabilitation.
    - The initial 60° arc of knee flexion has been found to have similar quadriceps and hamstring strength ratios.[17]
      - This minimizes tibial translation
      - Decreases the potential risk of injuring the ligamentous grafts

- This is also another important reason why early prevention of quadriceps atrophy is important, so that quadriceps and hamstring strength ratios remain equal, thus limiting tibial translation.
- Once muscular strength and control improve, resistance exercises are implemented.
  - Muscular strength should be symmetrical with the contralateral, nonsurgical leg. Once the patient is able to balance himself or herself on the balance board, the patient has achieved adequate control of the operative leg.
  - A combination of both concentric and eccentric exercises can be used.
    - Concentric exercises occur when muscles shorten during contraction.
      - Resisted hamstring curls or resisted quadriceps extensions
    - Eccentric exercises occur when muscles Lengthen during contraction.
      - Known as "negative resistance" exercises
  - Studies have shown that the use of negative resistance training in combination with standard concentric exercises provides for a twofold greater increase in quadriceps peak cross-sectional area and volume.[18]
    - These exercises improve quadriceps recruitment and strength.
- The final step in re-establishing quadriceps muscular strength is the use of open kinetic chain exercises.
  - It is important that the patient and therapist be aware that open kinetic chain exercises can create larger anterior shear forces across the tibiofemoral joint than do closed chain exercises.[15,16] Thus these exercises are deferred until the 16 weeks of rehabilitation to allow the ligamentous grafts time to incorporate and strengthen.
    - Excellent examples of open kinetic chain exercises are:
      - Hamstring curls
      - Quadriceps extensions
    - These exercises are implemented gradually and with regard to the patient's subjective reports.[7]
  - Progressing to open kinetic chain exercises too quickly can lead to the development of anterior knee pain.
    - This is typically the result of an offset between the quadriceps and hamstring strength ratios, leading to excessive force across the knee structures. Thus the patellofemoral joint reaction forces are augmented.[7]
      - Patella tendonitis and patellofemoral chondromalacia are the most likely result that occur as the result of breakdown and inflammation of the cartilage and tendon.[7] This can be prevented with close monitoring of the patient's response to the exercises, and use of cryotherapy at the end of each exercise.[7]
- Although focusing on quadriceps strength is a large component of this phase of rehabilitation, it is also vital to not neglect the importance of improving ROM.
  - Setting ROM goals for the patient during this phase of therapy is important.
    - At the end of approximately the third month of rehabilitation, 100° to 110° of flexion should be achieved, progressing toward 120° of flexion by the sixth month of rehabilitation.
    - This is achieved by continuation of passive knee flexion exercises and the incorporation of active knee flexion exercises, as previously discussed.
- Once adequate quadriceps strength and knee ROM are achieved, progressive challenging exercises may be implemented. Quadriceps strength should be symmetrical to the contralateral nonoperative leg with near full pain-free symmetrical range of motion of the knee joints. This is typically achieved by the 20th week of rehabilitation.
  - At this point, straight-line jogging is allowed.
    - Initially the patient is monitored for altered gait biomechanics.[7]
      - If an obvious dysfunction is identified, the patient is prevented from jogging, and returns to working on ROM and strength training.
      - However, if no gait abnormalities are identified, the patient is allowed to continue with straight-line jogging.
        - This means that muscular strength and coordination of the operative leg are within normal limits for the patient.
- Near the end of Phase III of rehabilitation, the patient is instructed to continue addressing and promoting the following, which becomes an important part of his or her recovery.
  - Dynamic stabilization
    - Dynamic stabilization can be performed with the continuation of closed kinetic chain exercises such as wall sits and single leg squats.
    - A study in 2009 showed that PCL forces were significantly lower in one leg squats exercises up to 70° compared with the bilateral leg squats to 90°.[19]
      - Thus limiting closed chain exercises to 70° of flexion will help minimize excessive forces across the grafted PCL.
  - Proximal strengthening
  - Core body exercises
    - Properly performed situps and crunches are excellent ways to advance core strength.
      - Focused abdominal exercises. Full situps result in the entire back being lifted off the floor while crunches only lift the upper portion of the trunk of the floor. Both provide adequate core strengthening.
  - Cardiorespiratory training
    - Stationary bicycles are an excellent way to promote the patient's cardiopulmonary rehabilitation by maintaining the patient's targeted heart rate. This can be achieved by repetitions, sets, and tempo of training. Adjusting them as needed to meet the patient's demands and goals.
    - Stationary bicycles also provide a great way for the patient to work on the entire lower extremity.
      - Stationary bicycles promote:
        - Range of motion
        - Strengthening the gastrocsoleus muscle complex, quadriceps, hamstring, and hip flexors and extensors

- Stationary bicycling not only improves muscular strength and coordination, but also improves both muscular and cardiopulmonary endurance.
- Completing Phase III of rehabilitation is a significant accomplishment for the patient, and is typically finished by about the 24 weeks of rehabilitation.
  - Most patients are beginning to feel ready to return to activity.
    - However, it is important to remind and reinforce to the patient that he or she continue to require additional rehabilitation, and will likely not be ready to return to unrestricted activity for another 3 to 6 months.[7]
- Once the patient has achieved the goals of Phase III, which include improved knee flexion, progressive closed-chain strengthening, the initiation of open-chain quadriceps strengthening and straight-line jogging, improvement in cardiovascular endurance, then he or she is allowed to progress to Phase IV.

Phase IV (weeks 26 to 52): Improving Strength, Range of Motion, and Returning to Jogging (and Sports)

Attaining and maintaining maximum knee flexion and quadriceps strength is an important aspect of Phase IV. Phase IV is geared toward returning to sports and work-related activities.

- Goals for Phase IV:
  - Attain maximum flexion and quadriceps strength.
  - Progress to sport-specific activity.
  - Return to unrestricted jogging and sports.

Rehabilitation months 6 to 9 are typically a period of refining all previously mentioned exercises, as well as incorporating nonlinear jogging and cutting as well as low-level plyometrics.

- Plyometrics includes both double and single leg exercises.
  - This is the "jump program" (Table 33-2).
    - Focus is placed on the mechanics of landing and posture. The patient should be able to maintain the landing position for 2 to 5 seconds.
    - This is a progressive program that typically takes 6 weeks to complete.
    - It is designed to minimize potential risks of injury by increasing the load across the knee to enhance functional stability of the knee.[7,18,20-23]
    - The patient is allowed to advance to the next stage only after successfully completing the previous stage.
    - The patient is again monitored during this phase for the development of anterior knee pain, and measures are taken as previously stated, to prevent and treat this problem if it develops.
- The completion of the "jump program" should coincide with the ninth month of rehabilitation.
  - At this point, returning to unrestricted activity, such as jogging, is considered if the patient is able to meet certain criteria.
    - Has minimal or no pain and swelling
    - Has the ability to spring without any gait alteration. (Spring is assessed by comparing it to the contralateral leg.)
    - Compliance with functional bracing
    - Meets the functional testing goals of the operative knee, as described in the following

In the end, range of motion of the knee and leg neuromuscular function should be evaluated.

- It is expected that the patient will have a 10° to 15° loss of terminal flexion in the operative knee when compared with the uninvolved knee.
- It is important to quantify the operative knee and leg neuromuscular function before return to activity.

Table 33-2 The Geisinger HealthSouth/Geisinger Sports Medicine Jump Program

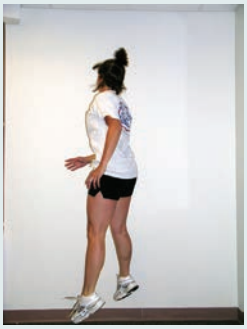
1.1.1.1.1 Platform Drop-Down Landing			Soft landing into knee flexion, avoiding the weaker leg falling behind the stronger leg.
			
Stand on an 8" platform.	Step off platform and prepare for landing into double leg stance.	Soft neutral landing in knee flexion: hold position for 2 seconds and repeat.	

Table 33-2 The Geisinger HealthSouth/Geisinger Sports Medicine Jump Program—cont'd

1.1.1.1.2 Tuck Jump			Simultaneous takeoff and landing with feet parallel to one another. Soft landing into knee flexion, avoiding the weaker leg falling behind the stronger leg. *Keep back and shoulders upright bringing knees up to chest and avoid slouching chest forward into the jump.*
			
Neutral semi-squat start position	Jump straight up and tuck knees up to chest.	Soft neutral landing in knee flexion: Hold position for 2 seconds and repeat.	
1.1.1.1.3 Squat Jump			Simultaneous takeoff and landing with feet parallel to one another. Soft landing into knee flexion, avoiding the weaker leg falling behind the stronger leg. *Avoid valgus of knees with initial squat position and in takeoff.* *Avoid a forward or lateral shift; should maintain symmetry in squat position.*
			
Neutral squat until fingertips touch the floor at outside of feet.	Jump straight up, raising arms overhead for maximal vertical leap keeping legs straight while airborne.	Soft neutral landing in knee flexion: Hold position for 2 seconds and repeat.	
1.1.1.1.4 Barrier Jumps—Side to Side			Simultaneous takeoff and landing in non-algus position with feet parallel to one another. Soft landing into knee flexion avoiding the weaker leg falling behind the stronger leg. *Jump up and slightly tuck knees to clear the barrier; adjust height of barrier accordingly if unable to clear it.*
			
Neutral semi-squat start position while standing beside a 6" barrier.	Jump up and across the cone. Keep knees bent while airborne.	Soft neutral landing in knee flexion: Hold position for 5 seconds and repeat.	

Continued

Table 33-2 The Geisinger HealthSouth/Geisinger Sports Medicine Jump Program—cont'd

180° Jumps			Simultaneous takeoff and landing in a nonvalgus position with feet parallel to one another. Soft landing into knee flexion, avoiding the weaker leg falling behind the stronger leg. *Do not attempt to turn before takeoff.*
			
Neutral semi-squat start position.	Jump straight up and rotate 180° to the right while in the air, keeping knees straight while in the air.	Soft neutral landing in knee flexion facing opposite direction from start: Hold position for 2 seconds and repeat in the opposite direction to the left.	
1.1.1.1.5 Broad Jump			Simultaneous takeoff and landing in a nonvalgus position with feet parallel to one another. Soft landing into knee flexion, avoiding the weaker leg falling behind the stronger leg. *Stable landing into deep knee flexion; if unable to maintain balance, instruct patient to shorten jump.*
			
Neutral semi-squat start position.	Jump up while advancing forward.	Soft neutral landing in knee flexion: Hold position for 5 seconds and repeat.	
1.1.1.1.6 Platform Jump-ups			Simultaneous takeoff and landing in a nonvalgus position with feet parallel to one another. Soft landing into knee flexion, avoiding the weaker leg falling behind the stronger leg. *Jump up and slightly tuck knees to clear the platform; reduce height of platform accordingly if unable to clear it.*
			
Neutral semi-squat start position standing behind an 8″ platform.	Jump up onto the platform.	Soft neutral landing in knee flexion: Hold position for 5 seconds and repeat.	

- Some objective means to measure knee and leg neuromuscular function is to perform the following:
  - Single-leg hop for distance
  - Single-leg vertical jumps for height
  - Shuttle runs
- The patient has successfully met the goals.
- When the patient is found to have neuromuscular function strength and range of motion within 10% of the uninvolved knee, he or she is allowed to return to unrestricted activity, such as jogging.[7]
  - However, if not, the patient must continue with rehabilitation until adequate strength and ROM are achieved.
  - This objective is typically satisfied sometime between the 9th and 12th month of rehabilitation.

Although knee bracing is controversial, it allows for an added level of stability. The eventual goal is to transition the patient out of the knee brace, and get him or her to rely on the knee's own static, dynamic, and muscular strength.

- Because of the complex nature of a multiligamentous knee injury and subsequent surgery, prophylactic knee bracing is continued throughout the formal rehabilitation period.
- Knee bracing becomes optional at the 18th rehabilitation month, and the patient should be encourage to continue bracing if he or she finds it beneficial.[7]

At the point in which the patient is released from rehabilitation and allowed to return to unrestricted activity, the patient has spent approximately 1 year recovering from multiligamentous knee reconstruction.

- It is important to remind the patient that maintaining muscle strength, ROM, flexibility, and proprioception in the operative knee is the best way to prevent reinjury in the future and provide the most satisfying long-term outcome.

Summary

- Multiligamentous knee injuries and subsequent surgery present orthopedic surgeons and physical therapists with a complex problem on how to provide appropriate rehabilitation for the patient.
- Although jogging is defined as running at a slow and leisurely pace, a significant amount of stress is placed across the knee joint.[24,25]
- Before allowing a patient to return to jogging and other activities, a methodical rehabilitation protocol must be followed.
- Appropriate rehabilitation results in a precarious balance between knee stiffness and knee function, while restoring ROM to the knee without compromising the static stability and integrity of the grafted tissues.[7]
- Although recovery can be anticipated to take approximately 1 year, studies support that good patient outcomes and satisfaction can be achieved following the methodical rehabilitation program outlined in this chapter.[7,26-34]

Evidence

Edson CJ, Fanelli GC, Beck JD: Rehabilitation after multiple-ligament reconstruction of the knee. *Sports Med Arthrosc Rev* 19:162–166, 2011.

A review article that outlines the overall rehabilitation protocol following a multiligamentous knee reconstruction. This article outlines the timeline and goals for the patient as they progress through rehabilitation. (Level V evidence)

Fanelli GC, Orcutt DR, Edson CJ: Current concepts: The multiple ligament injured knee. *Arthroscopy* 21:471–486, 2005.

This is a well-written review article over knee dislocations, ligamentous knee injury, and subsequent reconstruction techniques. (Level V evidence)

Li G, Pappannagari R, Meng Li MS, et al: Effect of posterior cruciate ligament deficiency in vivo translation and rotation of the knee during weightbearing flexion. *Am J Sports Med* 36:474–479, 2008.

Eight patients with a PCL injury to one knee and intact PCL in the contralateral knee were evaluated. Using MRI, three-dimensional models of the femur and tibia were created for both knees. Each knee was imaged during quasistatic weightbearing flexion (0° to 105°) using dual-orthogonal fluoroscopic system. Six degrees of freedom kinematics were assessed. Findings supported that PCL injuries not only affect anterior-posterior tibial translation, but also medial-lateral translation and rotation of the knee. PCL reconstruction should restore all planes of stability. (Level III evidence)

Lutz GE, Palmatier RA, An KN: Comparison of tibiofemoral joint forces during open-kinetic-chain and closed-kinetic-chain exercises. *J Bone Joint Surg Am* 75:732–739, 1993.

Five healthy subjects performed open-kinetic-chain extension, open-kinetic-chain flexion, and closed-kinetic-chain exercises at 30°, 60°, and 90°. Data from the electromyographic activity from the quadriceps and hamstrings, as well as load and torque across the knee joint were collected. A two dimensional biomechanical model was used. Open-kinetic-chain extension exercises produced maximum posterior shear forces at 30° flexion, and maximum anterior shear forces at 90° of flexion. Closed-kinetic-chain exercises produced significantly less posterior and anterior shear forces at all angles. (Level I evidence)

Roman PD, Hopson CN, Zenni EJ, Jr: Traumatic dislocation of the knee: A report of 30 cases and literature review. *Orthop Rev* 16:917–924, 1987.

Thirty cases of traumatic knee dislocations are reviewed. Nonoperative versus operative treatment and outcomes are assessed. Nonoperative treatment can result in a functional knee in low-demand patients, but for young active patients, early operative reconstruction, bracing, physical therapy to restore strength, and ROM provided the best outcomes. (Level III evidence)

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Multiple Choice Questions

QUESTION 1. A football player sustains an injury to his right knee during a playoff game. A knee dislocation is identified. Which of the following physical exam findings is the most important to determine?

A. Range of motion of injured knee
B. Ligamentous stability of injured knee
C. Neurovascular status in injured leg
D. Muscular strength of injured leg

QUESTION 2. The operative knee is immobilized in extension during Phase I of rehabilitation. All except which of the following are important reasons to maintain full extension following multiligamentous knee reconstruction?

A. Forces across the PCL are minimized.
B. Causes knee stiffness, which improves postoperative recovery
C. Prevents the development of early flexion contractions
D. Allows for healing of the PCL graft and restoring static stability of the knee

QUESTION 3. Initiation of passive flexion exercises and protected weightbearing with crutches is an important part of recovery. However, being too aggressive with early ROM and ambulation can lead to which complication?

A. Tearing of the grafted tissues
B. Decreased articular cartilage nourishment
C. Falls
D. Patellar tendonitis

QUESTION 4. Closed kinetic chain exercises have been shown to be beneficial during recovery following multiligamentous knee reconstruction because of which of the following reasons?

A. Shear forces across the tibiofemoral joint are decreased by the axial orientation of the applied forces.
B. Tibial translation in relation to the femur is minimized.
C. Potential risk of injuring the surgical graft is decreased.
D. All of the above

QUESTION 5. At the completion of a methodical rehabilitation program following multiligamentous knee reconstruction, the patient can expect to have which functional deficit?

A. Continued quadriceps atrophy and weakness in the operative leg.
B. Permanent 10° to 15° loss of ROM in the operative knee.
C. Instability in the operative knee requiring lifelong bracing.
D. All of the above

Answer Key

QUESTION 1. Correct answer: **C** Documenting the neurovascular status of the injured leg is the most important in the acute setting, because the incidence of neurovascular damage is directly proportional to the energy of injury. (see Introduction)

QUESTION 2. Correct answer: **B** Early ROM of the knee has been found to be detrimental to attaining static stability of the knee. Immobilization in extension minimizes forces across the PCL, prevents flexure contraction, and allows for PCL graft healing with restoration of knee static stability. However, knee stiffness can be a problematic result. The few patients that do develop knee stiffness can undergo a manipulation of the knee under anesthesia or arthroscopic lysis of adhesions once static stability of the knee is reached and maintained. (see Phase I)

QUESTION 3. Correct answer: **A** Being too aggressive with ROM during this phase of recovery can lead to a catastrophic injury or tearing of the grafted tissues. This can ruin the patient's ability to ever return to preinjury status. Although falls are a concern during this phase of recovery, maintaining gentle passive ROM exercises and protected weightbearing not only minimize falls, but also improve articular cartilage nourishment and introduces weightbearing forces across the surgical graft that aid with graft healing and incorporation. (see Phase II)

QUESTION 4. Correct answer: **D** Closed kinetic chain exercises have been shown to decrease the shear forces across the tibiofemoral joint because of the axial orientation of the applied force and muscular co-contraction. This minimized tibial translation and decreases the potential risk of injuring the ligamentous grafts. (see Phase III)

QUESTION 5. Correct answer: **B** It is expected that the patient will have a permanent 10° to 15° loss of terminal flexion in the operative knee when compared with the uninvolved knee. Although leg weakness can be problematic, it is rarely permanent. Leg strength should be quantified and be within 10% of the uninvolved leg before returning to activity. Knee bracing also becomes optional after the 18th rehabilitation month (see Table 33-2).

Chapter 34



Medial Collateral Ligament Injuries

INTRODUCTION

Michael J. Battaglia II, MD

Epidemiology

Age

- 20 to 29

Gender

- 68% men, 32% women

Sport

- In general, virtually any sport, especially those involving contact or pivoting. Football, rugby, soccer, basketball and skiing are specific examples.

Position

- An isolated medial collateral ligament (MCL) injury may occur in virtually any player. There is a greater likelihood for players involved in contact.

Anatomy

- The MCL of the knee originates on the medial femoral condyle and approximately 5 cm distal to the joint line on the tibia. It has an average length of 11 cm and a width of 1.5 cm.
- The medial side of the knee is composed of three layers. The MCL resides in layer 2.[1] It is composed of a superficial and deep band and is the primary stabilizer to the medial knee[2,3] (Figure 34-1). The superficial MCL converges with the posterior oblique ligament, forming the posteromedial joint capsule. This structure has recently been shown to play an important role in stability as well.[4] The deep MCL forms a thickening in the middle portion of the medial joint capsule and has attachments to the medial meniscus. The MCL also has attachments to the semimembranosus muscle via several fibrous bands (Figure 34-2).

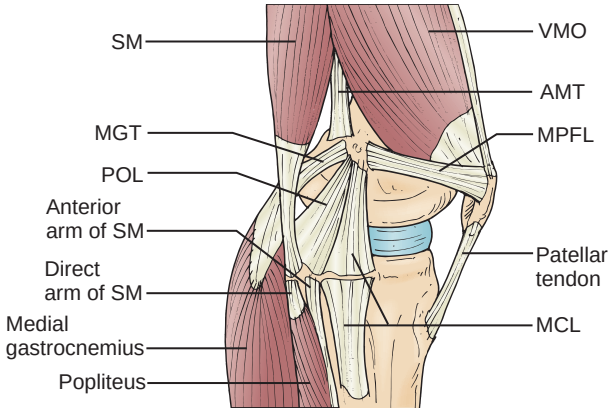

FIGURE 34-1. The superficial medial collateral ligament (medial aspect, left knee).

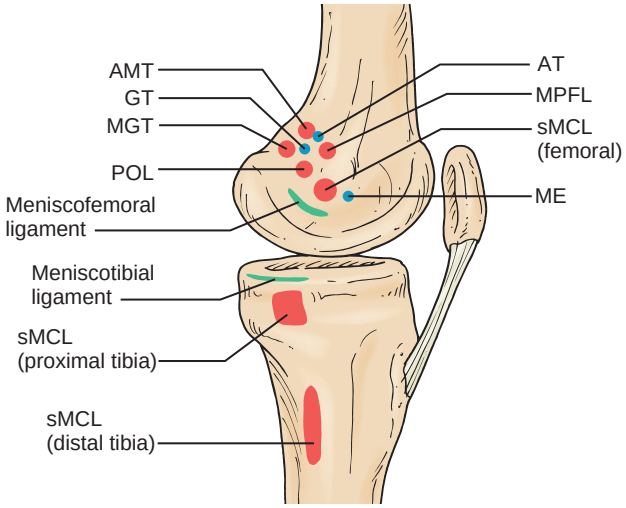

FIGURE 34-2. The medial knee bony attachment sites (medial aspect, left knee). (*AMT, adductor magnus tendon; AT, adductor tubercle; GT, gastrocnemius tubercle; ME, medial epicondyle; MGT, medial gastrocnemius tendon; MPFL, medial patellofemoral ligament; POL, posterior oblique ligament; SM, semimembranosus; VMO, vastus medialis obliquus.*)

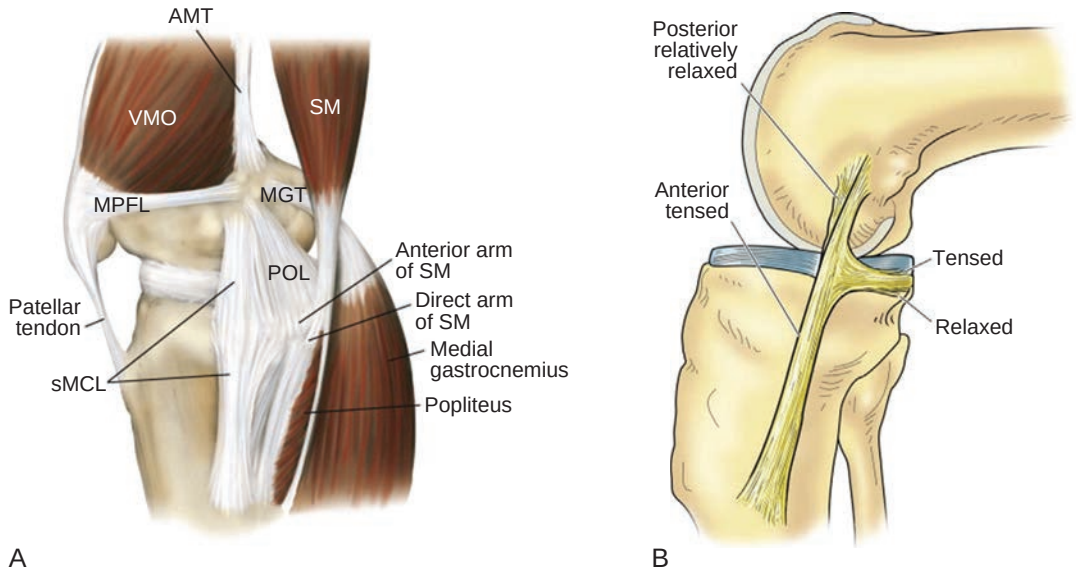

FIGURE 34-3. A, The medial right knee in extension. The entire medial collateral ligament (MCL) complex is on tension; however, the anterior aspect of the superficial MCL is slightly slackened versus the posterior components. AMT, Adductor magnus tendon; MGT, medial gastrocnemius tendon; MPFL, medial patellofemoral ligament; POL, posterior oblique ligament; SM, semimembranosus muscle; sMCL, superficial medial collateral ligament; VMO, vastus medialis obliquus muscle. **B,** The medial knee in flexion. Illustrates the posterior oblique ligament on slack and the anterior superficial MCL on greater tension than the posterior aspect. The darkened region denotes the deep MCL. The posterior oblique fibers become tenser in flexion.

- The MCL functions as a static stabilizer of the medial knee, resisting valgus and external rotation stresses. The superficial MCL is the primary restraint to valgus stress when the knee is positioned in slight flexion (Figure 34-3*A*,*B*).
- Most injuries to the MCL occur with a direct blow to the lateral knee while in slight flexion.
- The severity of MCL injuries is graded on a scale from I to III.
  - In a grade I injury, there is partial tearing of the ligament without laxity.
  - Grade II injuries consist of partial tissue tearing with laxity of up to 5 mm of joint opening.
  - Complete MCL ligament tears are grade III injuries and lead to joint instability with greater than 10° of joint opening.[5]

Pathophysiology

Intrinsic Factors

- Valgus deformity (increased Q angle) (Figure 34-4)
- Hip anteversion
- Previous injury (anterior cruciate ligament [ACL]) deficiency

Extrinsic Factors

- No difference between natural and synthetic surfaces in football
- Ski type/binding type (occurs more frequently with skiing than in snowboarding)

Traumatic Factors

- As the primary restraint to valgus instability, the MCL is most commonly injured by a direct blow to the lateral aspect of the knee with the foot planted (Figure 34-5).
- The MCL also provides significant restraint to external rotation of the tibia. Other mechanisms of injury include forced external rotation of the tibia with the foot planted (Figure 34-6) or forced external rotation with excessive valgus force in the unloaded extremity.

Classic Pathological Findings

- Local pain and edema
- Tenderness to palpation: careful palpation to determine exact site of injury (distal versus proximal MCL)

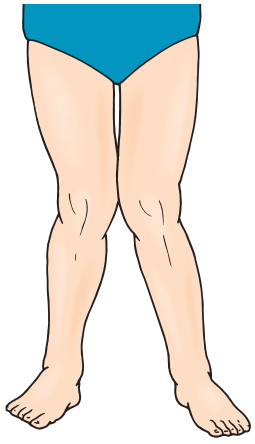

FIGURE 34-4. Valgus deformity.

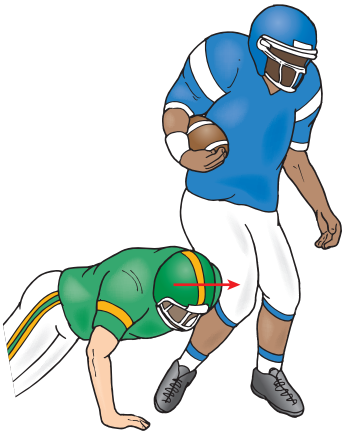

FIGURE 34-5. Lateral blow to the knee with foot planted.

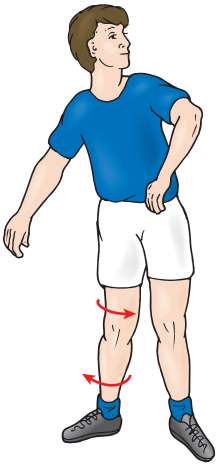

FIGURE 34-6. Forced valgus with external rotation of tibia with foot planted.

- Limited range of motion (ROM)
- Valgus laxity (Figure 34-7)

Clinical Presentation

History

- Blunt force to outside of knee
- Foot stuck, knee/body kept going (lateral or rotatory direction)
- Medial knee pain

Physical Examination

Abnormal Findings

- Positive valgus stress test for pain and/or laxity
- Tenderness to palpation: proximal or distal to medial joint line
- Local edema
- Limited ROM

Pertinent Normal Findings

- No anterior laxity
- ROM is limited by pain, no hard end-feel
- Negative meniscus signs

Imaging

- Radiographs to rule out avulsion fracture
- Magnetic resonance imaging (MRI) scans if suspected injury to other structures. Coronal T1-weighted images may show edema of the lateral femoral condyle. Posterior coronal cuts can be useful to confirm disruption of the MCL fibers.

Differential Diagnosis

- Meniscus: no pain/laxity with valgus stress test; on careful palpation, MCL proximal or distal to joint line, meniscus will be tender over the joint line (Figure 34-8*A, B,* and *C*).
- Combined ACL/MCL injury: knee effusion and anterior laxity with ACL rupture. Valgus laxity in extension may be indicative of concomitant ACL rupture (Figure 34-9*A, B,* and *C*).

Treatment

Nonoperative Management

- Rest, Ice, Compression, Elevation (RICE)
- Nonsteroidal antiinflammatory drugs (NSAIDs)
- Supervised physical therapy (PT) (see nonoperative rehabilitation section for details)
- Bracing: dependent on severity of injury and player demands
- Limited weightbearing: with higher-degree injuries only

Guidelines for Choosing Among Nonoperative Treatments

- Severity of injury: More severe injuries require more involved treatment, such as bracing, limited weightbearing, PT (see nonoperative rehabilitation section).



FIGURE 34-7. Valgus stress test with palpation for joint gapping.

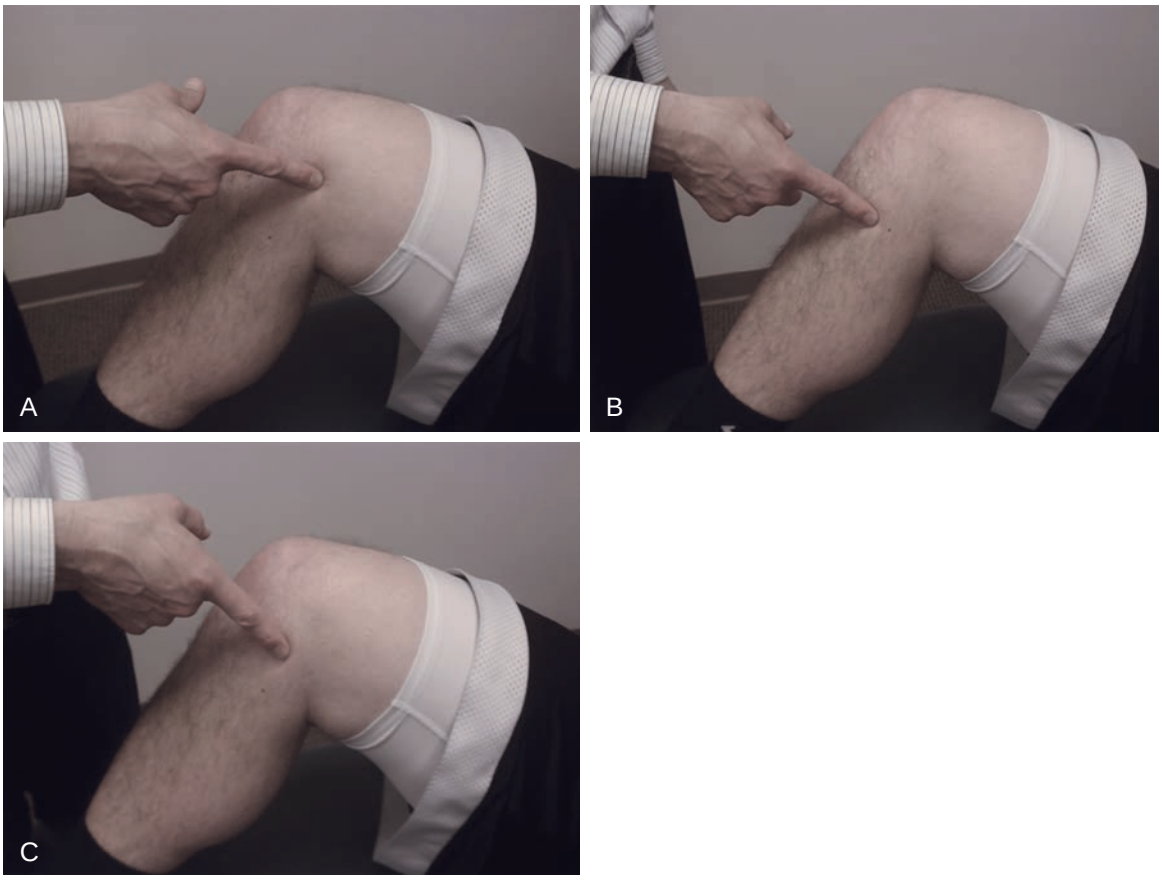

FIGURE 34-8. **A,** Palpation of proximal medial collateral ligament (MCL) insertion. **B,** Palpation of distal MCL insertion. **C,** Palpation of medial joint line.

- Sport demand: use of bracing for play, time until return to play

Surgical Indications

- Surgery is not indicated for most isolated MCL tears. Grades I and II isolated MCL injuries are always treated nonsurgically.
- Surgery is indicated in cases of combined injury, such as ACL/MCL.
- Surgery may be indicated in cases of persistent, significant laxity that prevents full return to sport. Surgery may also be appropriate in cases of persistent pain.

Aspects of History, Demographics, and Examination Findings that Affect Choice of Treatment

- Sport and position: Wide receivers and defensive backs will not return to play as quickly as linemen.
- Level of competition (recreational vs. collegiate/professional): Rehabilitation will likely be more aggressive with higher-level athletes, and return to participation will be quicker
- Severity of injury (grade I vs. III): Higher-grade injuries will require more care, progression to return to sport will be slower.
- Injury to other structures

Aspects of Clinical Decision Making When Surgery Is Indicated

- Complete ACL/MCL combined injury
- Possible as early treatment for complete proximal rupture or bony avulsion (confirmed by MRI)
- Failure of nonoperative treatment

Evidence

Battaglia MJ, 2nd, Lenhoff MW, Ehteshami JR, et al: Medial collateral ligament injuries and subsequent load on the anterior cruciate ligament: a biomechanical evaluation in a cadaveric model. *Am J Sports Med* 37:305–311, 2009.

The results of this cadaveric biomechanical study demonstrate the need for surgical intervention to treat combined MCL/ACL injuries.

Grant JA, Tannenbaum E, Miller BS, et al: Treatment of combined complete tears of the anterior cruciate and medical collateral ligaments. *Arthroscopy* 28:110–122, 2012.

In this systematic review, the authors compared five different treatment approaches for combined ACL/MCL injuries. The results demonstrate improved outcomes with delayed ACL reconstruction, which may allow the MCL to heal. (Level IV evidence)

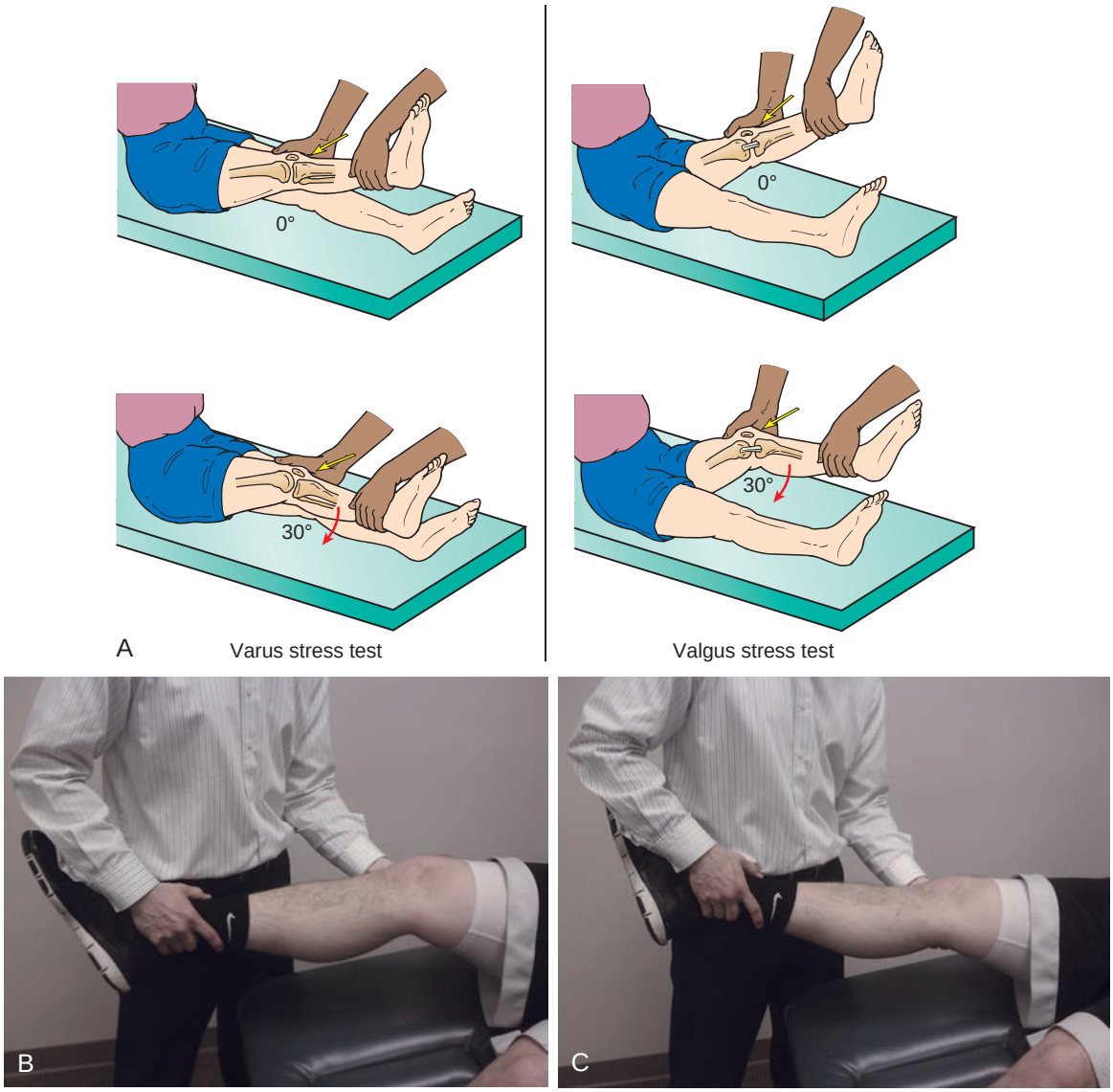

FIGURE 34-9. A, Valgus stress in flexion and extension. Stress in extension tests the medial collateral ligament and the posteromedial capsule. Stress in 30° of flexion tests only the medial collateral ligament. **B,** Valgus stress test in slight flexion. **C,** Valgus stress test in extension.

Hershman EB, Anderson R, Bergfeld JA, et al: An analysis of specific lower extremity injury rates on grass and FieldTurf playing surfaces in National Football League games: 2000–2009 seasons. *Am J Sports Med* 40:2200–2205, 2012.

In this epidemiology study, the authors reviewed game-related injury data during the time period stated and compared injury rates on FieldTurf surfaces versus grass. They found no significant difference when they compared MCL injury rates on grass versus FieldTurf surfaces. (Level II evidence)

Majewski M, Susanne H, Klaus S: Epidemiology of athletic knee injuries: a 10-year study. *Knee* 13:184–188, 2006.

In this epidemiology study, the authors reviewed 19,530 sport injuries over a 10-year period. Among all injuries, 39.8% were related to the knee, and 68.1% of those with knee injuries were men. Those 20 to 29 years of age comprised 43.1% of the sample. MCL sprains accounted for 7.9% of knee injuries. Judo and skiing were the activities that most commonly led to MCL injuries. (Level II evidence)

Marchant MH, Jr, Tibor LM, Sekiya JK, et al: Management of medial-sided knee injuries, part 1: medial collateral ligament. *Am J Sports Med* 39:1102–1113, 2011.

In this comprehensive review, the authors detail the anatomy, biomechanics, and mechanisms of injury; the imaging modalities to use; and nonoperative and operative treatment. (Level V evidence)

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4. Griffith CJ, Wijdicks CA, LaPrade RF, et al: Force measurements on the posterior oblique ligament and superficial medial collateral ligament proximal and distal divisions to applied loads. *Am J Sports Med* 37:140–148, 2009.
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Multiple-Choice Questions

QUESTION 1. Which of the following is not an accurate list of factors that contribute to MCL injuries in the knee?

A. Valgus deformity, direct blow to the lateral knee, hip anteversion
B. Direct blow to the lateral knee, hip anteversion, synthetic playing surface
C. Valgus deformity, forced external rotation of the tibia, direct blow to the lateral knee
D. Previous injury, forced external rotation of the tibia, hip anteversion

QUESTION 2. Which of the following is not an appropriate initial treatment option for isolated MCL injuries of the knee?

A. Rest, Ice, Compression, Elevation (RICE)
B. NSAIDs and bracing
C. Surgical reconstruction
D. PT

QUESTION 3. When is surgery indicated as an initial treatment?

A. When there is a combined ACL/MCL injury
B. In cases of acute, severe pain and edema
C. In highly competitive, skilled athletes
D. None of the above

QUESTION 4. Which of the following are abnormal examination findings following isolated MCL injury of the knee?

A. Limited ROM, positive valgus stress test, anterior laxity, pain with palpation at the medial epicondyle
B. Limited ROM, positive valgus stress test, local edema, pain with palpation at the medial epicondyle
C. Limited ROM, positive valgus stress test, local edema, pain with palpation over the medial joint line
D. Limited ROM, anterior laxity, pain with palpation over the medial epicondyle, medial knee pain

QUESTION 5. Which of the following is the most common mechanism of injury for isolated MCL tears of the knee?

A. Direct blow to the lateral aspect of the knee with the foot planted
B. Forced external rotation of the tibia with the foot planted
C. Forced external rotation of the tibia with valgus force in an open kinetic chain
D. None of the above

Answer Key

QUESTION 1. Correct answer: **B** (see Pathophysiology)

QUESTION 2. Correct answer: **C** (see Treatment)

QUESTION 3. Correct answer: **A** (see Treatment)

QUESTION 4. Correct answer: **B** (see Clinical Presentation)

QUESTION 5. Correct answer: **A** (see Pathophysiology)

NONOPERATIVE REHABILITATION OF MEDIAL COLLATERAL LIGAMENT INJURIES

Robert J. Bradbury, BS, PT, OCS, and Michael J. Battaglia II, MD

GUIDING PRINCIPLES OF NONOPERATIVE REHABILITATION

- Protect healing tissues
- Reduce/control edema
- Regain/maintain mobility and strength
- Maintain endurance
- Safe return to sports activities
- Medial collateral ligament (MCL) injuries of the knee are one of the most common injuries in sports and occur either in noncontact (pivoting) or, commonly, in contact sports caused by a direct blow to the lateral knee that results in valgus stress.
- Surgical reconstruction is almost never required, and therefore both accurate initial diagnosis and grading of the injury are critical prognostic factors in predicting return to play.
- Return to play can be recommended fairly early in grade I or II injuries and with treatment and bracing for up to 8 weeks in grade III tears.[1]
- A coordinated treatment plan developed by the physician and therapist will allow the athlete to have realistic expectations for progress.

Phase I (weeks 0 to 2)

Protection

- Crutches as needed to minimize gait deviations and weightbearing as tolerated
- Bilateral hinged brace, 0° to 30°
  - Grade I injuries typically do not require any bracing, because there is no joint laxity associated with this injury.
  - Grades II and III injuries do involve varying degrees of joint laxity[2] and need to be protected during the initial phases of healing.

Management of Pain and Swelling

- Rest, Ice, Compression, Elevation (RICE)
- Ultrasound: Nonthermal effects of ultrasound are most beneficial for tissue healing, so it is recommended that lower-duty cycles (i.e., pulsed ultrasound) be used for the treatment of acute injuries. (Daniel Lorenz, course notes for "Thermal Agents in Rehabilitation: Evidence-Based Update," 2010)
- Electrical stimulation
  - Transcutaneous electrical nerve stimulation (TENS)
    - TENS provides temporary pain relief
  - Interferential current (IFC)
    - IFC provides pain relief and also has antiinflammatory and edema reduction properties
  - High-voltage pulsed electrical stimulation (HVPS)
    - HVPS promotes soft-tissue healing
  - Neuromuscular electrical stimulation (NMES)
    - NMES may be used for quadriceps facilitation if the athlete has a decreased ability to fully contract the quadriceps musculature.
  - It is recommended that IFC or HVPS be used for treatment during this initial phase of rehabilitation.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Patellofemoral mobilizations

Soft-Tissue Techniques

- Gentle effleurage massage for edema reduction
- Cross-friction massage over healing tissue to promote tissue healing and optimize collagen organization

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Passive/active/active-assisted range of motion (PROM/AAROM/AROM) to tolerance
- Hamstrings
- Quadriceps
- Gluteals
- Hip adductors and abductors
- Gastroc-soleus
- The ability to fully stretch the musculotendinous unit will depend on the available ROM at the knee. As an example, if knee flexion ROM is limited caused by pain or to protect the healing MCL, the quadriceps muscles will not be able to be fully stretched.
- The MCL complex is reinforced by the pes anserine and by direct attachments to the vastus medialis and semimembranosus tendons.[3,4] It can be hypothesized that placing excess tension through these tendons may lead to increased strain on the healing MCL complex.

Other Therapeutic Exercises

- Total body strengthening (TBS)
  - The athlete should continue with the usual exercise regimen as much as possible to maintain conditioning for the specific sport as well as to promote strength in noninjured limbs.
  - Some lower-body training may have to be limited or modified. Trunk strength and core stabilization exercises should continue with planks in the frontal and sagittal planes, abdominal exercises, and spinal extensor strengthening.
- Total arm strengthening (TAS)
  - Upper-body training should continue with minimal restrictions. Care should be taken to protect the injured knee in the gym with careful positioning or use of a brace, using parameters based on grade of injury.
- Total leg strengthening (TLS)
  - Lower-body strengthening will be limited, depending on the severity of the injury.
    - Full lower-body strengthening workouts should be resumed as quickly as possible following grade I injuries.
    - Protective bracing should be used with weight training initially following grades II and III injuries.

TIMELINE 34-1: **Nonoperative Rehabilitation of MCL Injuries (Grade III)**

PHASE I (weeks 0 to 2)	PHASE II (weeks 2 to 4)
• Brace 0° to 30° • Physical therapy (PT) modalities • Effleurage massage for edema if needed • Patellar mobilizations • PROM/AROM/AAROM to tolerance • Lower-extremity flexibility exercises • OKC exercises to tolerance • CKC exercises as tolerated • TBS/TAS/TLS activities as recommended and tolerated	• Brace to 90° by 4 weeks • PT modalities • Deep transverse/cross-friction massage • Patellar mobilizations • Full ROM • Lower-extremity flexibility exercises • OCK exercises • CKC exercises with <90° flexion angles • SLS activities on unstable surfaces and/or with perturbations • Functional/sport-specific activities as tolerated • TBS/TAS/TLS activities as recommended and tolerated • Stationary bike

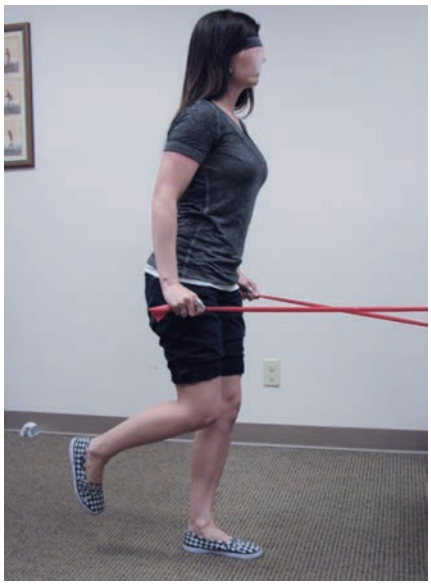

FIGURE 34-10. Single-limb stance with upper extremity perturbation.

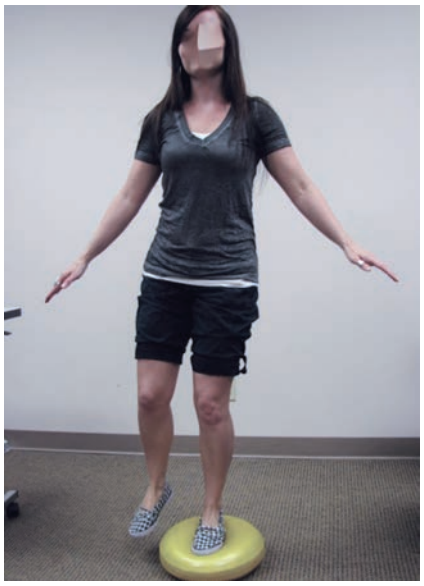

FIGURE 34-11. Single-limb stance on air disc for proprioception training.

As ROM improves and the athlete demonstrates good functional stability with single-limb stance activities on the involved lower-extremity, the brace may be discontinued during workouts.
- Safe closed-chain strengthening exercises of the contralateral limb should be initiated immediately following injury.

Activation of Primary Muscles Involved

- The quadriceps muscles, hamstrings, and gastocnemius directly affect the knee joint.
- Exercises to facilitate and maintain strength of these muscle groups are outlined below under open and closed kinetic chain (OKC/CKC) exercises.
- In addition to maintaining strength of the local musculature, it is imperative to maintain proximal strength and core stability. Weakness at the hip, specifically weakness of the hip extensors and abductors, creates unwanted joint reaction forces at the knee with weightbearing activities. During dynamic activities, weakness in hip abduction causes the knee to fall into a position of excess valgus, potentially placing excessive loads across the MCL.[5]

Sensorimotor Exercises

- Single-limb stance (SLS) activities
  - SLS should initially be performed on a stable surface with the eyes open. Once this is performed with ease, closing the eyes will eliminate visual input and provide greater challenge to the proprioception system.
  - SLS activities can be progressed by creating perturbations during the activity. Initially, these perturbations may be created by having the athlete perform an activity, such as upper movements with resistance or movements of the contralateral leg while standing on the injured leg (Figure 34-10). Perturbations may also be created manually by the therapist.

TIMELINE 34-1: **Nonoperative Rehabilitation of MCL Injuries (Grade III)** (Continued)

PHASE III (weeks 4 to 8)	PHASE IV (weeks 8 to 12)
• Brace for full ROM (per individual case) • PT modalities as needed • Patellar mobilizations • Tibiofemoral mobilizations if needed • OKC exercises without limitations • CKC exercises as tolerated • SLS activities: Increase amplitude and/or frequency of perturbations • Functional/sport-specific/agility activities to tolerance • Plyometrics • TBS/TAS/TLS activities as recommended and tolerated	• Brace for sports activities on an individualized basis • OKC exercises to preinjury level • CKC exercises without restrictions • Plyometric exercise to tolerance • Return to sports participation • TBS/TAS/TLS to preinjury levels

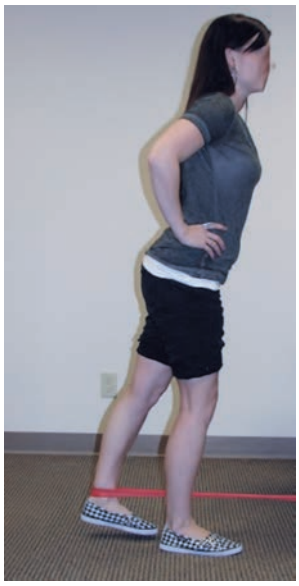

FIGURE 34-12. Closed kinetic chain extension. Involved lower extremity is the stance limb. Movement of the opposite lower extremity creates perturbations for the stance limb.

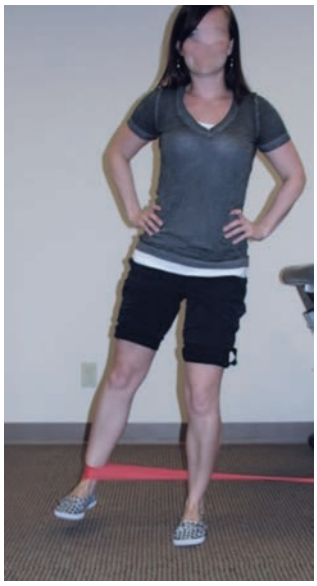

FIGURE 34-14. Closed kinetic chain abduction. Involved limb is the stance limb.

- Once the athlete demonstrates good dynamic control on a stable surface, these activities should be performed on an unstable surface such as Biomechanical Ankle Platform System (BAPS) board, an air disc, or foam mat, or Bosu ball (Figure 34-11).

OKC and CKC Exercises

- OKC
  - Three-way leg raises: Straight-leg raise (SLR), abduction, and extension. No adduction as this will place a valgus stress across the knee.
  - Short arc quadriceps/terminal knee extension (TKE): Full TKE may be restricted initially following grade III injuries.
  - Prone and standing hamstring curls
- CKC
  - Three-way leg raises with tubing/exercise band: abduction, extension, flexion (Figures 34-12 to 34-14)
  - Minisquats (Figure 34-15)
  - Leg press
  - Step-ups/step-downs (Figure 34-16)
  - Lunges (Figure 34-17)
  - Heel raises
  - Lateral steps with exercise band

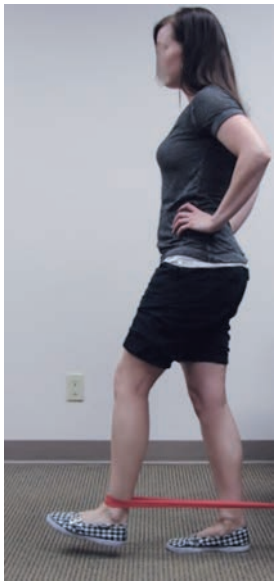

FIGURE 34-13. Closed kinetic chain flexion. Involved limb is weightbearing.



FIGURE 34-15. Forward stepdown.

- Lateral steps with squat (with band)
- Bridges/Swiss ball bridges
- Eccentric hamstrings

Techniques to Increase Muscle Strength, Power, and Endurance

- Strengthening exercises should be performed as noted above during Phase I of MCL rehabilitation.
- Muscular endurance training can be achieved with high repetitions during exercise and use of stationary cycling (when ROM allows) or an elliptical trainer.
- Power training should not be undertaken during Phase I.

Neuromuscular Dynamic Stability Exercises

- See Sensorimotor Exercises above

Functional Exercises

- Single-limb stance progression as outlined above
- Step-up/step-down
- Partial squats
- Lunges (Figure 34-18)

Sport-Specific Exercises

- Functional exercises can be performed or modified as needed to match the athlete's sport-specific needs.

Milestones for Progression to the Next Phase

- Full ROM with minimal to no pain
- Restoration of normal gait pattern

Phase II (weeks 2 to 4)

Protection

- Crutches as needed (wean as able): Use of crutches should be discontinued for injuries of all severities, and gait pattern should normal by 4 weeks postinjury.

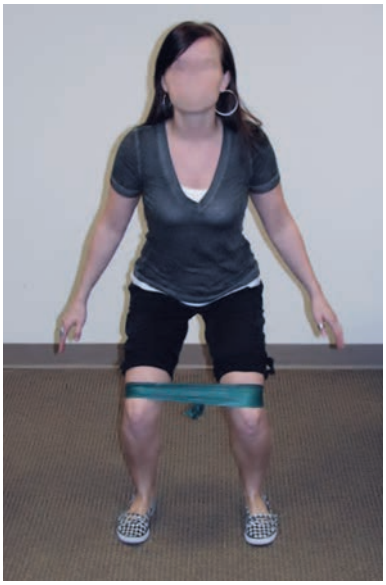

FIGURE 34-16. Minisquat with resisted abduction.



FIGURE 34-17. Lunge with resisted abduction.

TIMELINE 34-2: **Nonoperative Rehabilitation of MCL Injuries (Grade II)**

PHASE I (weeks 0 to 2)	PHASE II (weeks 2 to 4)	PHASE III (weeks 4 to 8)
• Brace 0° to 30° • PT modalities • Effleurage massage for edema if needed • Patellar mobilizations • PROM/AROM/AAROM to tolerance • Lower-extremity flexibility exercises • OKC exercises to tolerance • CKC exercises as tolerated • TBS/TAS/TLS activities as recommended and tolerated	• Brace for full ROM • PT modalities • Cross-friction massage • Patellar mobilizations • Full ROM • Lower-extremity flexibility exercises • OKC exercises • CKC exercises • SLS activities on unstable surfaces and/or with perturbations • Functional/sport-specific activities as tolerated • TBS/TAS/TLS activities as recommended and tolerated • Stationary bike	• Brace for full ROM (per individual case for sports activities) • PT modalities as needed • Tibiofemoral mobilizations if needed • OKC exercises without limitations • CKC exercises to preinjury levels • Return to sports participation • Plyometrics • TBS/TAS/TLS activities as recommended and tolerated

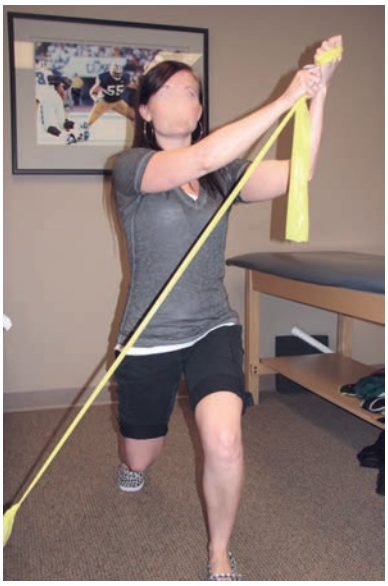

FIGURE 34-18. Lunge with upper-extremity resisted diagonal, perturbations created with upper-extremity movement.

- Bracing may be continued as needed. If continued bracing is required, full ROM should be allowed. Bracing is often an individual choice with MCL injuries, and continued use of a brace depends on the athlete's sport, position, and mobility required. For example, in football, a lineman will likely continue protective bracing, whereas receivers or defensive backs may choose not to wear a brace when returning to sports activity.

Management of Pain and Swelling

- Use of modalities can be continued as needed for pain control and decreased inflammation.

Techniques for Progressive Increase in ROM

Manual Therapy Techniques

- Patellofemoral mobilizations as needed
- Tibiofemoral mobilizations may be used at this stage if there is persistent stiffness in end-range flexion or extension.
- Anterior glides of the tibia on the femur will assist in improving knee-extension ROM.
- Posterior glides will improve flexion ROM in cases of persistent joint stiffness.[6]
- Caution should be used with grade III injuries, as tibiofemoral mobilizations may create unwanted strain to other ligaments, such as the anterior cruciate ligament (ACL), especially if mobilizations are performed in slight flexion.[7]

Soft-Tissue Techniques

- Retrograde effleurage should continue in cases of persistent edema.
- Cross-friction massage should be continued over the injured portion of the ligament to promote ideal collagen construction and repair.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Flexibility exercises for the lower extremity should be performed without limitations, and ROM should be increased to equal that of the contralateral limb.
- In cases of grade III injuries adductor stretching may need to be progressed more slowly, and full ROM may not be achieved until Phase III of rehabilitation. Pain is to be used as a guide.

Other Therapeutic Exercises

- TBS: During Phase II, TBS and core training should return to full level for grades I and II injuries. For those with grade III injuries, TBS should continue to be gradually progressed to the athlete's normal level of training with use of a brace if needed.
- TAS should be performed without restrictions for all grades of injury.
- TLS should be returned to the athlete's normal level of training. Deep squats, lunges, or full-range leg presses should be avoided in cases of grade III injuries.

Activation of Primary Muscles Involved

- Exercises that specifically affect the muscles that perform knee motions should be progressed to normal levels. See Phase I above for specific exercises.

Sensorimotor Exercises

- SLS stance activities should be progressed at this stage, with perturbations increasing in amplitude and/or frequency.
  - As discussed under this topic for Phase I of rehabilitation, perturbations may be created manually by the therapist, by the athlete via movements of other limbs, or with the use of exercise bands, tubing, or resistance cables.

OKC and CKC Exercises

- OKC exercises should continue as outlined under Phase I.
- Adduction SLR may be added for all athletes.
- For athletes with grade III injuries, any weight added for adduction SLR should be placed proximal to the knee.
- Full-ROM quadriceps isotonic exercises may also be initiated at this stage.
- CKC exercises may be performed with larger ROM as pain allows.
- Flexion angles greater than 90° should be avoided in cases of grade III injuries.
- Exercises should be performed without use of protective bracing if the athlete demonstrates normal functional stability and full confidence with CKC activities.

Techniques to Increase Muscle Strength, Power, and Endurance

- Clean
- Snatch

- Push–pull
- Squats
- Initiate running program (grade II and III injuries)
- Strengthening exercises should be progressed to normal levels during this phase of rehabilitation.
- Resistance and speed of movement should be increased to tolerance.
- To maintain and/or improve muscular endurance, aerobic-type exercises can be progressed by increasing resistance, velocity, and/or duration.

Neuromuscular Dynamic Stability Exercises

- See Sensorimotor Exercises

Plyometrics

- Bilateral hopping on level surface
  - During plyometric and jumping activities, close attention must be paid to landing mechanics to ensure proper lower-extremity alignment to avoid excessive valgus forces through the knee. Sufficient hip and core strength is required to maintain proper positioning during eccentric landing. Foot and ankle mechanics must also be assessed for excessive pronation with landing, as this mechanical fault may lead to excessive valgus stress at the knee.[5]

Functional Exercises

- Functional exercises should be continued as listed under Phase I and progressed as the athlete tolerates. These exercises should become more sport-specific as tolerance improves.
- Athletes with grade II injuries are likely ready or close to ready to return to full sports activity toward the end of Phase II, so the program will consist mostly of sport-specific exercises.
- For athletes with more severe injuries, lower-level, uniplanar functional exercises may have to be continued for a longer period of time.

Sport-Specific Exercises

- See Sensorimotor Exercises and Functional Exercise sections above.

Milestones for Progression to the Next Phase

- Full ROM without pain
- No increase in swelling with light activity
- No functional instability

Phase III (weeks 4 to 8)

Protection

- Crutches should no longer be used.
- Bracing may be continued based on individual preferences.

Management of Pain and Swelling

- Ice and IFC electrical stimulation may be continued in cases of persistent edema.
- All other modalities should be discontinued during this phase of recovery.

Techniques for Progressive Increase in ROM

Manual Therapy Techniques

- Tibiofemoral mobilizations
  - Anterior or posterior glides may be used at end ranges of physiologic ROM if there is any joint stiffness.
  - Rotational mobilizations may be required to restore concomitant external rotation at TKE or internal rotation with end-range flexion.[6]

Soft-Tissue Techniques

- Cross-friction massage may be continued over the healing ligament and should be performed directly over the site of the tear.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Lower-extremity stretching should continue without restrictions and at this point should be at preinjury levels.
- Proprioceptive neuromuscular facilitation (PNF) may be used for dynamic stretching. PNF is also facilitatory and will improve neuromuscular responses to dynamic loads across the lower extremity. Hip and knee patterns are most effective in cases of injuries to the knee.
- Dynamic stretching or warmup should be performed prior to sport activities. The Sportmetrics warm-up for injury prevention and performance program and Santa Monica sports medicine research foundation prevent injury, enhance performance are good examples of a thorough dynamic stretching routine for the lower extremities.

Other Therapeutic Exercises

- At this stage of recovery, exercise regimens should be at preinjury levels for athletes with any severity level of isolated MCL injury.
- TBS, TAS, and TLS exercises can be performed without restrictions; however, athletes with more severe injuries may wish to continue to wear a brace when performing dynamic multiplanar activities.

Activation of Primary Muscles Involved

- Training of local musculature is now unrestricted, and all exercises should be performed to the athlete's tolerance and at full speed if not already done.

Sensorimotor Exercises

- Sensorimotor exercises should be performed to tolerance with use of protective bracing if needed.

OKC and CKC Exercises

- Exercise regimens should return to preinjury levels during this phase of rehabilitation.

Techniques to Increase Muscle Strength, Power, and Endurance

- As stated under the previous topic, at this point following injury, there are no restrictions on exercise.

Neuromuscular Dynamic Stability Exercises

- Dynamic stability exercises should continue to be progressed to meet the athlete's sport-specific demands.

Plyometrics

- Box jumps
- Zig-zag hops
- Squat jumps
- Split jumps
- Plyometric exercises can be progressed as the athlete tolerates. Jumping activities may also be progressed to unilateral take-offs and landings with the involved lower extremity.

Functional Exercises

- Running and agility training should continue to be progressed.
- Agility drills should be specific to the athlete's sport.
- Some athletes with grade III injuries will return to live practice activities at this stage, and most athletes with grade II MCL tears will already have returned to sports participation.

Sport-Specific Exercises

- See above.

Milestones for Progression to the Next Phase

- Successful completion of a running program
- 90% of normal strength in isokinetic testing or passing grade on functional testing

Phase IV (weeks 8 to 12)

Protection

- Protective bracing is no longer required; however, some athletes will continue to use a hinged knee brace.
- In cases where external support is needed but use of a bulky brace is not practical, tape may be applied to provide support to the medial knee. The reader is referred to athletic training textbooks and taping manuals for further information on taping techniques.

Management of Pain and Swelling

- Ice can continue to be applied after exercise as needed.
- IFC electrical stimulation may be used in cases of edema following activity.

Techniques for Progressive Increase in ROM

Manual Therapy and Soft-Tissue Techniques

- Manual therapy and soft-tissue techniques are no longer required and should be discontinued.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- The athlete is now able to perform their normal stretching routine and may do so independently or with a trainer.

Other Therapeutic Exercises

- There are no restrictions to exercise.
- Exercise programs should return to preinjury levels, and the athlete may fully participate in team's regular training routine.
- The athlete should return to full sports participation during this stage of rehabilitation.

Criteria for Abandoning Nonoperative Treatment and Proceeding to Surgery or More Intensive Intervention

- Surgical treatment is not indicated in cases of isolated grade I or II MCL injuries.
- It has been demonstrated that joint laxity may persist following tissue healing in grade III injuries. Despite persistent joint laxity, functional outcomes are similar with operative vs. conservative care. The authors choose to treat all isolated grade III injuries nonoperatively; however, surgical repair may be required in cases of chronic instability or persistent pain.
- Surgery is required in cases of combined injuries. Treatment of combined injuries is beyond the scope of this chapter and thus is not discussed here.

Milestones and Criteria-Based Rehabilitation Guidelines to Progress to Sport-Specific Training and Conditioning

- As discussed under Phase III, the athlete must successfully complete a running program without increased pain, swelling, or sense of instability.

- Isokinetic strength testing
  - In order for the athlete to return to participation in his or her sport, they either must be at 90% of normal or of the contralateral limb or they must achieve a passing score with functional testing
- Return to sport participation should be graded and incremental. After demonstrating readiness to progress to sports activity, the athlete should participate in practice drills. If participation in basic practice drills is successful, the athlete may participate in team scrimmage activities. If there is no adverse reaction with participation in scrimmage, the athlete may return to full competition.

Tips and Guidelines for Transitioning to Performance Enhancement

- Progression to performance enhancement should occur during Phase III or IV of rehabilitation. At this stage of recovery, physiologic tissue repair is stable, ROM should be full, and strength should be normal. Therapy sessions may continue less frequently, as needed, to monitor the athlete's status and progress.

Performance Enhancement and Beyond Rehabilitation: Training/Trainer and Optimization of Athletic Performance

- Performance enhancement can be achieved by progressing agility activities, such as T-runs, side-step drills, or agility ladder exercises. Performance enhancement activities should be specific to the athlete's sport-specific demands. Speed, agility, and power training should be employed and tailored to match the athlete's needs.

Specific Criteria for Return to Sports Participation: Tests and Measurements

- Normal strength (isokinetic)
- Completion of running and/or agility program
- Passing score on functional testing

Evidence

Battaglia MJ, 2nd, Lenhoff MW, Ehteshami JR, et al: Medial collateral ligament injuries and subsequent load on the anterior cruciate ligament: a biomechanical evaluation in a cadaveric model. *Am J Sports Med* 37:305–311, 2009.

This biomechanical evaluation provides information on excess strain to other knee ligaments in the presence of combined injuries. This information can be used by clinicians to minimize possible iatrogenic injuries during rehabilitation.

Hengeveld E, Banks K, editors: *Maitland's peripheral manipulation*, ed 4, New York, Elsevier, 2005, Elsevier.

This textbook provides rationale and technique instruction for passive mobilization of peripheral joints.

Mandelbaum B, Silvers HJ, Watanabe DS, et al: Effectiveness of a neuromuscular and proprioceptive training program in preventing anterior cruciate ligament injuries in female athletes: 2-year follow-up. *Am J Sports Med* 33:1003–1010, 2005.

In this nonrandomized prospective study, the authors compared injury rates among teenage girl soccer players participating in traditional warmups versus sport-specific training. Athletes participating in sport-specific training had a significantly lower incidence rate of ACL injuries.

Marchant MH, Jr, Tibor LM, Sekiya JK, et al: Management of medial-sided knee injuries, part 1: medial collateral ligament. *Am J Sports Med* 39:1102–1113, 2011.

This article is focused on the anatomy and biomechanics of the medial knee structures and includes a review of nonoperative and operative treatments.

Phisitkul P, James SL, Wolf BR, et al: MCL injuries of the knee: current concepts review. *Iowa Orthop J* 26:77–90, 2006.

This article reviews the anatomy and biomechanics of the MCL and the classification systems for MCL injuries.

Powers CM: The influence of abnormal hip mechanics on knee injury: a biomechanical perspective. *J Orthop Sports Phys Ther* 40:42–51, 2010.

This clinical commentary and review provides evidence for incorporating proximal hip and trunk strengthening in rehabilitation of various knee injuries, including medial soft-tissue restraints. (Level V evidence)

Reider B, Sathy MR, Talkington J, et al: Treatment of isolated medial collateral ligament injuries in athletes with early functional rehabilitation: a five-year follow-up study. *Am J Sports Med* 22:470–477, 1994.

This prospective study demonstrated that early functional rehabilitation (EFR) is safe and effective compared to immobilization or operative treatment and that athletes participating in EFR returned to sports activities earlier than those treated with casting or surgical repair. This was the first article to provide long-term follow-up after isolated MCL injury.

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Multiple-Choice Questions

QUESTION 1. Which of the following is the most effective type of electrical stimulation to control pain and edema following an acute MCL injury?

A. Neuromuscular electrical stimulation (NMES)
B. Interferential current (IFC)
C. High-voltage pulsed electrical stimulation (HVPS)
D. B and C

QUESTION 2. Which of the following is not an appropriate OKC exercise to perform during Phase I of rehabilitation following an acute MCL injury?

A. Straight-leg raise
B. Hip adduction
C. Short-arc knee extensions
D. Prone hamstring curls

QUESTION 3. Single-limb stance activities may be performed with perturbations created by the athlete or therapist. These activities can be progressed by increasing which of the following?

A. Amplitude and/or frequency
B. Amplitude only
C. Frequency only
D. None of the above

QUESTION 4. An athlete must meet which of the following milestones to return to sport following an isolated MCL injury of the knee?

A. Normal strength, completion of a running program, passing score on a functional testing protocol
B. Full ROM, normal strength, able to run without pain
C. Normal gait pattern, passing score with functional testing, no joint laxity
D. No functional instability, normal strength, completion of a running program

QUESTION 5. MCL injuries are treated nonoperatively in most cases, but surgical intervention may be required for which of the following reasons?

A. Persistent pain
B. Chronic instability
C. Combined injuries
D. All of the above

Answer Key

QUESTION 1. Correct answer: **D** (see Phase I: Treatment for Pain and/or Swelling)

QUESTION 2. Correct answer: **B** (see Phase I: OKC and CKC exercises)

QUESTION 3. Correct answer: **A** (see Phase II: Sensorimotor Exercises)

QUESTION 4. Correct answer: **A** (see Phase IV)

QUESTION 5. Correct answer: **D** (see Criteria for Abandoning Rehabilitation)

POSTOPERATIVE REHABILITATION AFTER REPAIR OR RECONSTRUCTION OF THE MEDIAL COLLATERAL LIGAMENT

Timothy S. Mologne, MD, and Molly Van Zeeland, DPT

Indications for Surgical Treatment

- Acute repair
  - Intraarticular entrapment of one of the ends of the ligament
  - Displaced bony avulsion of the medial collateral ligament (MCL)
  - Complete MCL tear in patients with valgus alignment
  - Associated tibial plateau fracture
  - Anteromedial rotatory instability
  - Complete tibial side avulsion in cutting sport athletes
  - In conjunction with anterior or posterior cruciate ligament (ACL or PCL, respectively) reconstruction when there is valgus laxity in full extension
- MCL reconstruction
  - Symptomatic chronic valgus instability

Brief Summary of Surgical Treatment

Major Surgical Steps

- Acute repair
  - Location of the tear and assessment of tissue quality and damage are assessed by examining a preoperative magnetic resonance imaging scan
  - Supine position
  - Tourniquet on proximal thigh
  - Arthroscopy is performed to assess for intraarticular pathology and to assess the deep MCL and the meniscocapsular junction.
  - Incision from the medial proximal tibia to the medial epicondyle
  - For isolated proximal or distal repairs, a more limited incision can be utilized.
  - The sartorial fascia is incised to expose the torn ligamentous tissue. Distally, the ligament is deep to the pes anserine tendons.
  - All torn tissue is repaired, including peripheral meniscus tears, posterior oblique ligament tears, meniscofemoral ligament tears, and meniscotibial ligament tears. Suture anchors are utilized in some cases.
  - Tibial avulsion injuries are repaired to the tibia using suture anchors or screws with soft-tissue washers (Figure 34-19*A,B*).
  - Femoral avulsion injuries are repaired anatomically using suture anchors or screws and soft-tissue washers (Figure 34-19*C*).
- For patients with chronic valgus laxity or those found to have inadequate tissue to repair primarily, an augmentation or reconstruction is performed (Figure 34-19D).
  - Standing hip-to-ankle alignment x-rays should be obtained to assess for valgus alignment. If present, a varus-producing distal femoral osteotomy should be performed before MCL reconstruction.
  - Reconstruction can be performed with autograft or allograft tissue. The authors' preference is the ipsilateral semitendinosis tendon.

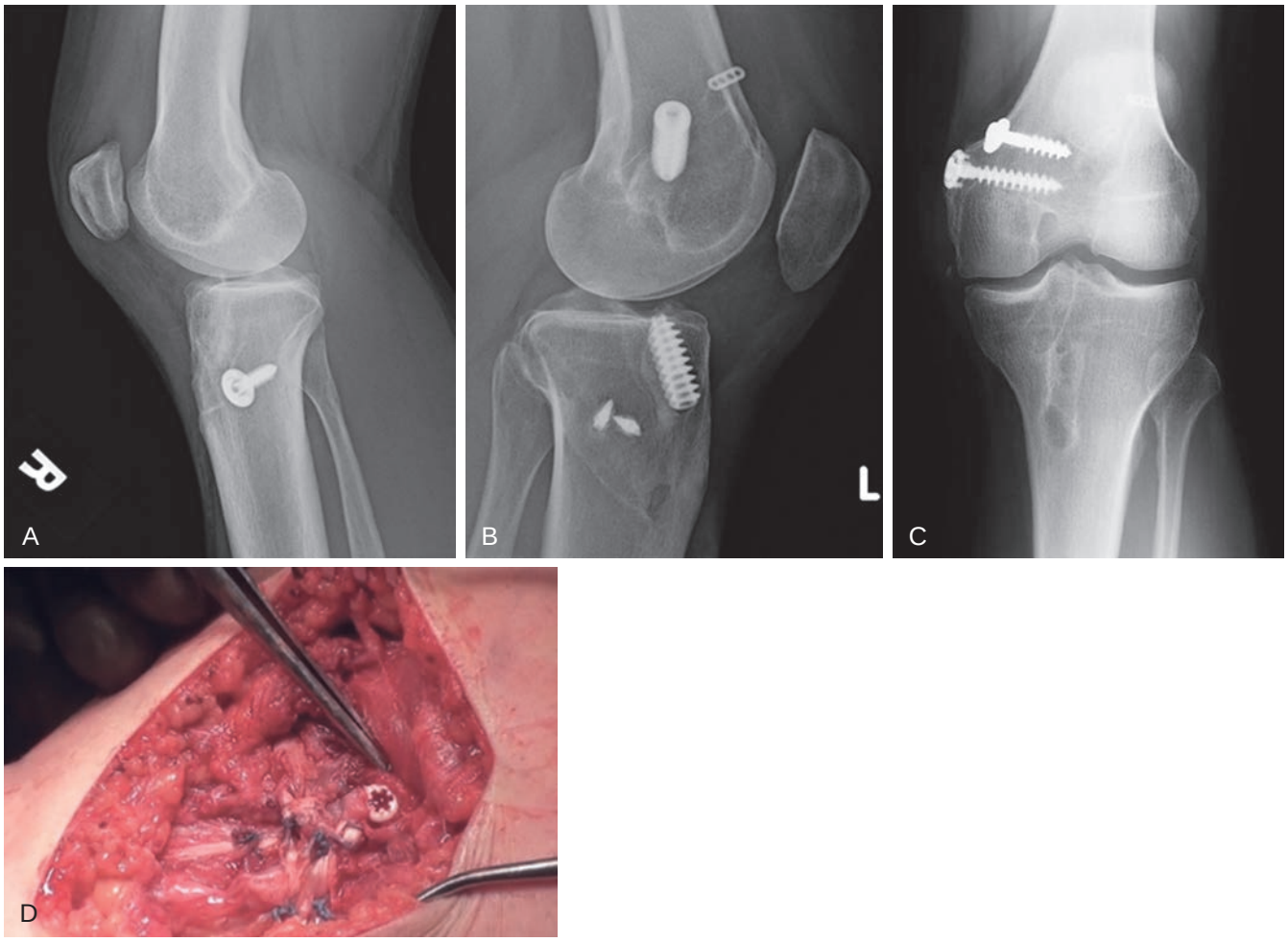

FIGURE 34-19. A, Distal MCL repair using a screw and washer in a patient who also underwent an ACL reconstruction. **B,** Repair of a distal MCL detachment using suture anchors in a patient following a knee dislocation. Other metallic implants are fixations for ACL and PCL reconstruction. **C,** Repair of a proximal MCL detachment using a screw and spiked washer. This patient also underwent reconstruction of the ACL and PCL. **D,** MCL reconstruction using an autogenous semitendinosis tendon graft. (*Solid black arrow:* Interference screw holding the tendon graft in a tunnel in the medial epicondyle. *Dashed black arrow:* Anterior limb of the graft reconstructing the superficial MCL. *White arrow:* Posterior limb of the graft reconstructing the posterior oblique ligament.)

- An open-looped tendon stripper is used to harvest the semitendinosus tendon, leaving the distal insertion/attachment intact.
- A pin is drilled into the medial epicondyle at the MCL origin, and ligament isometry is assessed by taking the knee through a range of motion (ROM). The pin is moved until isometric testing reveals less than 2 mm of excursion.
- A 7- to 8-mm socket is drilled to a depth of 30 mm at the isometric spot.
- The semitendinosis tendon is looped onto itself and sutured together for 30 mm.
- The loop is pulled into the femoral socket by passing a Beath pin across the knee and using a traction suture to pull and tension the semitendinosis tendon.
- The knee is placed at 30° of flexion, and varus stress is applied.
- The graft is fixated in the femoral tunnel using an absorbable interference screw.
- The free limb of the graft is then tensioned distally and posteriorly.
- If enough length is present, the free limb can be fixated to the posterior and proximal tibial using a screw with a soft tissue washer. If not, it is sutured to the semimembranosis.

Before Surgery: Overview of Goals, Milestones, and Guidelines[1]

GUIDING PRINCIPLES OF POSTOPERATIVE REHABILITATION

- The same protocol is used for MCL repair and MCL reconstruction.
- Repair of femoral avulsions of the MCL are associated with stiffness and loss of motion due to capsular adhesions. Aggressive motion exercises and overpressure can help prevent this problem.
- Understand the anatomic structures repaired and which positions and activities stress the healing structures.
- Isolated MCL repair or reconstruction is rare; the evidence suggests that surgical intervention provides no benefits over conservative management in most cases. MCL repair is often performed in patients with multiple ligament involvement, and, as a result, rehabilitation is usually slower than the timeline presented. Clinicians must pay particular attention to the milestones during each stage of rehabilitation and be careful not to progress patients too early.
- Studies have shown that epiphyseal injuries are frequently associated with ligamentous injuries in children. Clinicians must carefully monitor these individuals for development of genu valgus deformities after MCL injuries.[1]

[1]*Prehabilitation, if appropriate, is described in the Nonoperative Rehabilitation section of this chapter.*

Phase I (days 0 to 14): Immediate Postoperative Period

Clinical Pearls

- It is important to avoid aggressive ROM exercises for the first 3 weeks postoperatively to avoid placing tension on the repaired ligament or graft.
- Research has shown that knee stiffness after medial repair/reconstruction is one of the most common complications; therefore, initiation of ROM exercises between 30° and 90° is necessary and should be strongly encouraged as part of a home exercise program (HEP) to avoid capsular adhesion formation.[2,3]
- It is imperative to control swelling during the first two phases of rehabilitation, as research has proven that swelling causes notable quadriceps inhibition and reduces quadriceps electromyographic activity with as little as 10 ml of fluid.[4]

Goals

- Decrease pain and inflammation
- Protect the repaired structures
- Avoid scar hypertrophy
- Avoid knee capsular adhesion formation
- Prevent quadriceps atrophy

Protection

- Hinged knee ROM brace with thigh and leg extensions limited to 30° to 90° knee flexion for the first 3 weeks.[2,5] Brace must be used at all times, including during HEP and at night.
- Non–weightbearing (NWB) using an assistive device (most often crutches) must be utilized for ambulation for the first 3 weeks postoperatively.[2,5]

Management of Pain and Swelling

- Cryotherapy for 20 to 30 minutes every hour during the first week[4]
- Interferential current (IFC) or transcutaneous electrical nerve stimulation (TENS) for pain
- Oral pain medications
- Leg elevation
- Compression
- High-voltage galvanic stimulation

Techniques for Progressive Increase in ROM

Manual Therapy Techniques

- ROM limited to 30° to 90° knee flexion for 3 weeks.
- ROM exercises may include passive ROM, active assisted ROM, and active ROM (PROM/AAROM/

AROM as tolerated and should be performed frequently to facilitate scar remodeling and to prevent adhesion formation.
- Patellar mobilization all directions to prevent adhesion formation and hypomobility
- Cephalic glides to promote knee extension and caudal glides to promote knee flexion

Soft-Tissue Techniques

- Cross-friction massage to MCL insertions to break up scar tissue/adhesions if limiting motion or flexibility
- Soft-tissue mobilization of quadriceps and hamstring musculature
- Scar mobilization when incision is healed

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Quadriceps and hamstring stretching per ROM guidelines
- Initiate early ankle ROM exercises and gastrocnemius/soleus stretching using a belt or towel.
- Static stretching should be held for 30 seconds for younger patients and 60 seconds for patients older than 60.

Other Therapeutic Exercises

- Ankle pumps every hour
- Hamstrings and quadriceps isometric contractions at 30°, 50°, 70°, and 90°
- Cocontractions of quadriceps and hamstrings
- Hamstring and quadriceps isotonics per ROM guidelines without resistance
- Hip three-way straight leg raise (SLR) (avoid adduction to avoid valgus stress at the knee)
- Core stability training
- Upper-body exercises (UBEs) are permitted, provided that they comply with weightbearing (WB) status and ROM guidelines.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- It is important to begin isometric quadriceps strengthening on postoperative day 1 to minimize muscle atrophy.
- Neuromuscular electrical stimulation (NMES) may also be used to facilitate or assist with quadriceps activation and minimize muscle inhibition due to effusion for up to 8 h/day.[4]

Neuromuscular Dynamic Stability Exercises

- Begin with isometric quadriceps postoperative day one.
- Progress to SLR with brace once neuromuscular control is obtained.
- NMES may be used to facilitate or assist with quadriceps muscle activation.
- Biofeedback may also be useful during this phase.

Milestones for Progression to the Next Phase

- Good quadriceps set
- ROM 30° to 90°
- Controlled knee pain and swelling

Phase II (weeks 2 to 4 postoperatively)

Clinical Pearls

- It is essential to avoid hyperextension during this phase to minimize tension on the repair/graft.
- It is critical that the patient avoid externally rotating the hip on the surgical side in an attempt to unload the limb. This rotation creates a valgus moment at the knee and puts tension on the graft/repair.[3]
- Research has shown that knee proprioception and kinesthesia are disrupted after injury and that mechanoreceptors within collateral ligaments and the joint capsule are often damaged, which will slow the individual's response to perturbations.[6] Balance and proprioception exercises should be started shortly after the patient begins full weight bearing (FWB).

Goals

- Achieve 0° to 90° knee ROM
- Normal gait mechanics with weightbearing as tolerated (WBAT) and use of crutches
- SLR with no extensor lag

Protection

- Hinged brace with 0° extension stop to avoid hyperextension
  - Brace should be locked at 0° extension for ambulation and sleeping until the patient has good quadriceps control. Brace should be worn at all times for 8 weeks postoperatively.
- Week 3: The patient may begin WBAT with the use of crutches and hinged brace with 0° extension stop once full knee extension has been achieved and there is no evidence of quadriceps lag.[2,5,6]

Management of Pain and Swelling

- Cryotherapy
- IFC
- TENS

Techniques for Progressive Increase in ROM

Manual Therapy Techniques

- Continue PROM/AAROM/AROM exercises: Extension exercises may include towel extension or prone hangs in hinged brace with 0° extension stop.

- Flexion exercises may include wall slides, heel slides, and seated AAROM.
- Patellar mobilizations to increase ROM as needed
- Grades I and II tibiofemoral joint mobilizations as needed

Soft-Tissue Techniques

- Cross-friction massage to MCL insertions to break up scar tissue/adhesions if limiting motion or flexibility is present.
- Soft-tissue mobilization of quadriceps and hamstring musculature
- Scar mobilization when incision is healed

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Ankle ROM and gastrocnemius/soleus stretching is encouraged and can be done as part of the HEP.
- Continue quadriceps and hamstring stretching per ROM.

Other Therapeutic Exercises

- Hamstring isotonics per ROM
- Quadriceps isotonics per ROM
- Short-arc quadriceps with bolster
- Progressive hip three-way SLR (avoid adduction); progress 1 to 2 lb/wk
- Controlled upper-body strengthening
- Core stability exercises (e.g., hooklying transverse abdominus recruitment exercises, double-leg bridging)

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Focus should be on regaining full quadriceps control so progression to FWB status can be done safely.

Sensorimotor Exercises

- Controlled weightshifting
- Single-leg balance

Open and Closed Kinetic Chain Exercises

- Closed kinetic chain (CKC)
  - Leg press/total gym: 0° to 45° ROM to protect the patellofemoral joint (begin exercise at no more than one-fourth body weight and slowly progress the patient as tolerated.)
  - Double-leg bridges
- Open kinetic chain (OKC)
  - Short-arc quadriceps with bolster: Progress 1 to 2 lb/wk
  - Three-way SLRs: Progress 1 to 2 lb/wk
  - Clam exercise with Thera-Band

Techniques to Increase Muscle Strength, Power, and Endurance

- Upper-body strengthening permitted in controlled environment and may include UBEs, machine weights, and free weights

Neuromuscular Dynamic Stability Exercises

- Manual rhythmic stabilization of trunk and core

Functional Exercises

- Continue gait training with crutches to normalize gait pattern with gradual progression to FWB.

Milestones for Progression to the Next Phase

- Knee ROM 0° to 90°
- Controlled knee pain/effusion

TIMELINE 34-3: **Postoperative Rehabilitation After Isolated MCL Repair or Reconstruction**

PHASE I (weeks 0 to 2)	PHASE II (weeks 2 to 4)
• Hinged brace with leg and thigh extensions limited to 30°–90° knee flexion • Physical therapy (PT) modalities (NMES for quadriceps, TENS, cryotherapy) • NWB for first 3 wk • Ambulate with bilateral crutches • PROM/AAROM/AROM exercises 5 to 8 times/day • TBS/TAS/TLS activities as recommended and tolerated • Three-way SLR: Avoid adduction • Isometric quadriceps/hamstrings postoperative day 1	• Hinged brace: 0° extension lock and open flexion • WBAT at 3 wk if full knee extension achieved • Single-leg balance/proprioception training • Wk 5: D/C crutches when good quadriceps control and normal gait achieved • ROM wk 3: 0°–90° • ROM wk 4: 0°–110° • ROM wk 6: 0°–120° • TBS/TAS/TLS activities as recommended and tolerated • Wk 5: Standing three-way SLR (avoid adduction) • Wk 5: Bike without resistance for ROM • CKC exercises as recommended

- Ambulation with normal gait pattern using bilateral crutches and FWB
- No quadriceps lag with SLR

Phase III (weeks 4 to 8 postoperatively)

Clinical Pearls

- Research has shown that individuals have a tendency to unload their surgically treated extremity for up to 6 months after knee surgery; therefore, progression from double-leg exercises to single-leg exercises should be begun as soon as possible during this phase.
- It is important that all exercises be performed with careful monitoring of good lower-extremity (LE) control and knee alignment.
- Patients should continue to avoid resisted hip adduction exercises and external rotation of the tibia to avoid stress on the repair/graft.
- Recurrent pain and swelling are signs of too-rapid progression during this phase.

Goals

- Full knee ROM
- Ambulate with normal gait pattern without crutches
- Good quadriceps control

Protection

- Hinged brace with 0° extension stop to avoid hyperextension (should be worn at all times for 8 weeks postoperatively)
- Week 4: Begin ambulation with FWB and hinged brace with 0° extension stop and bilateral crutches.
- Week 5: Discharge Crutches when patient has good quadriceps control and is able to ambulate with normal gait mechanics

Management of Pain and Swelling

- Cryotherapy
- IFC
- TENS

Techniques for Progressive Increase in ROM

Manual Therapy Techniques

- Continue ROM exercises as recommended above
- Week 5: Begin bicycle exercise for ROM with no resistance (brace can be removed at this point)
- Patellar mobilizations as needed
- Grades II and III tibiofemoral joint mobilizations as needed

Soft-Tissue Techniques

- Cross-friction massage to MCL insertions to break up scar tissue/adhesions if limiting motion or flexibility
- Soft-tissue mobilization of quadriceps and hamstring musculature
- Scar mobilization when incision is healed

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Ankle ROM and gastrocnemius/soleus stretching is encouraged and can be done as part of the HEP.
- Quadriceps and hamstring stretching

TIMELINE 34-3: **Postoperative Rehabilitation After Isolated MCL Repair or Reconstruction** (Continued)

PHASE III (weeks 4 to 8)	PHASE IV (weeks 8 to 12)	PHASE V (weeks 12 to 24)
• DC hinged brace for activities of daily living at 8 wk • Functional Hinged Brace for HEP/return to sport for 12–18 mo postoperatively • PT modalities as needed • Full knee ROM at wk 8 • ROM exercises and flexibility exercises: Quadriceps, hamstrings, calves, gluteals • TBS/TAS/TLS activities as recommended and tolerated • Single-leg balance/proprioception training with perturbations • CKC concentric and eccentric hamstring and quadriceps PREs at 6 wk • Wk 7: Four-way standing SLR with Thera-Band • Brisk walking/elliptical/bicycle with resistance/StairMaster at 7 wk • Controlled lateral movements at 8 wk • OKC quadriceps strengthening 8 wk • Return to jogging/running progression at 10 wk	• Functional hinged brace for HEP/return to sport for 12–18 mo postoperatively • Flexibility exercises • Plyometrics on leg press at 10 wk • Body weight plyometrics at 12 wk • Sport-specific activities at 12 wk • TBS/TAS/TLS activities as recommended and tolerated • Eccentric quadriceps and hamstring strengthening • Isokinetic quadriceps and hamstring strengthening • Hip abductor/adductor PREs • Quadriceps/hamstring PREs • OKC exercises • CKC exercises	• Functional hinged brace for HEP/return to sport for 12–18 mo postoperatively • Flexibility exercises • Total body strengthening, total arm strengthening, and total leg strengthening (TBS/TAS/TLS) activities as recommended and tolerated • Speed/agility/plyometric training • Sport-specific activities • Eccentric quadriceps strengthening • Proprioception/balance training with perturbations • Isokinetic quadriceps/hamstring strengthening • Hip abductor/adductor PREs • Quadriceps/hamstring PREs • OKC exercises • CKC exercises • Completion of return to running progression • Completion of functional testing algorithm • Return to sport: 4–6 mo postoperatively

Other Therapeutic Exercises

- 4 to 5 weeks postoperatively
  - Hamstring isotonics through full knee ROM
  - Quadriceps Isotonics through full knee ROM
  - Hip three-way SLR with ankle weights (avoid adduction): Progress by 1–2 lb/wk
  - Continue progressing upper-extremity (UE) progressive resistive exercises (PREs) and core stability exercises
- 6 weeks postoperatively
  - Progress hip and hamstring PREs
  - Begin eccentric and concentric quadriceps strengthening

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Focus should be on regaining full quadriceps strength and control in this phase. Special attention must be given to surrounding musculature that may have atrophied during NWB phase, including gluteus medius, gluteus maximus, and core muscles.

Sensorimotor Exercises

- 6 weeks postoperatively
  - Progressive single-leg balance exercises with biomechanical ankle platform system (BAPS), wobble board, Dyna Disc, Bosu ball, etc.
  - Grid exercises
- 8 weeks postoperatively
  - LE perturbation training (e.g., single-leg balance on Dyna Disc with bodyblade and ball tosses)

OKC and CKC Exercises

- CKC: Exercises should be performed three times per week at a minimum. To achieve optimal gains of both muscle strength and endurance, dosage should be 3 × 10 repetitions for each exercise unless otherwise noted.
  - 4 to 5 weeks postoperatively
    - Progress single-leg leg press/total gym from 0° to 90° knee flexion
    - Wall sits: 3 × 30- to 60-second holds
    - Bilateral heel raises
    - Carpet rolls or rolling stools for CKC hamstring strengthening
    - Single-leg bridge with march for core stability and hamstring strengthening
  - 6 weeks postoperatively: Begin quadriceps strengthening
    - Forward stepups focusing on pelvis and LE control and alignment
    - Stepdowns: Slowly, focusing on eccentric quadriceps control
    - Single-leg heel raises
    - Minisquats
    - Partial forward lunges to 30°
    - Single-leg Russian deadlift
  - 7 weeks postoperatively
    - Double-leg ball squats
    - Partial forward and backward lunges to 45°

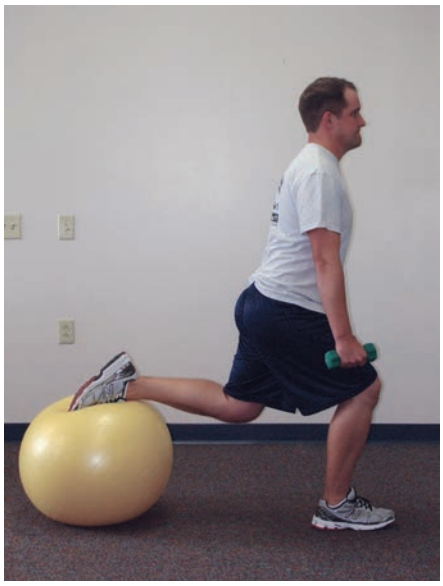

FIGURE 34-20. Lunges on stability ball: Patient performs partial lunge (0° to 45° knee flexion) with back foot propped on stability ball while focusing on keeping hips level and the knee in line with the ankle. This exercise is focused on eccentric quadriceps and gluteus medius strengthening.

    - Lateral stepups
    - Thera-Band sidestepping
  - 8 weeks postoperatively
    - Begin lateral and multiple angle lunges with tibia vertical.
    - Lunges with stability ball (Figure 34-20)
    - Single-leg ball squats
    - Single-leg sit to stand (Figure 34-21)



FIGURE 34-21. Single leg sit to stand to a target: Patient stands 6 to 8 inches away from a sturdy target at approximately thigh height. Patient slowly lowers the hips to the target and back up, focusing on ipsilateral quadriceps and gluteus maximus eccentric and concentric contractions.

- OKC: Exercises should be performed three times per week at a minimum. To achieve optimal gains of both muscle strength and endurance, dosage should be 3 × 10 repetitions for each exercise unless otherwise noted.
  - 5 weeks postoperatively
    - Knee extension 0° to 90° with no weight and against gravity
    - Hamstring curls with resistance
    - Clam exercise with Thera-Band
    - Thera-Band standing three-way SLR (avoid adduction)
  - 7 weeks postoperatively
    - Thera-Band standing three-way SLR (avoid adduction)
  - 8 weeks postoperatively
    - Resisted OKC knee extension

Techniques to Increase Muscle Strength, Power, and Endurance

- Focus should be on single-leg concentric and eccentric quadriceps strengthening, as research has shown that quadriceps muscle power deficits after combined MCL and ACL repair are up to 30.7% compared to the contralateral side at 1 year after surgery.[7]
- Most functional activities use both concentric and eccentric muscle contractions, which makes strengthening both modes a vital part of rehabilitation. Progression of quadriceps strengthening should be fast-paced and should include isokinetic training.
- 6 weeks postoperatively
  - Bicycle exercise with resistance, brisk walking on treadmill
- 8 weeks postoperatively
  - Incline and reverse walking on treadmill, elliptical machine, bicycle with resistance, and StairMaster to enhance cardiovascular fitness.

Neuromuscular Dynamic Stability Exercises

- Progress manual rhythmic stabilization of trunk and core exercises.

Functional Exercises

- 7 weeks postoperatively
  - Begin controlled lateral movements.
  - Sidestepping with Thera-Band
  - Slow and controlled lateral shuffles and carioca

Milestones for Progression to the Next Phase

- Full knee ROM
- Good LE alignment with all single-leg exercises
- Can tolerate 1 to 2 miles of brisk walking without a limp

Phase IV (weeks 8 to 12 postoperatively)

Clinical Pearls

- During this phase, the patient must demonstrate 75% quadriceps strength compared to the contralateral side before starting a return to running program at 10 weeks postoperatively and/or plyometrics, agility, and/or sport-specific exercises at 12 weeks postoperatively.
- It is important that the patient avoid external rotation of the tibia during higher-level activities/exercises to avoid putting stress on the healing graft and/or repair.
- It has become the general consensus that CKC exercises are safer than OKC exercises after knee surgery; however, the trend is toward incorporating OKC knee extension exercises earlier in rehabilitation, as they seem to be more sufficient than CKC exercises for isolated quadriceps strengthening.[7]

Goals

- No knee pain or effusion
- Isokinetic quadriceps strength = 75% of contralateral side
- Functional tests = 75% of contralateral side
- Jogging or running with normal gait pattern
- Good landing mechanics with double- and single-leg plyometrics

Protection

- Discharge brace for activities of daily living at 8 weeks postoperatively, but functional hinged brace for must be used for sport and/or vocation for 12 to 18 months postoperatively.[5,6]

Techniques for Progressive Increase in ROM

- Continue LE stretching/flexibility exercises for quadriceps, hamstrings, calves, and gluteal muscles

Other Therapeutic Exercises

- Continue progressive UE strengthening exercises.
- Continue progressive LE strengthening exercises, including wall squats, lateral lunges, knee extension, vertical squats, stepups, hip abductors/adductors, leg press, and hamstring curls.
- Isokinetic hamstring and quadriceps strengthening.
- Continue progressive core stability exercises.

Sensorimotor Exercises

- Continue progressive balance/proprioception exercises with perturbations, including single-leg BAPS with ball toss and bodyblade, wobble board, and tilt board.

OKC and CKC Exercises

- CKC: Continue progressing as above.
- OKC: Begin OKC knee extension PREs at 8 weeks postoperatively.

Techniques to Increase Muscle Strength, Power, and Endurance

- Continue UE and LE strengthening exercises, avoiding any resisted adduction exercises that put undue stress on graft/repair.
- Focus on eccentric quadriceps and fast-speed isokinetics.

Neuromuscular Dynamic Stability Exercises

- Begin combining UE functional movement with LE control, such as UE medicine ball proprioceptive neuromuscular facilitation patterns with forward, backward, and lateral lunges
- Progress to forward, backward, lateral, and multiple-angle stepdowns with focus on LE control and vertical tibia
- Slide board

Plyometrics

- 10 weeks postoperatively
  - Begin plyometrics on leg press, starting with double leg and progressing to single leg. Focus should be on good LE alignment and soft landing.
  - Initiate slide board exercises (3 × 60 seconds (Figure 34-22)) if patient has good LE control with all other exercises. Make sure patient wears the hinge brace to prevent valgus stress on the knee.
- 12 weeks postoperatively
  - Begin body weight plyometrics and agility exercises when at 75% strength compared to contralateral side, functional hop test at >75% compared to contralateral side, and good control on stepdown.[3] Start with double-leg ladders, box jumps, and vertical jumps, focusing on landing on heels with a flexed knee and good LE control. Patient must be able to jump off and land evenly with both legs and demonstrate good form before progressing to single-leg plyometrics (Figure 34-23).
  - Progress to (1) single-leg lateral jumps when the patient has good control with single leg forward and (2) retro plyometrics.

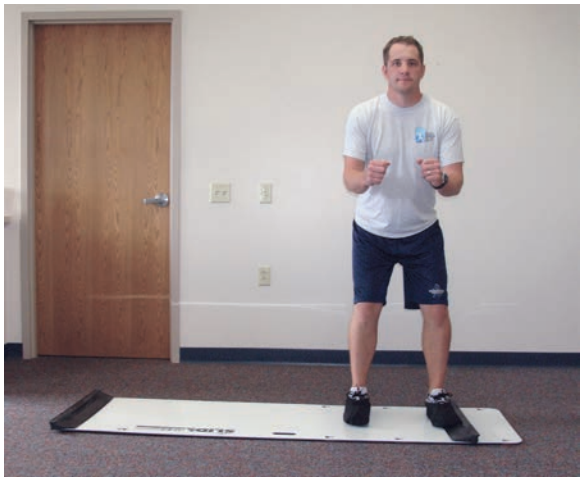

FIGURE 34-22. Slide board side shuffles: Keeping knees bent, toes forward, and hips level, the patient performs side shuffles on a slide board until fatigue.



FIGURE 34-23. Demonstration of proper landing mechanics.

Functional Exercises

- 10 weeks postoperatively
  - Begin jogging and/or running progression when 75% strength compared to contralateral side has been achieved, functional hop test is >70% compared to contralateral side, and good control on stepdown is demonstrated. Progression may start with fast walk, then progress to light jog, run, sprint without resistance, and sprint with bungee cords.
- 12 weeks postoperatively
  - Begin higher-level lateral movements, starting with lateral cutting, figure-eights, and zigzags and progressing to lateral shuttle with bungee cord and combination movements such as plant, cut, and pivot.

Sport-Specific Exercises

- 12 weeks postoperatively
  - At 12 weeks postoperatively, begin skilled, sport-specific exercises if 75% quadriceps strength and 75% functional hop test compared to contralateral side have been achieved.

Milestones for Progression to the Next Phase

- 75% isokinetic quadriceps strength compared to contralateral side

- 75% single-leg hop distance compared to contralateral side
- Able to jog or run without limp
- Good kinematic control with double-leg and single-leg jumps

Phase V (weeks 12 to 24 postoperatively)

Clinical Pearls

- It is important that athletes do not return to sport before they are physically ready, as the rate of reinjury is high in patients with ligament injuries of the knee.
- Davies and Zillmer developed a functional testing algorithm that focuses on fundamental and progressive stages of rehabilitation for athletes planning to return to sport.[8] The athlete must complete all stages of the functional tests before full participation in sports. Successful return to sport usually occurs at 4 to 5 months postoperatively with use of a functional hinged brace for 12 to 18 months postoperatively.

Goals

- Negative valgus stress test of the knee at both 0° and 30° knee flexion
- Demonstration of good landing mechanics with double- and single-leg plyometrics
- Completion of running progression program[2]
- Completion of sport-specific activities/functional exercise program/functional testing algorithm[6]
- Functional tests
  - At the end of this phase, if planning to return to sport, the athlete should complete the functional testing algorithm presented by Davies and Zillmer.[8]
    - Subjective: Pain score <3 on a visual analogue scale
    - Basic measurements: <10% bilateral comparison
    - KT1000 ligament arthrometer testing: <3 mm bilateral comparison
    - Balance test: <30% bilateral comparison
    - CKC supine isokinetic test: <30% bilateral comparison
    - OKC isokinetic test: <25% bilateral comparison
    - CKC squat isokinetic test: <20% bilateral comparison
    - Functional jump test: <20% bilateral comparison
    - Functional hop test: <15% bilateral comparison
    - LE functional test: <90 seconds for males, <120 seconds for females
    - Sport-specific test: <10% bilateral comparison
- Continue UE and LE strengthening program, proprioception training, endurance exercises, plyometric training, and sport-specific exercises throughout this phase.
- Emphasis should remain on speed/agility program, functional exercise drills, eccentric quadriceps strengthening, and fast-speed isokinetics of hamstring and quadriceps muscles.
- Completion of a full running progression program, such as the program presented by Phisitkul et al., in one session[2]
  - Jog 1 mile.
  - Five successive 100-yd sprints at half-speed
  - Five successive 100-yd sprints at three-fourths speed
  - Five successive 100-yd sprints at full speed
  - Five zigzag sprints at half speed
  - Five zigzag springs at full speed

After Return to Sport

Continuing Fitness or Rehabilitation Exercises

- Continue strengthening the dynamic stabilizers of the medial side of the knee, including the semimembranosus complex, quadriceps, and pes anserine tendons.
- Continue quadriceps and hamstring fast-speed isokinetic strengthening.
- Continue flexibility exercises.
- Continue proprioception/balance exercises

Exercises and Other Techniques for Prevention of Recurrent Injury

- Continue use of hinged brace for 12 to 18 months postoperatively for all athletic activity.
- Continue high-level plyometric training with focus on proper landing mechanics.
- Continue speed and agility training. Focus on good LE alignment during lateral cutting, lateral shuffles, and jumping activities to valgus stress to knee joint and tension on the MCL.

Evidence

Chen L, Kim PD, Ahmad CS, et al: Medial collateral ligament injuries of the knee: current treatment concepts. *Curr Rev Musculoskelet Med* 1:108–113, 2008.

A review of the current treatment concepts of the medial collateral ligament of the knee. (Level V evidence)

Davies GJ, Zillmer D: Functional progression of exercise during rehabilitation. In Ellenbecker T, editor: *Knee Ligament Rehabilitation*, New York, 2000, Churchill-Livingstone, pp 345–360.

The functional testing algorithm presented in this article serves as a guideline for clinicians to determine when an athlete is ready to return to sport after injury. (Level IV evidence)

Halinen J, Lindahl J, Hirvensalo E: Range of motion and quadriceps muscle power after early surgical treatment of acute combined anterior cruciate and grade-III medial collateral

ligament injuries: a prospective randomized study. *J Bone Joint Surg Am* 91:1305–1312, 2009.

A comparison of repair or nonoperative treatment of the MCL on ROM and quadriceps muscle strength in patients with combined MCL and ACL injuries. Results showed decreased ROM with operative treatment at 6-, 12-, and 36-week follow-up examinations, but no difference at 52 weeks and a 30.7% quadriceps muscle power deficit with MCL repair compared to 20.5% quadriceps muscle power deficit with nonoperative treatment. These results highlight the importance of early ROM and quadriceps strengthening postoperative MCL repair. (Level I evidence)

Indelicato PA: Non-operative treatment of complete tears of the medial collateral ligament of the knee. *J Bone Joint Surg Am* 65:323–329, 1983.

A prospective study comparing results of operative and non-operative management of complete, Grade III, isolated MCL tears. The results support no obvious advantage of surgical repair and highlights importance of early-protected mobilization of the knee in a cast or brace. (Level IV evidence)

Kovachevich R, Shah JP, Arens AM, et al: Operative management of the medial collateral ligament in the multi-ligament injured knee: an evidence-based systematic review. *Knee Surg Sports Traumatol Arthrosc* 17:823–829, 2009.

This review suggests that surgical repair or reconstruction of the MCL in the multi-ligament-injured knee yields satisfactory results. (Level III)

Phisitkul P, James SL, Wolf BR, et al: MCL injuries of the knee: current concepts review. *Iowa Orthop J* 26:77–90, 2006.

This review supports conservative management of most MCL injuries and offers a goal-oriented rehabilitation program based on recent clinical studies. The review also includes incidences when surgery may be warranted and summarizes basic surgical technique and postoperative rehabilitation. (Level V evidence)

Rice DA, McNair PJ: Quadriceps arthrogenic muscle inhibition: neural mechanisms and treatment perspectives. *Semin Arthritis Rheum* 40:250–266, 2010.

Supports the use of cryotherapy, TENS, and NMES to decrease pain and swelling and decrease quadriceps muscle inhibition after knee surgery. (Level V evidence)

Romeyn RL, Jennings J, Davies GJ: Surgical treatment and rehabilitation of combined complex ligament injuries. *N Am J Sports Phys Ther* 3:212–225, 2008.

A review of the current literature of the optimal surgical procedures and rehabilitation protocol for patients with combined/complex ligament injuries of the knee. The article supports the selection of selected OKC and CKC exercises and the milestones for progression through each phase of rehabilitation and return to activity/sport. (Level V evidence)

Wijdicks CA, Griffith CJ, Johansen S, et al: Injuries to the medial collateral ligament and associated medial structures of the knee. *J Bone Joint Surg Am* 92:1266–1280, 2010.

This comprehensive literature review summarizes the most favorable nonoperative and operative treatment options for injuries of the medial structures of the knee. There is a consensus that nonoperative treatment of Grade III MCL tears produces more favorable outcomes. The review describes incidences when surgery may be warranted. (Level IV evidence)

Wilson TC, Satterfield WH, Johnson DL: Medial collateral ligament "tibial" injuries: indication for acute repair. *Orthopedics* 27:389–393, 2004.

These authors claim that the current research suggests Grade III and some Grade II MCL injuries with tibial insertion avulsions lead to chronic knee instability and worse outcomes and that surgical repair is therefore the best intervention. Two case studies of athletes undergoing early surgical repair and the same postoperative rehabilitation protocol led to good outcomes and return to sport-specific activities in a hinged brace at 3 months and return to full sports at 4 months postoperatively. (Level IV evidence)

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2. Phisitkul P, James SL, Wolf BR, et al: MCL injuries of the knee: current concepts review. *Iowa Orthop J* 26:77–90, 2006.
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5. Wilson TC, Satterfield WH, Johnson DL: Medial collateral ligament "tibial" injuries: indication for acute repair. *Orthopedics* 27:389–393, 2004.
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8. Davies GJ, Zillmer D: Functional progression of exercise during rehabilitation. In Ellenbecker T, editor: *Knee Ligament Rehabilitation*, New York, 2000, Churchill-Livingstone, pp 345–360.

Multiple-Choice Questions

QUESTION 1. In cases of isolated MCL tears, surgery usually is not warranted unless:

A. The patient demonstrates valgus laxity greater than 10 mm at both 0° and 30° of knee flexion.
B. The posterior oblique ligament is torn in conjunction with the superficial and deep medial collateral ligaments.
C. The patient is an elite athlete who needs to perform high-powered lateral cutting for their sport.
D. The patient demonstrates anteromedial instability of the knee.

QUESTION 2. After repair of an acute isolated MCL tear, the patient may progress to FWB in a hinged brace at the end which week?

A. 1
B. 2
C. 3
D. 4

QUESTION 3. Early knee ROM in a hinged brace after MCL repair/reconstruction is necessary to prevent adhesion formation during early postoperative rehabilitation, but should be limited to _____ for the first 3 weeks.

A. 0° to 30°
B. 30° to 60°
C. 30° to 90°
D. 60° to 90°

QUESTION 4. At 5 weeks after isolated MCL repair/reconstruction, patients may discharge use of crutches if they have:

A. Full knee ROM
B. Good quadriceps control
C. No valgus laxity at both 0° and 30° knee flexion
D. No knee pain or effusion

QUESTION 5. The patient must demonstrate _____ before returning to sport after isolated MCL repair/reconstruction.

A. 90% isokinetic quadriceps strength compared to the contralateral side
B. Ability to run with a normal gait pattern
C. 60% hamstring/quadriceps ratio with isokinetic strength testing at 60°/sec
D. Single-leg plyometrics with no knee valgus

Answer Key

QUESTION 1. Correct answer: **D** (see Surgical Indications)

QUESTION 2. Correct answer: **C** (see Phase II: Postoperative Rehabilitation)

QUESTION 3. Correct answer: **C** (see Immediate Postoperative Rehabilitation)

QUESTION 4. Correct answer: **B** (see Phase II: Rehabilitation)

QUESTION 5. Correct answer: **A** (see Phase III: Rehabilitation)

BEYOND BASIC REHABILITATION: RETURN TO FOOTBALL AFTER MEDIAL COLLATERAL LIGAMENT SURGERY

Luke O'Brien, BPhty, GCertPhty, SCS, Nicholas Kennedy, BS, and Robert F. LaPrade, MD, PhD

Introduction

ASPECTS OF FOOTBALL THAT REQUIRE SPECIAL ATTENTION IN REHABILITATION

- There are a number of physical performance characteristics that are essential to a successful return to football. These include throwing, running, cutting, accelerating, decelerating, catching, blocking, jumping, and tackling.
- The degree to which each of these characteristics is emphasized in a rehabilitation program is position-dependent, with appropriate adjustments made to emphasize position-specific demands.
- Restoration of knee stability and full knee range of motion (ROM) are fundamental to the ability to return to play.
- Position-specific energy system and muscular strength characteristics should be identified and developed in the rehabilitation program.

- Isolated anterior cruciate ligament (ACL) injuries are extremely common for National Football League (NFL) athletes. Shah et al. reported 209 ACL injuries over a 5-year span (1994–1998).[1]
- High occurrence of previous ACL injuries in players at NFL combine.[2]
- Football accounts for the highest percentage of ACL, medial collateral ligament (MCL) multiligamentous injuries, with 31% to 37% of the injuries seen clinically being the result of football.[3,4]
- Return to play following ACL reconstruction has been reported to be 63%. This is lower than common perceptions.[1]

Literature

- To the knowledge of the authors of this chapter, there is no literature regarding return to play at the NFL level after a combined ACL, MCL multiligamentous injury and subsequent surgical reconstruction.
- With regard to return to play from isolated ACL injuries, the injury has been shown to decrease game

performance of NFL players and has been reported to inhibit up to 37% of players who experience said injury from returning to play.[1,5]
- Grade III MCL injuries have been reported to heal well with conservative and with surgical treatment.[6-10]

Advanced Rehabilitation Program

- The authors felt that an additional phase—phase 0—should be added to the rehabilitation protocol for this injury. Phase 0 focuses on mobility and base strength following surgery and creates the foundation upon which the physiological benefits of the advanced rehabilitation exercises are built.
- The weekly structure of the rehabilitation program commonly involves 6 or 7 days per week of targeted exercise. Recovery, particularly in the strengthening phases, plays an important role in the athlete's ability to complete the prescribed sessions.
- To assist post exercise recovery, we advocate cold water immersion in 59°F (15°C) water for 15 minutes. These parameters have been shown to improve subsequent exercise performance by 10% compared to active recovery, contrast water therapy, and hot-water immersion, and they have also been found to reduce muscle soreness.[11,12]
- In the absence of an available immersion pool, a cryotherapy device such as a Game Ready cold compression device may be a viable alternative. Although no results on it's exercise performance efficacy have been published, it has been shown to reduce postsurgical pain and inflammation[13]
- Quality sleep is an important recovery element. Athletes are encouraged to set room temperature to between 66°F and 70°F, maintain a regular sleep–wake cycle, and avoid naps of long duration that may interfere with nighttime sleep.
- Although used extensively outside the United States, global positioning system (GPS) monitoring systems (such as Catapult) have only recently begun to catch on in sporting environments. GPS systems, when interpreted correctly, can provide valuable training information that can be used to effectively manipulate training variables to minimize the risk of unnecessary training volume spikes and to decrease reinjury risk.

Phase 0: Mobility and Base Strength

Periodization

- Linear periodization is focused on restoring correct muscle-firing patterns and patellofemoral and tibiofemoral joint mobility.
- Macrocycles are used throughout the rehabilitation protocol and are focused upon restoration of performance and return to play.
- Mesocycles are implemented during the first 3 months of the rehabilitation process and are focused upon restoration of normal joint ROM, muscle initiation patterns, and endurance base building.

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- Training continuum
- Flexibility/joint mobility for joint stability
- Training with optimum posture
- Sensorimotor and balance training
- Core training
- Cardiorespiratory training
- Training for optimum muscle balance
- Training for optimum muscular endurance

Training Principles Used in the Design of the Program

- Principle of progression
- Principle of overload
- Principle of variation
- Principle of individualization
- Principles of specificity–specific adaptation to imposed demands (SAID)

Application of Acute Training Variables

- To properly design the athlete's rehabilitation program, a thorough needs analysis is completed. This includes position-specific athletic performance needs, prior injury history, physical strengths and weaknesses, and major team date milestones such as start of training camp, start of preseason, and start of regular season.
- The established time milestones can then be matched with the anticipated rehabilitation phases. Because the timeline of recovering from surgery rarely perfectly match the start of training camp or the start of the regular season, the length of each rehabilitation phase may need to be manipulated (either lengthened or shortened), based upon the athlete's recovery and performance needs.
- The authors advocate a backward-planning approach when determining the length of each rehabilitation phase. In this approach, high-impact activities are initiated as late in the recovery as possible while still allowing sufficient time for the athlete to fully develop the training characteristic. For example, if the return-to-play date is 10 months in the future, there is limited value in initiating a running progression program at 5 months. Rather, delaying running until 7 months allows for a continued focus on muscular development, accommodation of the joint to increasing loads, and restoration of joint homeostasis while still allowing sufficient time for running development.
- The goal of this phase is to regain mobility, prevent joint stiffness, and limit scar tissue formation while protecting the reconstructed ligaments.[14]
- ROM is restored through a combination of exercise and manual therapy.
- Patellar mobilization (Figure 34-24*A,B*) is used to restore patellofemoral mobility, help to ensure the integrity of the anterior fat pad interval and suprapatellar pouch, and prevent a decrease in joint mobility.[15,16,18,19]

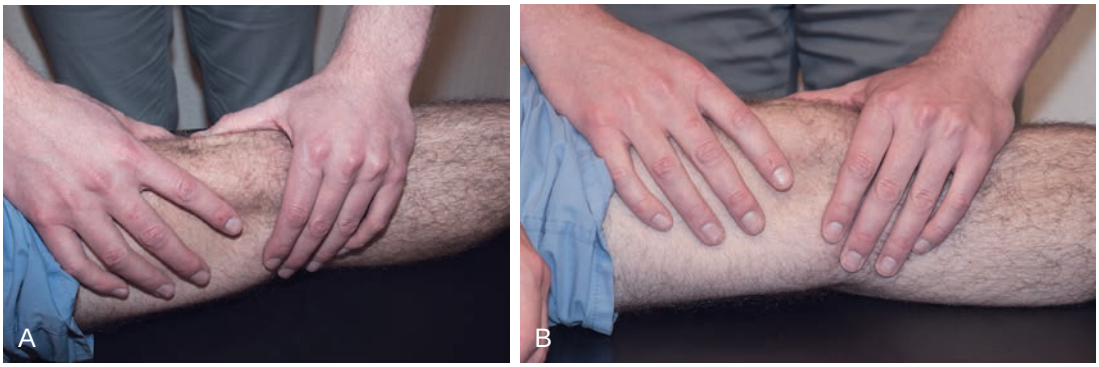

FIGURE 34-24. Patellar mobilization.

- With extension mobilization, the aim is to restore symmetrical extension, allowing the quadriceps to function in their inner range while also allowing joint contact forces to be distributed over the entire available surface area.[20]
- Wall slides and flexion on a Swiss ball help to restore flexion ROM.
- Quadriceps exercises are first focused on restoring the correct initiation pattern. This involves high-repetition, low-intensity parameters. Because of the low intensity, minimal rest is required between sets.
- Once the correct muscle patterning is established, the exercise parameters are adjusted to stress type 1 slow-twitch fibers, which atrophy predominantly following surgery. These exercises have an increasing intensity of at least 25 repetitions and a 45-second to 1-minute rest period.
- Training frequency for both ROM and muscle initiation exercises should be numerous: two to four times per day, 7 days per week.
- Sample exercise and training parameters are outlined in Table 34-1.

Phase I: Advanced Strength and Conditioning Programs

Periodization

- Linear periodization: Focused on restoring correct muscle pattern initiation and building a muscular endurance base
- Undulating
- Macrocycles are used throughout the rehabilitation protocol and are focused upon restoration of performance and return to play.
- Mesocycles implemented during the first 3 months of the rehabilitation process are focused upon restoration of normal joint ROM, muscle initiation patterns, and endurance base building.

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- Training continuum
- Flexibility/joint mobility for joint stability
- Training with optimum posture
- Sensorimotor and balance training
- Core training
- Cardiorespiratory training
- Training for optimum muscle balance
- Neuromuscular dynamic stability exercises
- Functional training
- Sport-specific training
- Training for optimum muscular endurance

Training Principles Used in the Design of the Program

- Principle of progression
- Principle of overload
- Principle of variation
- Principle of individualization

Table 34-1 Range of Motion and Muscle Initiation (weeks 1–6)

	Repetitions	Sets	Frequency
Wall slides	10 min	1	2–4 times daily, 5–7 times per week
Patella mobility (image 1 and image 2)	10 min	1	2–4 times daily, 5–7 times per week
Extension mobilization	5 min	1	2–4 times daily, 5–7 times per week
Flexion on Swiss ball	10 min	1	2–4 times daily, 5–7 times per week
Quadriceps initiation continuum: • Patellar glide • Patellar glide with biofeedback: holds • Patellar glide with TKE • TKE with manual overpressure • Straight-leg raise • Standing TKE with sports cord	25+	3	2–4 times daily, 5–7 times per week

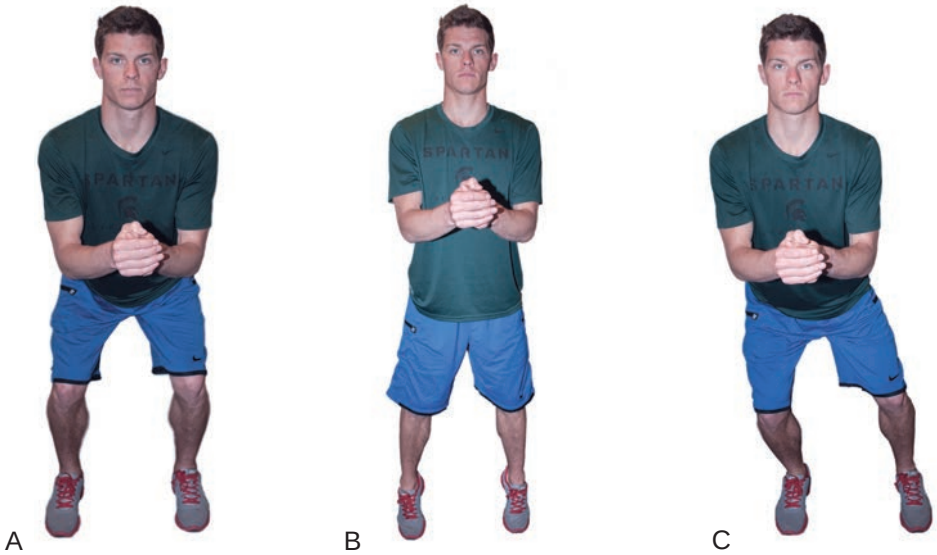

FIGURE 34-25. Squat progression.

- Principles of specificity–specific adaptation to imposed demands (SAID)

Application of Acute Training Variables

- Exercise parameters are designed to establish a muscular endurance base upon which further gains in strength and power can be made in later phases.
- Set and repetition structure is generally 3–6 × 20+ to promote the development of a muscular endurance base (reference). Three sets are commonly prescribed at the beginning of the program, with an increase in set number serving to incrementally increase training volume over time.
- Rest intervals between sets are 30–45 seconds
- Training frequency is usually three times per week. Strength days are alternated with low load/active recovery days, with 1 day of the week completely off.
- Training duration is between 60 and 90 minutes, including active warmup, strength session, cool down, and ice time.
- Training volume is manipulated depending upon intensity. Generally, during this stage of rehabilitation, intensity remains constant while overload is created through increased training volume (e.g., from three sets to six sets).
- Exercises at this stage of recovery focus on double-leg, shallow range motions (squat progression; Figure 34-25*A*, *B*, and *C*) and tuck squat (Figure 34-26*A*,*B*) or single-leg static holding positions (static box hold with medicine ball press) (Figure 34-27*A*,*B*).
- This emphasis allows the athlete to gain muscular control over simpler movement patterns before progressing to more challenging movements.

TIMELINE 34-4: **Return to Football after Medial Collateral Ligament Surgery**

PHASE 0 (weeks 1 to 6 postoperatively)

Weeks 1 to 2

- Immobilizer brace
- ROM 0°–90°: Wall slides, flexion on Swiss ball, end of table
- Non–weightbearing
- Patellofemoral mobilization
- Extension mobilization
- Quadriceps initiation drills
- Ankle dorsiflexion stretch
- Ankle pumps
- Ice

Weeks 3 to 6

- Immobilizer brace
- Full passive ROM: Wall slides, flexion on Swiss ball, end of table
- Non–weightbearing
- Patellofemoral mobilization
- Extension mobilization
- Quadriceps continuum
- Ankle dorsiflexion strength
- Ankle pumps
- Ice

PHASE I (weeks 7 to 12 postoperatively)

- Hinged knee brace
- Wk 6–8: Wean off crutches
- Flexion/extension/patellofemoral mobilization as needed
- Stationary bike
- Incline treadmill walking
- Pool
- CKC exercises: Endurance base building focus
- Shallow range double-leg or static single-leg CKC exercises
- Begin core + UE lifting + cardio
- Ice

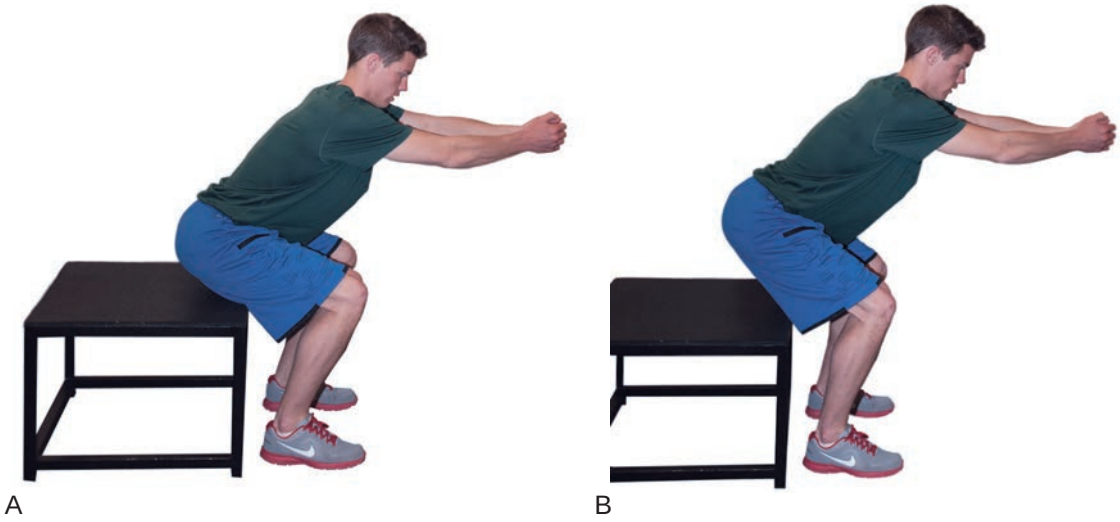

FIGURE 34-26. Tuck squat.

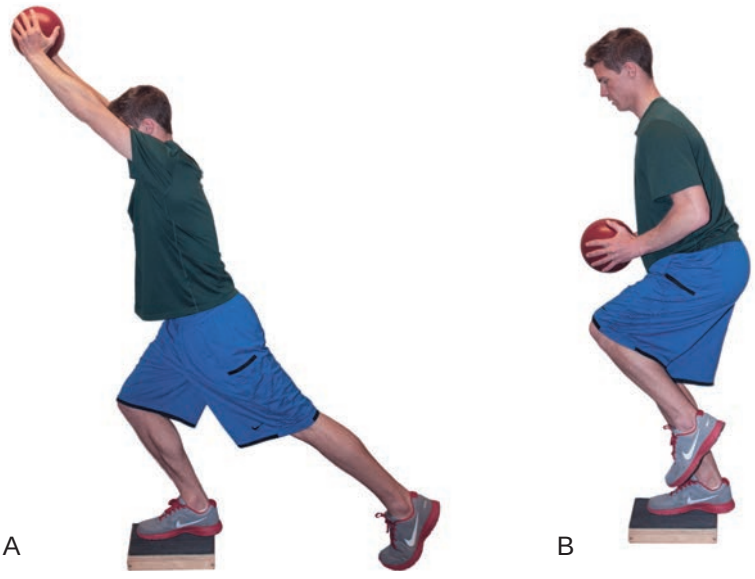

FIGURE 34-27. Single-leg static holding position: static box hold with medicine ball press.

TIMELINE 34-4: **Return to Football after Medial Collateral Ligament Surgery** (Continued)

PHASE II (weeks 13 to 24 postoperatively)

Weeks 13 to 18

- Flexion/extension/patellofemoral mobilization as needed
- Stationary bike
- Incline treadmill walking
- Pool
- CKC exercises: Muscular strength focus
- OCK exercises: Hamstring and gluteals
- Single-leg through range CKC exercises
- Core + UE lifting + cardio

Weeks 19 to 24

- Stationary bicycle
- Pool
- Alter G running progression
- CKC exercises: Muscular power focus
- OCK exercises: Hamstring and gluteals
- Core + UE lifting + cardio

PHASE III (weeks 25 to 29+ postoperatively)

Weeks 25 to 28

- Stationary bicycle
- Pool
- Vail Sports Test + girth measurements
- Land-based running progression
- CKC exercises: Olympic lifting incorporated
- Core + UE lifting

Weeks 29+

- Stationary bicycle
- Pool
- Week 29: Single-plane agility
- Wk 30–32: Multiplanar agility
- CKC strength maintenance plan
- Agility T-Test
- Resume training

Table 34-2 Muscular Endurance Base Building (weeks 7–12)

	Repetitions	Sets	Rest	Intensity	Frequency
Double-leg press	20+	3–6	1–2 min	50% 1RM	3–4 times/wk
Squat progression (Figure 34-25) • Body weight squat • Body weight squat to calf raise • Body weight squat to weightshift	30 (10 each)	3–6	1–2 min	50% 1RM	3–4 times/wk
Static box hold with medicine ball press (Figure 34-27)	20+	3–6	1–2 min	50% 1RM	3–4 times/wk
Single-leg deadlift	1+ min	3–6	1–2 min	50% 1RM	3–4 times/wk
Double-leg bridges with alternating leg lift	20+	3–6	1–2 min	50% 1RM	3–4 times/wk
Tuck squat (Figure 34-26)	1+ min	3–6	1–2 min	50% 1RM	3–4 times/wk
Static hold with two-way slider disc	20+	3–6	1–2 min	50% 1RM	3–4 times/wk

- Sample exercises and training parameters are outlined in Table 34-2.

Phase II: Performance Enhancement Training Techniques

Periodization

- Linear periodization with a focus on gaining strength and power upon the muscular endurance foundation that has been built.
- Undulating
- Macrocycles are used throughout the rehabilitation protocol and are focused upon restoration of performance and return to play.
- Mesocycles are implemented during the second 3 months and are focused more on improving strength and power.
- Microcycles

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- Training continuum
- Flexibility/joint mobility for joint stability
- Training with optimum posture
- Sensorimotor and balance training
- Core training
- Cardiorespiratory training
- Training for optimum muscle balance
- Training for optimum muscle functional strength
- Training for optimum muscle functional power
- Neuromuscular dynamic stability exercises
- Functional training
- Sport-specific training

Training Principles Used in the Design of the Program

- Principle of progression
- Principle of overload
- Principle of variation
- Principle of individualization
- Principles of SAID

Application of Acute Training Variables

- During this performance enhancement phase, a liner periodization approach is used to first develop muscular strength and then muscular power.
- A 6-week period is dedicated to the development of each physiological characteristic.

Muscular Strength (weeks 12 to 18)

- Sets and repetitions are generally 3–6 × 8–12 to promote the development of muscular strength. This structure allows the clinician some leeway to alter training intensity from session to session. For example, a higher-intensity session may have a 3 × 8 structure, while a lower intensity session may be 4–5 × 12.[21]
- The rest interval between sets increases from the endurance phase. Here, 1 or 2 minutes is available for the athlete to recover before further sets are conducted.
- Intensity is increased to 70% to 85% of 1RM. For many exercises, this is difficult to accurately calculate; therefore, an approach where appropriate load is added to an exercise so that the athlete can complete the prescribed repetitions without loss of form or control is advocated.
- A training frequency of 2 days on followed by 1 active recovery/low-impact day can be used in this phase. This allows for 4 training days, 2 active recovery days, and 1 day off.
- Training duration is typically between 60 and 90 minutes, including active warmup, strength session, cool-down, and ice time.
- Training volume can be manipulated by altering the set and repetition structure. Generally, lower-intensity sessions (higher repetitions) predominate in the first 3 weeks.
- Some specific exercises used in the training include a single-leg squat with sport cord resistance (Figure 34-28*A,B*) and a balance squat (Figure 34-29*A,B*). Although there are many exercises that are suitable at this stage of recovery, the authors advocate the use of single-leg exercises that may initially be completed with a shallow ROM and are steadily increased as strength and proof of control allow.

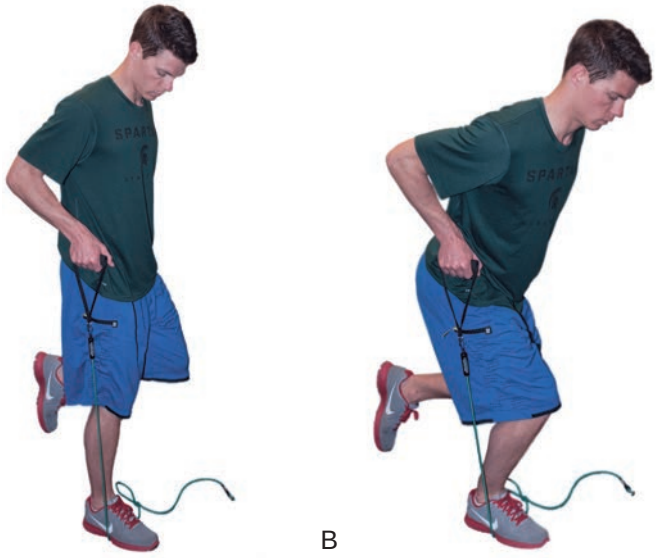

FIGURE 34-28. Single-leg squat with sport cord resistance.

- Leg extension, forward and walking lunges are avoided. The authors feel that these exercises place significant and unnecessary stress on the anterior knee, increasing the risk for the development of anterior knee pain and delaying the total recovery time.
- Sample exercises and training parameters are outlined in Table 34-3.

Muscular Power (weeks 18 to 24)

- A set and repetition structure of 1 to 3 × 1 to 6 is used to develop muscular power. As with strength, the number of sets and repetitions can be manipulated to vary training intensity between sessions, with lower repetitions equating to increased training intensity.
- The increased intensity necessitates an increase in rest time between sets. During muscular power development, 3 to 5 minutes between sets is allowed for recovery.
- Because speed of contraction is emphasized in this phase, the loads used during exercise are decreased from the strength phase to 30% to 45% of 1 RM. Practically, the athlete should be able to complete each exercise set without failure of form or intensity due to the prescribed load.
- Training frequency remains constant at 2 days on, followed by an active recovery/low-impact day. One day in the week is committed to being completely off.
- A typical training duration at this stage is 45 to 60 minutes. The higher intensity dictates a shorter training time.
- As with the strengthening phase, volume is constantly manipulated through adjustments in the set + repetition structure. Commonly, volume is added to the



FIGURE 34-29. Balance squat.

Table 34-3 Muscular Strength Development (weeks 13–18)

	Reps	Sets	Rest	Intensity	Frequency
Single-leg press	8–12	3–6	1–2 min	70%–85% of 1RM	3–4 times/wk
Single-leg squat with sport cord (Figure 34-28)	8–12	3–6	1–2 min	70%–85% of 1RM	3–4 times/wk
Balance squat (Figure 34-29)	8–12	3–6	1–2 min	70%–85% of 1RM	3–4 times/wk
Single-leg deadlift with kettle bell	8–12	3–6	1–2 min	70%–85% of 1RM	3–4 times/wk
High bench stepups with dumbbells	8–12	3–6	1–2 min	70%–85% of 1RM	3–4 times/wk
Reverse lunge	8–12	3–6	1–2 min	70%–85% of 1RM	3–4 times/wk

program over time by adding sets while repetitions and intensity remain constant.

- Specific exercises prescribed in this phase include reverse lunge into hip drive (Figure 34-30*A*,*B*) and prone leg press on shuttle with arm drive (Figure 34-31*A*,*B*).
- Exercise prescription focuses on power movements with the foot remaining on the ground. It is the authors' opinion that this allows for the safest training environment while providing adequate stimulus for muscular power development. Position players for whom jumping is a component of their game will require that ballistic movements with the foot leaving the ground be built into the plan. This can be done after 2 to 3 weeks with appropriate instruction on landing technique and strategies.
- Sample exercises and training parameters are outlined in Table 34-4.

Phase III: Sport-Specific Training

Periodization

- Linear periodization with a focus on speed, quickness, agility, and sport- and position-specific exercises to return to play
- Undulating
- Macrocycles are used throughout the rehabilitation protocol and are focused upon restoration of performance and return to play.

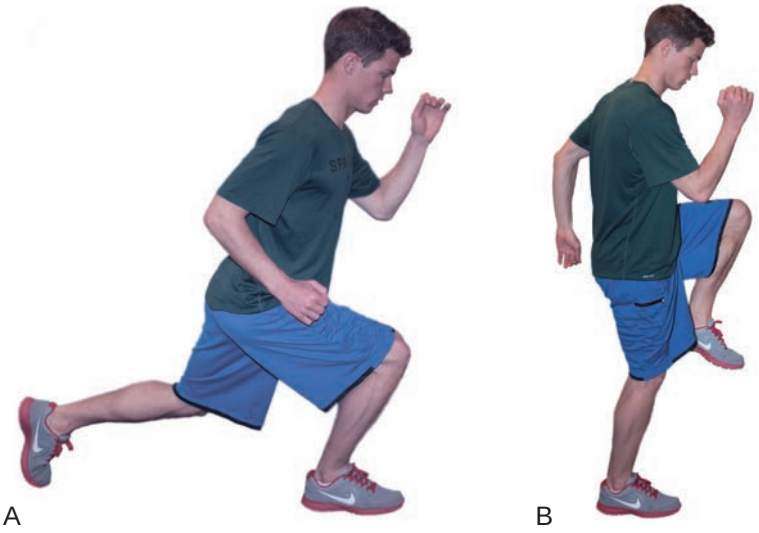

FIGURE 34-30. Reverse lunge into hip drive.

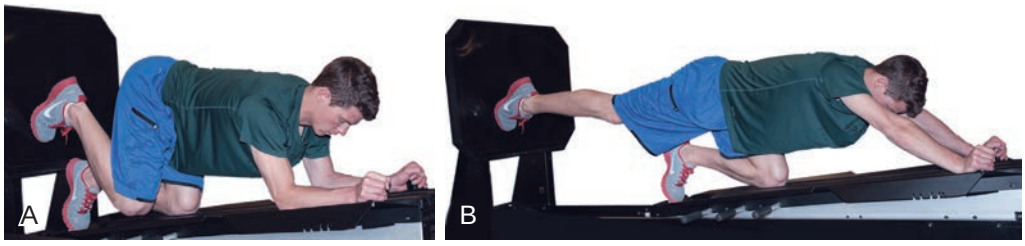

FIGURE 34-31. Prone leg press on shuttle with arm drive.

Table 34-4 Muscular Power Development (weeks 19–24)

	Repetitions	Sets	Rest	Intensity	Frequency
Single-leg press	1–6	1–3	3–5 min	30%–45% of 1RM	1–3 times per week
Reverse lunge into hip drive (Figure 34-30)	1–6	1–3	3–5 min	30%–45% of 1RM	1–3 times/wk
Prone press on shuttle with arm drive (Figure 34-31)	1–6	1–3	3–5 min	30%–45% of 1RM	1–3 times/wk
Lateral agility with sports cord	1–6	1–3	3–5 min	30%–45% of 1RM	1–3 times/wk
Lateral stepping with sports cord resistance	1–6	1–3	3–5 min	30%–45% of 1RM	1–3 times/wk
Forward drive with sports cord resistance	1–6	1–3	3–5 min	30%–45% of 1RM	1–3 times/wk

- Mesocycles for the last phase of rehabilitation are focused on sport- and position-specific exercises as well as regaining speed and quickness so the athlete can return to play.

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- Training continuum
- Flexibility/joint mobility for joint stability
- Training with optimum posture
- Sensorimotor and balance training
- Core training
- Cardiorespiratory training
- Multiplanar training activities
- Training for optimum muscle balance
- Training for optimum muscle functional strength
- Training for optimum muscle functional power
- Neuromuscular dynamic stability exercises
- Training for speed, agility, quickness (SAQ)
- Plyometric training
- Functional training
- Sport-specific training
- Conditioning training

Olympic Lifts Used in the Training Program

- Snatch
- Clean and jerk
- Power clean

Training Principles Used in the Design of the Program

- Principle of progression
- Principle of overload
- Principle of variation
- Principle of individualization
- Principles of SAID

Application of Acute Training Variables

- Similar to the prior phase, the sport-specific training phase is divided into two 4-week periods. The first 4-week period is characterized by the incorporation of powerlifting moves and the initiation of a running progression. The second 4-week phase is dedicated to the development of the position-dependent speed and agility movements required to return the athlete to play.
- Powerlifts and running progression
  - Powerlifts are introduced to the program at this time and include hang clean, power clean, and jump shrugs. They utilize the same acute training variables as the power exercises in the prior phase. They are not completed in isolation, but rather incorporated as key components in a wider-ranging power program that includes exercises from the prior phase.
  - Sample exercises and training parameters are listed in Table 34-5.
  - A running progression is initiated in this phase. It is a walk-run program that incrementally increases running volume over a 5-week period.
  - The volume of running can be tailored to the athlete's playing position. A lineman requires less total running time than a running back. Therefore, a lineman may stop the running progression at a 2-minute run: For example, a 3-minute walk × 4, whereas a running back may complete the running progression of 20 minutes of constant running.
  - Sample running progression is outlined in Table 34-6.
- Speed + agility
  - With the successful completion of a running progression, the athlete can begin a speed and agility program.

Table 34-5 Power Lifts during Running Progression (weeks 24–28)

	Repetitions	Sets	Rest	Intensity	Tempo	Frequency
Hang clean	1–6	1–3	3–5 min	30%–45% of 1RM	Explosive	1–3 times/wk
Power clean	1–6	1–3	3–5 min	30%–45% of 1RM	Explosive	1–3 times/wk
Jump shrugs	1–6	1–3	3–5 min	30%–45% of 1RM	Explosive	1–3 times/wk

Table 34-6 Running Progressions: Position-Dependent (Skill Positions) (weeks 24–28)

Running Progression (weeks)	Run Time (min)	Walk Time (min)	Frequency
1	1	4	3 times/wk
2	2	3	3 times/wk
3	3	2	3 times/wk
4	4	1	3 times/wk
5	20	–	3 times/wk

- The first week of the program focuses on single-plane agility. Multiplanar movements and a focus on increasing speed occur in the following weeks.
- A typical agility program involves completion of three sets of four different drills. Each drill will have a specific component (first step speed, deceleration, foot placement) that is emphasized and developed.
- A 3- to 5-minute rest interval is used to allow for complete recovery between sets. A heart rate monitor can be a useful tool to determine recovery time. After an agility set, heart rate can be monitored, and, once it has returned to resting levels, the next set can start.
- Initial agility drills, which focus on technique and skill acquisition, are typically completed at lower intensity levels. As the skills are learned, the intensity level progressively increases until the athlete is training at 100% effort.
- Three agility sessions are usually completed per week, with sessions lasting between 30 and 60 minutes depending upon recovery time. Training volume is increased by manipulating training intensity to create overload.
- Some of the exercises used during the single-plane agility work include dip-and-touch and a weave run. Once the program has advanced to multidirectional agility, drills such as sprint, shuffle touch, and jump over–sprint are useful in allowing the athlete to develop the performance characteristics necessary to return to football.
- Sample exercises and training parameters are outlined in Table 34-7.

Sports Performance Testing

General Information

- General history
- Subjective questionnaires
- Medical history
- Sports injury history
- Surgical history
- Chronic conditions/medication

Specific Tests

Clearance to Begin Running Progression: Beginning of Phase III

- Thigh girth 10 cm proximal to the superior border of the patella
- The Vail Sports Test[22]: The Vail Sports Test is a four-test battery of exercises that assesses an athlete's muscular endurance, muscular power, and ability to accept eccentric load.
- An athlete must demonstrate thigh girth within 1 cm of unaffected side and pass the Vail Sports Test to commence the running progression.

Table 34-7 Speed and Agility (weeks 29–32)

	Week of Agility Progressions	Intensity	Rest	Frequency	Sets
Weave run	1	50%	3–5 min	3 times/wk	3
Zigzag shuffle	1	50%	3–5 min	3 times/wk	3
Dip and touch	1	50%	3–5 min	3 times/wk	3
Circle around	1	50%	3–5 min	3 times/wk	3
Jump over–sprint	2	75%	3–5 min	3 times/wk	3
Front–back shuffle	2	75%	3–5 min	3 times/wk	3
Sprint–shuffle	2	75%	3–5 min	3 times/wk	3
Figure-6s	2	75%	3–5 min	3 times/wk	3
Up 2, back 1	3	100%	3–5 min	3 times/wk	3
Shuffle, explode, touch	3	100%	3–5 min	3 times/wk	3
Sprint, shuffle, touch	3	100%	3–5 min	3 times/wk	3
Run-through with hand plants	3	100%	3–5 min	3 times/wk	3
Run-through	4	100%	3–5 min	3 times/wk	3
Shuffle-through	4	100%	3–5 min	3 times/wk	3
Sprint–backpedal	4	100%	3–5 min	3 times/wk	3
Up and around	4	100%	3–5 min	3 times/wk	3

Clearance to Resume Training: Completion of Speed and Agility

- An agility T test is used after completing the speed and agility program as a clearance to resume training measure.
- The athlete must test with a time of at least 90% that of the unaffected side.

Objective Tests

- Physiological assessments
- Body composition tests
- Static/dynamic postural assessments
- Dynamic muscle performance testing
- Movement performance testing
- Sport-specific testing
- Others

Specific Criteria for Progression to the Next Stage to Determine Their Readiness for Football

- There are two key aspects in progress the athlete between phases.
  - Pass the eye test: Can the athlete complete the prescribed exercises with adequate control? Significant movement deficiencies in early phases will be magnified in later phases.
  - Time: Physiological adaptation to imposed load takes time. The authors recommend that a minimum of 6 weeks be devoted to the development of each muscle's physiological characteristics.

Specific Criteria for Releasing an Athlete to Unsupervised Complete Participation in Football

- Release to competition involves three steps
  - Successful completion of all scheduled training sessions, including contact training sessions, with no symptoms of pain, swelling, or instability in the knee
  - Clearance of the ligamentous stability of the knee by the treating physician
  - The athlete has complete confidence in the knee and his performance and is mentally ready to return to competition.

Recommended Ongoing Exercises

- The athlete should resume normal offseason/preseason conditioning programs after successfully completing the first season following injury. No specific exercises need to be completed; however, medical staff should closely monitor the passive and active extension in the athlete's surgically treated knee. A loss of extension motion may precipitate degenerative changes in the joint, as well as loss of quadriceps strength and a subsequent loss of performance.

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*There are no evidence-based trials on this topic.

Multiple-Choice Questions

QUESTION 1. What is the major concern during the first 6 weeks following surgical reconstruction?

A. Inability to bear weight on the affected leg
B. Loss of muscular strength
C. Loss of quadriceps girth
D. Excessive scar tissue formation and loss of motion

QUESTION 2. At which phase are Olympic lifts added to the rehabilitation protocol?

A. Phase 0
B. Phase I
C. Phase II
D. Phase III

QUESTION 3. What is the reported occurrence of ACL/MCL multiligamentous injuries in football?

A. 21% to 25%
B. 31% to 37%
C. 42% to 48%
D. 12% to 16%

QUESTION 4. When is the athlete allowed to focus on regaining speed and agility?

A. Immediately following muscular strength development during phase II
B. Immediately following establishment of muscular firing patterns and joint mobility during phase 0
C. Immediately following completion of a running progression program during phase III
D. Immediately following the muscular endurance program during phase I

QUESTION 5. What are the two clearance tests that allow an athlete to begin the running progression steps?

A. Ability to pass the Vail Sports Test of muscular endurance, muscular power, and ability to accept eccentric load
B. Ability to Olympic squat 75% of body weight
C. A thigh girth measured at 10 cm superior to the border of the patella within 1 cm of unaffected side
D. Ability to complete a full one-legged squat on the affected leg

Answer Key

QUESTION 1. Correct answer: **D** (see Phase 0)

QUESTION 2. Correct answer: **D** (see Phase III exercises)

QUESTION 3. Correct answer: **B** (see Introduction)

QUESTION 4. Correct answer: **C** (see Phase III)

QUESTION 5. Correct answer: **C** and **D** (see Phase III)

Chapter 35



Lateral Collateral Ligament and Posterolateral Ligament Injuries

ISOLATED LATERAL COLLATERAL LIGAMENT INJURIES: INTRODUCTION

William G. Clancy, Jr, MD

Epidemiology

- Frequency: relatively uncommon
- Age: under 30 years of age
- Sex: predominantly males
- Sport: football, wrestling, soccer

Pathophysiology

Traumatic Factors

- Isolated lateral collateral ligament injuries, although not rare, are still relatively uncommon and frequently go unrecognized. The major reasons why it is infrequent is that the necessary varus force to the knee is often blocked by the opposite leg with a resulting valgus to the protecting knee.
- Wrestling, soccer and football have produced more isolated lateral collateral ligament injuries in the author's experience.
  - In wrestling this injury can occur when the referee places the wrestlers in the neutral position in which one wrestler is standing while the other is put in the kneeling position facing his opponent. At the referee's whistle, the knee-lying player shoots for the inside knee of his opponent, while at the same time his hand grasps the foot of the same knee. With the foot now fixed there can be a significant varus load applied to the opponent's knee.
  - In soccer, this injury may occur when an opposing player attempts to slide tackle the ball from a player where the ball is on the foot of the player's extended outside leg. If the opposing player's body or leg hits the inside of the player's outside leg or knee, a varus load can be applied to that knee producing injury to the lateral collateral ligament.
  - In football, isolated lateral collateral ligament injuries occur more frequently in a pile up in which the player's foot is fixed by the bodies of fallen players and his upper body is adducted away from the fixed foot producing a varus load at the knee.

Classic Pathological Findings

- Stable to varus stress at full extension
- No appreciable laxity at 30° to varus stress in first- or second-degree sprains
- Mild laxity at 30° varus stress; minimal at 0° and no palpable fibular collateral ligament in the figure-four position for a third-degree sprain

Clinical Presentation

Physical Examination

Abnormal Findings

- Minimal knee effusion
- Minimal to mild laxity at 30° knee flexion but none at full extension (Figure 35-1)
- Pain to palpation of the intact lateral collateral in the figure four position for 1° and 2° sprains
- No palpable lateral collateral ligament in a figure four position in 3° sprains
- Careful examination will localize the pain to the lateral collateral ligament, particularly when the knee is placed in a figure four position allowing for palpation of the ligament. The lateral knee pain should be isolated only to palpation of the ligament and not the

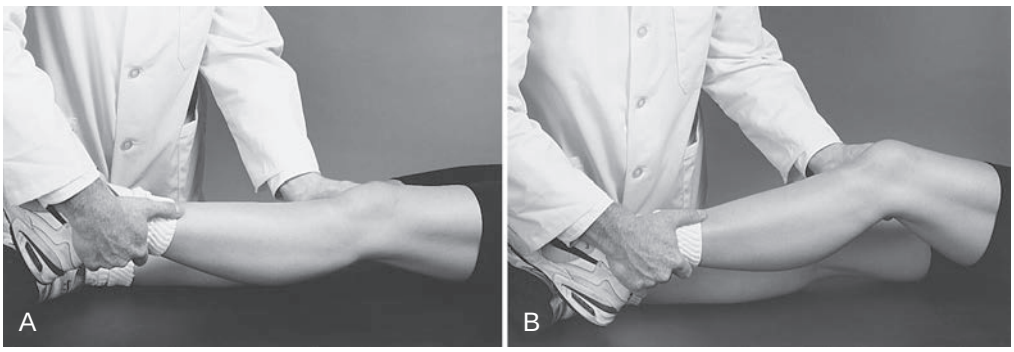

FIGURE 35-1. Varus stress lest. **A,** In extension. **B,** In flexion. Minimal to mild laxity at 30° knee flexion but none at full extension. *(From Reider B: The orthopaedic physical examination, ed 2. Philadelphia; WB Saunders, 2005.)*

anterolateral or posterolateral joint line. If there is a complete tear, the ligament will not be palpable and there should be mild increase in varus laxity at 30° of knee flexion but no appreciable laxity at full extension. Gollehon et al[1] in their report of sectioning of only the lateral collateral ligament found that there was only a 1° to 4° increase in external rotation at 30° of knee flexion and that varus laxity at 30° of knee flexion only increased from 1 to 4 mm. This study appears to correlate with our clinical findings that there is no appreciable laxity at 0° and 30° of knee flexion in isolated first and second degree lateral collateral ligament sprains. In isolated third degree sprains there should be only mild increase in varus laxity at 30° of knee flexion and minimal if at all at full extension. If there is moderate laxity at 0° and 30° of knee flexion this would suggest that there is also at least some injury to the posterolateral structures and perhaps to the cruciate ligaments.

- Varus stability is evaluated in the horizontal plane at 0° and 30° of flexion and should be equal to that of the opposite leg. External tibial rotation is measured at 30° and 90° of knee flexion. If the injury also involves a complete tear of the posterior cruciate ligament there is a marked increase in external rotation at 90° as compared to the rotational laxity measured at 30° of knee flexion as noted by Gollehon et al[1] and Grood et al[2]. In those with either an acute or chronic injury the dial test, either prone or supine performed at 30° and 90°, should establish that there is a significant difference in external tibial rotation between the normal and injured knee. However, when there has been an isolated posterior cruciate ligament injury one must maintain the neutral position of the tibia when performing the dial test otherwise the posterior tibial subluxation and coupled normal tibial external rotation may appear to be greater than it is due to the increase in posterior tibial translation. If there is normal varus laxity at 0° and 30° of knee flexion one must be suspect as to whether there is a significant injury to the posterolateral structures. A reverse pivot shift test as described by Jakob[3] is usually a sign of at least a severe posterolateral injury and a possible injury to the posterior cruciate ligament. In this test the tibia is externally rotated and flexed to 90°. A valgus load is applied and maintained as the tibia is extended while maintaining the external tibial rotation. At approximately 30° knee flexion one should feel a sudden pivot and reduction of the tibia. One must make sure this pivoting produces an anatomic reduction. In some cases this pivot-like sensation could actually be an anterior tibia subluxation due not to posterolateral laxity but due to anterior cruciate insufficiency. The pivot shift test for anterior cruciate ligament insufficiency, which is the reduction of the abnormal anterior translation, occurs at the same angle of knee flexion as does the reduction of the abnormal externally rotated tibia in those with posterolateral injury.

Pertinent Normal Findings

- No or minimal knee effusion
- Negative Lachman's test and negative posterior drawer test
- No appreciable increase in external rotation at 30° and 90° of knee flexion

Imaging

(Figure 35-2)

- MRI should be able to differentiate a lateral collateral ligament tear from a meniscal injury, and can document if there is some additional injury to the posterolateral structures and cruciate ligaments.
- Roentgenography: normal
- MRI: no lateral meniscus tear
- Edema of the lateral collateral ligament with partial or complete tear of only the lateral collateral ligament

Differential Diagnosis

- Lateral meniscus tear
- Lateral side soft tissue contusion
- Some isolated lateral collateral ligament injuries are often unrecognized due to the fact that they often do not produce severe knee pain nor produce a detectable knee effusion in first- or second-degree sprains. Often the initial diagnosis is that of a possible lateral meniscus tear.
- Lastly there is another abnormal entity that involves the posterolateral corner of the knee. This author has termed this entity *functional symptomatic posterolateral laxity*.

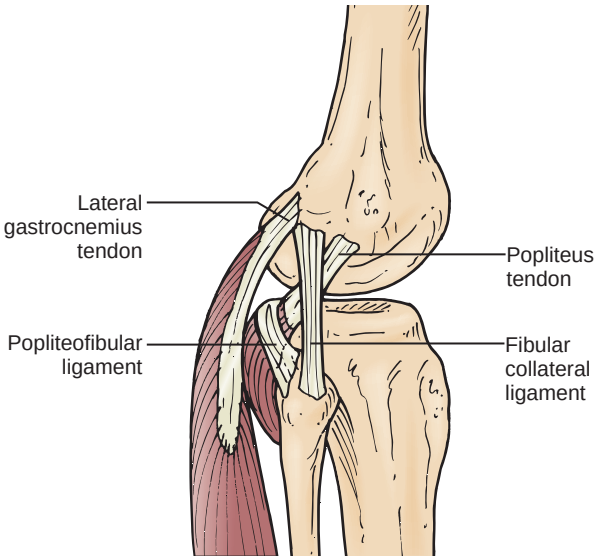

FIGURE 35-2. The isolated fibular collateral ligament, popliteus tendon, popliteofibular ligament, and lateral gastrocnemius tendon (lateral view, right knee). *(Redrawn from LaPrade RF, Ly TV, Wentorf FA, Engeretsen L: The posterolateral attachments of the knee. Am J Sports Med 31:854–860, 2003.)*

- These patients have no prior history of injury or have a history of a minimal injury.
- They all have complaints of frequent episodes of functional instability even when walking straight ahead.
- They do not have symptoms of an unstable lateral meniscus as seen in those with popliteomeniscal injuries or root avulsions and at the time of arthroscopy they do not have any signs of posterior nor posterolateral meniscal laxity.
- These patients usually have very significant increase in bilateral external tibial rotation with no increase in varus laxity at 0° or 30° of knee flexion. A dial test usually does not delineate any difference in external rotation. A reverse pivot shift test often reproduces their pain but they do not have a positive reverse pivot shift test.
- A number of these patients can reproduce their mechanism of instability. When sitting if they place the foot of the involved leg on a small stool with their knee approximately flexed 45° to 60° they can then readily sublux their tibia posterolaterally and then they can actively reduce it. This finding is similar to those patients who can voluntarily sublux their shoulder posterior or anteriorly and then voluntarily reduce it. In the shoulder, it is called electrical disassociation first described and documented in the shoulder with EMG by Rowe.[4] It appears that the biceps muscle, subluxes the tibia posterolaterally and the popliteus muscle then reduces the subluxation.

Treatment

Nonoperative Management

- The literature is extremely deficient in the treatment and follow-up of isolated lateral collateral ligament injuries. The only study in the literature is that of Kannus,[5] who reported on the follow up of nonoperative treatment of isolated grade II and grade III lateral collateral ligament sprains. He noted that all the nonoperated grade II sprains had good to excellent results whereas the non-operated grade III sprains did not fare well. The grade III sprains for the most part in this study were not isolated grade III sprains of the lateral collateral ligament as most if not all had additional injuries to the anterior cruciate and/or posterior cruciate ligament. MRI evaluations were not available at the time of this study.
- It has been the author's experience and Harner's[6] report that in surgery of the acute and chronic cases of lateral and posterolateral corner injuries that the posterior cruciate ligament must be reconstructed if injured for any successful repair of the lateral and posterolateral repairs and/or reconstructions. In the acute case all structures should be repaired or reconstructed. Nonbony avulsion injury to the popliteus tendon requires a reconstruction at the time of surgery. Thus one is creating a ligament to substitute for the popliteus muscle tendon complex. This is our treatment also for those with symptomatic physiologic posterolateral instability. The lateral collateral ligament might need an augmentation in the acute case or a graft substitute which is often needed in the chronic case. We as well as others have reported on techniques that appear to yield highly successful results. The surgical technique should include reconstruction of the popliteal ligament as it is the strongest and prime stabilizer of the posterolateral corner of the knee. In those patients with chronic instability who have a varus alignment and/or a varus thrust, a valgus osteotomy should be performed prior to or during the reconstructive procedure.

Surgical Indications

- Surgery indicated only when either cruciate ligament is torn.

Evidence

Kannus P: Nonoperative treatment of Grade II and Grade III sprains of the lateral ligament compartment of the knee. *Am J Sports Med* 17:83–88, 1989.

This is a retrospective study of 23 patients evaluated at an average 8 years after injury. There were 11 patients who were graded as having a grade II isolated lateral collateral ligament injury who were graded good or excellent. The 12 patients with a grade III injury all graded as poor. However, on review, all of these grade III injuries were not isolated but also involved either one or both cruciate ligament injuries. This paper documents that nonoperative treatment of grade II injuries did well with nonoperative treatment although the number of patients in this report was quite small. (Level IV evidence)

Grood ES, Noyes FR, Butler DL, et al: Ligamentous and capsular restraints preventing straight medial and lateral laxity in intact human cadaver knees. *J Bone Joint Surg* 58:159–172, 1981.
Markolf KL, Mensche JS, Amstutz HC: Stiffness and laxity of the knee—the contributions of the supporting structures. *J Bone Joint Surg* 58:583–594, 1976.

Nielsen S, Rasmussen O, Ovesen J, et al: Rotatory instability of cadaver knees after transection of collateral ligaments and capsule. *Arch Orthop Trauma Surg* 103:165–169, 1984.

Biomechanical studies of Grood et al., Markolf et al., and Nielsen et al. all documented that isolated sectioning of the lateral collateral ligament produced only 3° to 4° of varus laxity at 30° knee flexion and none or minimal laxity at full extension. Nielsen's also reported no increase in posterolateral rotational laxity at 30° knee flexion.

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Multiple-Choice Questions

QUESTION 1. In examining a patient with suspected isolated lateral collateral ligament injury, which of the following would be the most likely clinical finding?

A. Significant knee effusion, lateral joint line pain, mildly positive Lachman's test and mild varus laxity at full extension
B. Lateral knee pain, knee effusion, pain at the anterolateral joint line, negative Lachman's test, palpable and painless fibular collateral ligament
C. Lateral and posterior knee pain, mild knee effusion, moderate varus laxity at full extension and a positive posterior drawer test
D. Lateral knee pain, no effusion, negative Lachman's and negative posterior drawer test. No varus laxity at full extension, nor at 30° flexion and pain to palpation of an intact fibular collateral ligament
E. Lateral knee pain with mild varus laxity at full extension and moderate laxity at 30° knee flexion and noticeable increase in external rotation at 30° knee flexion

QUESTION 2. Isolated sectioning of the lateral collateral ligament:

A. Produces no significant increase in varus laxity at full extension but marked increase in varus laxity at 30° knee flexion
B. Produces marked increase in varus laxity at both full extension and 30° knee flexion
C. Can produce a positive reverse pivot shift test
D. Produces only a very minimal increase in varus laxity and external rotation at 30° of knee flexion
E. Produces marked increase in external tibia rotation at 30° of knee flexion but none at full extension

Answer Key

QUESTION 1. Correct answer: **D** (see Pathophysiology)

QUESTION 2. Correct answer: **D** (see Physical Examination)

COMBINED LATERAL COLLATERAL LIGAMENT AND POSTEROLATERAL LIGAMENTOUS INJURIES: INTRODUCTION

William G. Clancy, Jr, MD

Epidemiology

- Age: usually under 30 years of age
- Sex: male more predominate than females
- Sport: football, wrestling, soccer

Pathophysiology

Intrinsic Factors

- Severe injuries to the lateral and posterolateral structures are rarely if ever isolated injuries. These injuries, although rare, are seen in contact sports mainly football, wrestling, and soccer. Severe injuries to these structures will involve injuries to either or both of the cruciate ligaments and possibly the common peroneal nerve and to a lesser extent the popliteal artery. The structures vital to lateral and posterolateral stability include the lateral collateral ligament, the popliteofibular ligament, the popliteus muscle tendon complex, the posterolateral capsule including the arcuate ligament and the biceps muscle tendon complex. These structures combine to provide lateral stability and control tibial external rotation.
- In order to understand the importance of the lateral and posterolateral structures of the knee and the role they play in functional stability one needs to know the

normal range of external tibial rotation and the biomechanical strength of the static stabilizers. Wang and Walker[1] in their study on eight cadaver knees reported that there was approximately 8° of external rotation present at 25° of knee flexion with a minimum of 6° and a maxiumum of 10°. Fukubayashi et al.[2] documented that there is a coupled translation and rotation with anterior and posterior forces applied to the knee. With a posterior force there is a coupled posterior translation and an external rotation. They noted with a 100 N load that the greatest amount of external rotation was approximately 8° at 25°, 12° at 75°, and 6° at 90° of knee flexion.

- Biomechanical studies of sectioning of the various lateral structures and the effects on external rotation have been performed by numerous authors. Nielsen et al.[3] noted that the popliteus tendon as a passive stabilizer was the prime stabilizer to posterolateral stability due to its attachments to both the arcuate ligament and the tibia as documented by Last. Nielsen's study also documented that marked posterolateral instability was impossible with an intact popliteus tendon. Gollenhon et al.[4] and Grood et al.[5] noted that sectioning of all the posterolateral structures with an intact posterior cruciate ligament produced significant increase in external rotation most notably at 30° of knee flexion and additional sectioning of the posterior cruciate ligament further increased abnormal external rotation most notably at 90° of flexion.
- A summation of the reports in the literature on the biomechanical strengths of the lateral structures noted that the load to failure of the lateral collateral ligaments in 49 knees (age range 40 to 93 years) was 513 N (range 295 to 746 N). The maximum load to failure for the popliteofibular ligament in 37 knees (age range 40 to 93 years) was 132 N (range of 42 to 298 N). This structure which is a branch of the popliteus tendon appears to be the weakest of all the lateral stabilizers but is still an important stabilizer. The maximum load to failure for the popliteus muscle tendon complex in 8 knees (average age of 57 years) was 700 N. The popliteus muscle tendon complex is the strongest static stabilizer but of more importance is its strong muscular contraction counteracting excessive posterolateral rotation.

Extrinsic Factors

- Pile-up in football
- Takedown from the neutral position in wrestling
- Sliding tackle in soccer

Traumatic Factors

- A varus blow to the knee with a planted foot or an anterior varus blow to the knee with a planted foot

Classic Pathological Findings

- Anterior cruciate and/or posterior cruciate ligament with injury to the lateral collateral ligament, popliteal fibular ligament with injury to the popliteus muscle tendon complex, biceps tendon, common peroneal nerve, and possibly the popliteal artery

Clinical Presentaition

History

- A contact injury with a varus load to the knee either flexed or extended with the foot planted with ensuing severe lateral knee pain

Physical Examination

Abnormal Findings

- Marked varus laxity at 0° flexion
- Positive Lachman's test and/or a positive posterior drawer test. There may be neurologic findings such as inability to dorsiflex the foot and toes and loss of sensation on the lateral side of the leg and dorsum of the foot

Pertinent Normal Findings

- Usually intact medial structures without valgus laxity at 30° and 0° of flexion

Imaging

- MRI findings
  - Tear of the ACL and/or PCL
  - Tears of the lateral collateral ligament, the popliteal fibular ligament, lateral capsule and injury to the popliteus muscle tendon complex and the biceps tendon

Differential Diagnosis

- This entity should not be confused with any other except in those with open physeal growth plates, where a physeal fracture may also be present.

Treatment

Surgical Indications

- Reconstruction of the appropriate cruciate ligaments
- Repair and when necessary augment or reconstruct the appropriate lateral stabilizing structures especially the popliteus tendon complex
- Valgus tibial osteotomy in chronic cases with varus alignment or varus thrust prior to or at the time of reconstruction

Aspects of History, Demographics, or Exam Findings that Affect Choice of Treatment

- If there is a physeal fracture it should be stabilized first, after which the soft tissue injuries should be repaired or reconstructed.

Aspects of Clinical Decision Making When Surgery Is Indicated

- First the anterior and/or posterior cruciate ligaments need to be reconstructed and then the lateral and posterolateral structures need to be stabilized at the same operation and not staged. The common peroneal nerve needs to be explored as the nerve curves around the fibular neck and the fibrotic band under the anterolateral muscles needs to be released when present.

Evidence

BIOMECHANICAL

Fukubayashi T, Torzilli PA, Sherman MF, et al: An in Vitro biomechanical evaluation of anterior-posterior motion of the knee. *J Bone Joint Surg* 64:258–264, 1982.
Gollehon DL, Torzilli PA, Warren RF: The role of posterolateral and cruciate ligaments in the stability of the human knee. *J Bone Joint Surg* 69:233–242, 1987.
Grood ES, Stowers SF, Noyes FR: Limits of movement in the human knee. *J Bone Joint Surg* 70:88–97, 1988.
Nielsen S, Helmig P: The static stabilizing function of the popliteal tendon in the knee, an experimental study. *Arch Orthop Trauma Surg* 104:357–362, 1986.
Wang C, Walker PS: Rotatory laxity of the human knee joint. *J Bone Joint Surg* 56:161–170, 1974.

These reports document the abnormal translations and rotations that occur when sectioning the posterolateral structures and the posterior cruciate ligament.

CLINICAL

Cain EL, Clancy WG, Jr: *Posterolateral corner and fibular collateral ligament reconstruction. Master techniques in orthopedic surgery, reconstructive knee surgery*, ed 3, 2007, Lippincott Williams & Wilkins.
Harner CD, Vogrin TM, Höher J, et al: Biomechanical analysis of a posterior cruciate ligament reconstruction: deficiency of the posterolateral structures as a cause of graft failure. *Am J Sports Med* 28:32–39, 2000.
Jakob RP, Hassler H, Staeubli HU: Observations on rotator instability of the lateral compartment of the knee. *Acta Orthop Scand Suppl* 52:191, 1981. *(Level IV evidence)*.
LaPrade RF, Johansen S, Wentorf FA, et al: An analysis of an anatomical posterolateral knee reconstruction, an in vitro biomechanical study and development of a surgical technique. *Am J Sports Med* 32:1405–1414, 2004.
Miyatake Sh, Kondo E, Tsai T-Y, et al: Biomechanical comparisons between 4-strand and modified Larson 2-strand procedures for reconstruction of the posterolateral corner of the knee. *Am J Sports* 39:1462–1469, 2011.

These papers present the importance of diagnosing and stabilizing the posterolateral corner as well as surgical techniques encompassing reconstruction of the popliteal tendon as well as the other important posterolateral structures.

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Multiple-Choice Questions

QUESTION 1. In order to produce a reverse pivot shift there must be complete disruption of the:

A. Fibular collateral ligament
B. Fibular collateral ligament and the anterior cruciate ligament
C. Fibular collateral ligament and popliteomeniscal ligaments
D. Isolated sectioning of the posterior cruciate ligament
E. Fibular collateral ligament, popliteofibular ligament and popliteus tendon posterolateral capsule/arcuate ligament

QUESTION 2. In those patients with chronic lateral, posterolateral, and posterior cruciate ligament injuries one needs to treat:

A. Only the posterior cruciate ligament
B. Only the posterolateral structures
C. Only the posterior cruciate ligament and the posterolateral capsule
D. Only the popliteus muscle complex
E. The posterior cruciate ligament and all of the posterolateral structures

QUESTION 3. In those patients with an acute combined anterior cruciate, posterior cruciate and lateral and posterolateral corner injuries without popliteal or peroneal nerve injury the most appropriate treatment is:

A. No operative management
B. Reconstruct the anterior cruciate ligament first then at a later date surgically treat the other injuries
C. Reconstruct the posterior cruciate first then at a later date surgically treat the other injuries
D. Reconstruct the anterior and posterior cruciate ligaments first and at a later date treat the posterolateral corner injuries
E. Reconstruct the anterior cruciate, posterior cruciate ligament and the lateral and posterolateral corner injuries all at the same time

Answer Key

QUESTION 1. Correct answer: **E** (see Pathophysiology)

QUESTION 2. Correct answer: **E** (see Pathophysiology)

QUESTION 3. Correct answer: **E** (see Pathophysiology)

NONOPERATIVE REHABILITATION OF LATERAL COLLATERAL LIGAMENT SPRAINS

William G. Clancy, MD, Kevin E. Wilk, PT, DPT, and Leonard C. Macrina, MSPT, SCS, CSCS

GUIDING PRINCIPLES OF NONOPERATIVE REHABILITATION

- Initial focus of the rehabilitation should work to decrease pain and swelling while minimizing the effects of immobilization and muscular atrophy.
- Never overstress the healing tissue.
- Allow enough time for adequate healing to occur which will allow the athlete to return to sports without long-term deleterious effects

Phase I (weeks 0 to 4 to 6 postinjury)

Goals

- Early protected ROM
- Prevent quadriceps atrophy
- Decrease effusion/pain

Protection

- The knee is protected by placing the knee in a brace, typically locked at 0°, while walking on crutches to slightly unweight the injured extremity.

Management of Pain and Swelling

- The patient is instructed to ice and elevate the extremity for 20 minutes every hour throughout the first 2 weeks or until adequate swelling control is attained. Icing should be performed in full knee extension to prevent a flexion contracture from forming.
- A compression sleeve or ace wrap may be utilized to keep swelling to a minimum.
- Weight bearing may be allowed immediately, however, in a brace locked at 0° and while using crutches.
- Analgesic and antiinflammatory medications may be utilized to decrease pain and swelling.
- Low-level laser therapy (cold laser) may be utilized to improve tissue healing[1-3] (Figure 35-3).

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- The rehabilitation specialist may begin patella mobilizations immediately to tolerance. Also, gentle manual passive range of motion of the knee may be initiated to neuromodulate pain and aid in collagen alignment of the healing ligamentous tissue.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- The athlete may begin some gentle calf and hamstring stretching to maintain flexibility and assist in maintaining full knee extension.

Other Therapeutic Exercises

- Neuromuscular electrical stimulation to the quadriceps is initiated immediately during straight leg raises.
- Hip adduction and external and internal rotation may also be performed. Sidelying hip abduction should be avoided to decrease stresses on the lateral knee soft tissue structures.
- Ankle, hip, and core strengthening may be initiated as long as there are no deleterious stresses on the lateral knee structures.
- Hamstring and calf stretching may be performed to maintain lower leg flexibility

Activation of Primary Muscles Involved

- Quadriceps, hip abductors, adductors, extensors, external rotators

Sensorimotor Exercises

- Passive/active joint repositioning may be utilized to initially improve joint proprioception and awareness.

Open and Closed Kinetic Chain Exercises

- Straight leg raises, four-way ankle with resistance tubing

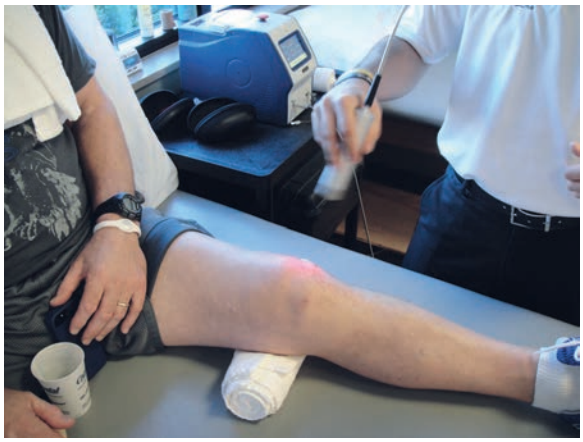


FIGURE 35-3. Low level laser therapy to promote a healing response at the site of the injury.

Neuromuscular Dynamic Stability Exercises

- Forward/backward weight shifting onto the involved extremity followed by lateral weight shifting as long as there's no lateral knee pain. Single leg stance activities may be initiated as tolerated to further challenge the patient's dynamic stability.

Functional Exercises

- Crutch training while in the brace locked at 0 degrees.

Milestones for Progression to the Next Phase

- Minimal pain or swelling
- Physical exam shows minimal to no lateral knee opening with varus stressing
- Good quadriceps control with straight leg raises with no quadriceps lag
- Voluntary quadriceps activation

Phase II (weeks 6 to 10)

Goals

- Full painless ROM
- Restore strength
- Ambulation without crutches

Protection

- Crutches no longer needed
- Brace used with walking but unlocked to available range of motion
- Progress to hinged-upright brace (DonJoy Playmaker) for medial/lateral stability

Management of Pain and Swelling

- Continue ice, compression, and elevation particularly after the rehabilitation visit. May initiate moist hot packs before the treatment to bring blood to the area and improve soft tissue mobility. PROM also utilized to decrease pain and stiffness.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Continue to progress passive range of motion to relative tolerance with careful attention to avoid over stressing the lateral knee.

Soft Tissue Techniques

- Soft tissue mobilization to the quadriceps and hamstrings may aid in improving flexibility. Cross friction massage to the LCL may aid in tissue healing and collagen alignment.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- The athlete may work on a complete stretching program for the quadriceps, hamstring, iliotibial band, and gastrocnemius-soleus complex.

Other Therapeutic Exercises

- Progress weight-bearing strengthening exercises
  - Bicycle
  - Leg press (0° to 80°)
  - Knee extensions 60° to 0°
  - Multi Hip machine
  - Hip external/internal rotation
  - Wall squats 0° to 60°

TIMELINE 35-1: **Nonoperative Rehabilitation of Lateral Collateral Ligament Sprains**

PHASE I (Maximal Protection, weeks 1 to 6)		
Week 1	**Week 2**	**Week 6**
• Ice, compression, elevation • Knee hinge brace non-painful ROM; if needed • Crutches, weight bearing as tolerated • Passive range of motion/active assistive range of motion to maintain ROM • Electrical muscle stim to quads (8 h a day) • Isometrics quads: quad sets, straight leg raises (flexion)	• Continue above exercises • Quadriceps sets • Straight leg raises (flexion, adduction) • Abduction isometrics • Hamstring isometric sets • Hip ER/IR • Sidelying clams • Well leg exercises • Initiate minisquats	• Continue above exercises • Crutches—weight bearing as tolerated • ROM as tolerated • Eccentric quadriceps work • Bicycle for ROM stimulus • Resisted knee extension with electrical muscle stimulation 60°-0° • Initiate hip abduction as symptoms allow • Initiate leg press 0°-80° • Brace worn at night, brace during day as needed • Weight shifts • Single leg balance

- Sidelying clams
- Lateral step-downs
- Resisted lateral walking (monster walks)—resistance should be just proximal to the knee joint and closely monitored for pain
- Single-legged balance on foam
  - Light perturbations

Activation of Primary Muscles Involved

- Weight-bearing strengthening to include the quadriceps, hamstring, hip musculature with particular attention to the abductors, extensors, and external rotators.

Sensorimotor Exercises

- Tilt board minisquat, single leg stance activities on unstable surfaces, light perturbation training

Open and Closed Kinetic Chain Exercises

- See abovementioned exercises

Techniques to Increase Muscle Strength, Power, and Endurance

- See abovementioned exercises

Neuromuscular Dynamic Stability Exercises

- As mentioned, perturbation training on unstable surfaces once the athlete demonstrates good leg control with ambulating and demonstrates adequate baseline strength

Functional Exercises

- Normalize gait; progressively challenging single leg balance activities; eccentric quadriceps strengthening. May initiate aquatic therapy including jogging and lateral movements

Sport-Specific Exercises

- See combination of above exercises

Milestones for Progression to the Next Phase

- Full, pain-free PROM and AROM
- Stable knee without excessive varus laxity on physical examination
- >4+/5 MMT for involved lower extremity musculature including the quadriceps, hamstrings, gluteals, hip rotators

Phase III (weeks 10 to 16)

Goals

- Increase strength and power

Protection

- Hinged knee brace (Figure 35-4) or a custom knee brace to protect the lateral collateral ligament

Management of Pain and Swelling

- Cryotherapy as needed in response to each treatment session

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Continue to maintain passive range of motion to full and work flexibility for the entire lower body.

TIMELINE 35-1 Nonoperative Rehabilitation of Lateral Collateral Ligament Sprains (Continued)

PHASE II (Intermediate Phase, weeks 6 to 10)	PHASE III (Advanced Phase, weeks 10 to16)	PHASE IV (Maintenance Program)

• Continue strengthening program with PRE's
• Continue electric muscle stim to quads during isotonic strengthening
• Continue ROM exercise
• Emphasize closed kinetic chain exercises; lunges, squats, lateral lunges, wall squats, lateral step-ups
• Bicycle for endurance
• Water exercises, running in water forward and backward
• Full ROM exercises
• Flexibility exercises, hamstrings, quads, IT Band, etc.
• Proprioception training (balance drills)
  • Weight shifts
  • Tilt board squats
  • Single leg balance on unstable surface
• Stairmaster/elliptical for cardiovascular work
	• Continue strengthening program
	  • Wall squats
	  • Vertical squats
	  • Lunges
	  • Lateral lunges
	  • Step ups
	  • Leg press
	  • Knee extension
	  • Hip abd/adduction
	  • Hamstring curls
	  • Emphasis:
	  • Functional exercise drills
	  • Sport cord lunges, cone drills
	  • Fast speed isokinetics
	  • Eccentric quads
	  • Isotonic hip add, medial hamstrings
	• Isokinetic test
	• Proprioception training
	• Endurance exercise
	• Stationary bike 30 to 40 min
	• Initiate agility program, sport-specific activities
		• Continue isotonic strengthening exercises
		• Continue flexibility exercises
		• Continue proprioceptive activities



FIGURE 35-4. Hinged knee brace (Playmaker, DJO Global, Vista, California) used to give lateral stability as the patient progresses through the rehabilitation program.

Soft Tissue Techniques

- For lower extremity musculature, if lacking full excursion a foam roller may be utilized as an adjunct treatment to release trigger points

Stretching and Flexibility Techniques for the Musculotendinous Unit

- See above

Other Therapeutic Exercises

- Continue with machine weights to entire lower body musculature
- Progressive body weight exercises including
  - Forward and lateral lunges
- Sports cord exercises to work on NM control, dynamic stability and hand-eye coordination (Figure 35-5)
- Core stabilization

Activation of Primary Muscles Involved

- Continue to progress complete lower body strengthening to quadriceps, hip musculature

Sensorimotor Exercises

- Perturbation training on unstable surfaces
- BOSU squats (Figure 35-6)
- Single leg stance drills including:
  - Star drill
  - Ball toss

Open and Closed Kinetic Chain Exercises

- See previous strengthening exercises



FIGURE 35-5. Sport cord lateral lunging while catching a ball to promote dynamic stability, neuromuscular control and hand-eye coordination.



FIGURE 35-6. BOSU squat on an unstable surface while catching a basketball.

Techniques to Increase Muscle Strength, Power, and Endurance

- Progressive resistance exercises, aerobic conditioning including stationary bike, elliptical, swimming and pool running

Neuromuscular Dynamic Stability Exercises

- See above

Plyometrics

- May initiate light plyometric exercises on leg press toward the end of this phase depending on strength and tissue healing
- Two-legged hops in place
- Two-legged hops forward/back emphasizing landing technique

Functional Exercises

- Pool exercises including swimming, running, antigravity treadmill as long as no increase in symptoms.

- Progression to treadmill running as long as the patient completes previous functional exercises without difficulty or pain.

Sport-Specific Exercises

- See functional exercises above

Milestones for Progression to the Next Phase

- Full PROM and AROM, pain free
- No effusion through joint line and suprapatella girth measurements
- No lateral instability with clinical examination
- Muscle strength 85% contralateral side per isokinetic testing
- No tenderness to palpation over the LCL
- No changes in posterolateral laxity
  - May use Dial test
  - Varus laxity testing at 0° and 25°
- Quadriceps peak torque to body weight 60% to 65% on isokinetic testing

Phase IV (weeks 16+)

Protection

- Functional knee brace if prescribed by the MD

Management of Pain and Swelling

- As needed. See previous sections

Techniques for Progressive Increase in Range of Motion

Soft Tissue Techniques

- Soft tissue mobilization as needed to lower extremity musculature as the patient progresses through higher level strengthening to diminish delayed onset muscle soreness (DOMS)

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Dynamic flexibility exercises before the athlete begins workouts.
- Static stretching may be employed as needed after exercising.

Other Therapeutic Exercises

- Continue total leg strengthening with progressive resistive exercises
- Gradually progress running on treadmill and slowly progressing to field work
- Initiate agility drills to focus on cutting and start-stop drills

Activation of Primary Muscles Involved

- Quadriceps, gastrocnemius-soleus complex, hip musculature

Sensorimotor Exercises

- Continued balance activities and perturbation training on unstable surfaces, incorporating functional activities including throwing and catching

Open and Closed Kinetic Chain Exercises

- Continue aforementioned exercises and progress plyometrics to include box jumps, skip jumps, and scissor jumps to improve power and endurance.
- Verbal cueing is utilized to ensure the athlete is landing correctly and with even weight distribution bilaterally to prevent compensation.

Techniques to Increase Muscle Strength, Power, and Endurance

- See above

Neuromuscular Dynamic Stability Exercises

- See above

Plyometrics

- See above

Functional Exercises

- Progression through running program depending on sport (Box 35-1)
- Agility drills
  - Lateral cariocas
  - Figure of 8's
  - Shuttle runs
  - Interval sprinting program
  - Specific sport drills and activities

Sport-Specific Exercises

- On field drills simulating the patient's sport

Milestones for Progression to Advanced Sport-Specific Training and Conditioning

- Full Strength 5/5 manual muscle test
- Full PROM and AROM
- Isokinetic testing criteria:
  - Quadriceps torque to body weight ratio ≥ 65%
  - Hamstrings/quadriceps ratio within 70%
  - Bilateral comparison of quadriceps within 90%
  - Bilateral hamstrings within 100%
  - Acceleration rate at 0.2 seconds (80% of quads peak torque)
- No pain with functional activities including running, jumping and cutting
- >85% proprioception on Biodex Stability System

Criteria for Abandoning Nonoperative Treatment and Proceeding to Surgery or more Intensive Intervention

- Continued pain
- Varus laxity that has progressed beyond 1+ end feel

BOX 35-1 Interval Running Program

- FORWARD RUNNING: Run at _____% of maximal effort for a distance of _____ feet straight ahead. Perform _____ times.
- BACKWARD RUNNING: Run backwards at _____% maximal effort for a distance of ___ feet. Repeat ____ times.
- SIDE SHUFFLE: Begin by standing side-ways, step out with the lead foot and follow with the back foot in a side-stepping motion. Perform at ____% of maximal effort for a distance of _____ feet. Repeat in opposite direction. Perform _____ times in each direction.
- START & STOP: Run straight forward at ____% of maximal effort for a distance of ____feet then stop as quickly as possible. Perform ____times.
- FIGURE of 8: Place two cones _____ feet apart. Start by standing in between cones and run a circle around one cone, then back to the starting position. Continue around opposite cone in a figure of 8 pattern. Perform at _____% maximal effort. Perform ____ times.
- 45-DEGREE CUTS: Run at ____% maximal effort for a distance of ____ feet, plant the involved leg and change direction such that the subsequent path you are running makes a 45-degree angle with the original path. Repeat the process while cutting on the uninvolved extremity. Perform ____ times.
- 90-DEGREE CUTS: Run at ____% maximal effort for a distance of ____ feet, plant the involved leg and change direction such that the subsequent path you are running makes a 90-degree angle with the original path. Repeat the process while cutting on the uninvolved extremity. Perform ____ times.
- FOUR-CORNERS DRILL: Place four cones in a square at a distance of ____ feet apart. Run forward at _____% maximal effort. Plant on the involved leg while maintaining the same body direction, then side step to the next cone. Backpedal to the next cone and another side step to the final cone. Repeat ____ times.

Indoor Interval Running Program

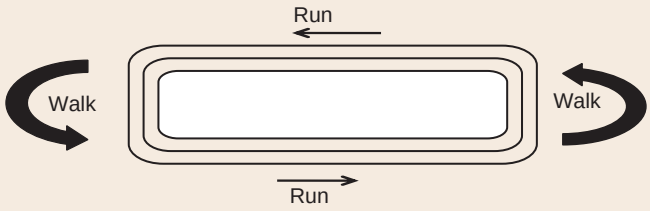
- Jog ~18 laps around the basketball court (~1 mile). Stop immediately if you begin to limp or feel any pain. If pain-free:
- Run____ lengths of the gym at ½ speed. If no pain, then:
- Run____ lengths of the gym at ¾ speed. If no pain, then:
- Run____ lengths of the gym at full speed. If no pain, then:
- Run____ lengths, cutting by planting on involved leg, at full speed. If pain free:
- Perform 10 minutes of running or jumping drills related to your sport. When you have completed the entire program, you are ready to return to competition.
  - If you do not complete the entire program on a particular day, you should begin at the first step the following day.
  - Each running session must be followed by a good stretching program for each major muscle group of the lower extremities, along with ice application for 15 minutes.

Outdoor Interval Running Program

- Jog 1 mile. Stop immediately if you begin to limp or feel any pain. If pain-free:
- Perform six 80-yard sprints at ½ speed. If no pain or limp:
- Perform six 80-yard sprints at ¾ speed. If no pain or limp:
- Perform six 80-yard sprints at full speed. If no pain or limp:
- Perform six 80-yard sprints with cutting at ½ speed. If no pain:
- Perform six 80-yard sprints with cutting at ¾ speed. If no pain:
- Perform six 80-yard sprints with cutting at full speed. Always plant on the outside foot to cut. If no pain:
- Perform 10 minutes of running and/or jumping drills related to your sport. When the entire program has been completed, you are ready to return to competition.
  - If you do not complete the entire program on a particular day, you should begin at the first step the following day.
  - Each running session must be followed by a good stretching program for each major muscle group of the lower extremities, along with ice application for 15 minutes.

Outdoor Track Interval Running Program

- Run on an outdoor track. Run at ____% of maximum on the straightaways and slow to a walk when going around the curves. Perform ____ laps.



- Unable to return to sports after 3+ months of nonoperative treatment

Specific Criteria for Return to Sports Participation: Tests and Measurements

- Able to perform all activities without increase in symptoms
- Satisfactory physical examination
- Clearance by physician

Evidence

Bushnell BD, Bitting SS, Crain JM, et al: Treatment of magnetic resonance imaging documented isolated grade III lateral collateral ligament injuries in national football league athletes. *Am J Sports Med* 38:86–91, 2010.

This cohort study looked at nine professional football players who had sustained LCL sprains between 1994 and 2004 utilizing the NFL's Injury Surveillance System database. Nonoperative management (n = 5) resulted in a more rapid return to play than the operative group (n = 4) and were able to continue playing for 4.4 additional seasons (nonoperative) versus 2.8 seasons (operative) p = .253. (Level III Cohort Study)

Meister BR, Michael SP, Moyer RA, et al: Anatomy and kinematics of the lateral collateral ligament. *Am J Sports Med* 28:869–878, 2000.

This cadaveric study looked at the anatomy and kinematics of the lateral collateral ligament in 10 unembalmed limbs and 20 isolated femurs and fibulas. On average the ligament measured 66 mm in length (range, 5 to 74 mm) while the average greatest dimension of its thin middle portion was 3.4 mm (range 3 to 4 mm).

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Multiple-Choice Questions

QUESTION 1. The *initial* focus of rehabilitation after an LCL sprain is:

A. Immobilization of the lower extremity for 4 to 6 weeks to allow for appropriate healing
B. Prevention of full knee extension as to not overstress the ligament
C. Decreasing pain and swelling and allowing time for healing to occur
D. Weight bearing strengthening exercises to increase muscle strength.

QUESTION 2. During Phase I of rehab for an LCL sprain, all of the following are appropriate therapeutic exercises for the patient, with the *exception* of:

A. Electrical stimulation of the quadriceps musculature
B. Sidelying hip abduction
C. Hamstring and calf stretching
D. Forward/backward weight shifts

QUESTION 3. Choose the TRUE statement from the following:

A. During Phase II of rehab, the patient's knee brace should be locked in full knee extension at all times.
B. In order to progress to Phase II, the patient must have 5/5 MMT for lower extremity musculature.
C. The time frame of Phase II consists of weeks 3 to 6.
D. During Phase II, light perturbation training and proprioception exercises on unstable surfaces can be initiated.

QUESTION 4. Light plyometric exercises can be initiated with your patient, if the patient demonstrates adequate strength and tissue healing, at approximately what stage during rehabilitation?

A. Weeks 4 to 6
B. Never before week 16
C. Weeks 8 to 10
D. Weeks 14 to 15

QUESTION 5. Identify below one of the correct criterion for progressing the patient to sport specific training and conditioning.

A. Greater than 60% proprioception on Biodex Stability System
B. The patient is able to complete 1 mile of treadmill running pain free in under 10 minutes and 30 reps pain free on the leg press machine with 150 lb
C. Isokinetic test within 15% of contralateral extremity at 180 degrees and 300 degrees
D. A score of Greater than 70/80 on the Lower Extremity Function Scale

Answer Key

QUESTION 1. Correct answer: **C** (see Guiding Principles of LCL Sprain box)

QUESTION 2. Correct answer: **B** (see Phase I)

QUESTION 3. Correct answer: **D** (see Phase II)

QUESTION 4. Correct answer: **D** (see Phase III)

QUESTION 5. Correct answer: **C** (see Phase IV)

POSTOPERATIVE REHABILITATION AFTER POSTEROLATERAL CORNER REPAIR OR RECONSTRUCTION

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Indications for Surgical Treatment

- MRI confirming soft tissue lesions
- Physical exam demonstrating excessive posterolateral laxity
- Functionally limited

Brief Summary of Surgical Treatment

- If either of the cruciate ligaments are injured which is almost always present, they need to be addressed before proceeding with acute repair of the posterolateral structures

Major Surgical Steps

- Tourniquet is applied but almost never need to be inflated
- Incision acute or chronic
- With the knee in approximately 30° of flexion
- Starting longitudinally approximately above the lateral femoral epicondyle then curved distally at the lateral femoral epicondyle and carried inferiorly between the anterior fibular head and Gerde's tubercle
- The iliotibial track is then split in the same fashion
- This gives exposure to the biceps tendon, posterolateral capsule, fibular collateral ligament and the peroneal nerve injury
- Palpate the common peroneal nerve as it curves around the fibular neck and free up the nerve both proximally and distally. Frequently there is a strong and tight fascial band posterior to the anterolateral muscular insertion which must be freed so that nerve compression does not occur post surgery from swelling which can lead to a foot drop 24 to 48 hours post surgery

Acute Injury

- A small longitudinal incision is made over the popliteus fovea to inspect the insertion of the popliteus tendon.
- If avulsed from the insertion, then direct repair with a suture anchor should suffice.
- If irreparable damage is present, then a popliteal ligament must be created (see chronic repair).
- The biceps tendon is explored and repaired as well as the posterolateral capsule if there is significant injury.
- If the posterolateral capsule is repaired, this must be carried out at or near full extension, and full extension is mandatory after repair.
- The fibular collateral ligament is repaired and may be supplemented with graft when necessary.

Brief Summary of Surgical Treatment for Chronic Posterolateral Knee Injury

- Tourniquet is applied but rarely needs to be inflated.
- Cruciate ligament(s) need to be addressed before posterolateral reconstruction.
- Knee varus alignment need to be addressed as to whether a valgus osteotomy needs to be performed before considering a soft tissue reconstruction.
- Surgical incision same as described for acute repair.
- The three major components that need to be addressed are:
  - popliteus muscle tendon complex
  - posterolateral capsule
  - fibular collateral ligament
- In severe chronic posterolateral instability the critical structure to be addressed is the popliteus tendon complex which is either irreparably injured or is nonfunctioning.
- A half of an Achilles tendon allograft with bone or a 8 mm quadriceps autograft with bone can be utilized to create a popliteal ligament which will be physiometric through the full range of motion by our studies.
- A drill hole 8 to 10 mm wide and 20 mm in depth is made at the femoral insertion of the popliteus insertion at the anterosuperior aspect of the popliteus fovea.
- An 8 to 10 mm tunnel is then made starting just below Gerde's tubercle after elevating the insertions of the anterolateral muscles and it should exit on the inferior tibial plateau half way between the PCL insertion and the posteromedial edge of the fibular head.
- The bone portion of the graft is placed in the femoral drill hole and held with an interference screw. The graft is then pulled into the knee joint through the popliteus hiatus and joint capsule exiting along the normal path of the popliteus hiatus and then through the tibial tunnel posterior to anterior. A graft passer will facilitate this.
- A new fibular collateral ligament can be created but utilizing the other half of the Achilles tendon allograft or a gracilis tendon autograft.
- A drill hole 8 to 10 mm wide and 20 mm in depth is made just at the inferior most aspect of the lateral femoral condyle (the FCL inserts just inferior to the LFC) and fixed with an interference screw.
- A second drill hole is made through the fibular head.
- The graft is then pulled through the previously drilled fibular tunnel posterior to anterior and can be fixed in the tunnel or brought up to the lateral femoral epicondyle and fixed with a suture anchor, and then the two bands are sutured together.
- If the posterolateral capsule is severely lax, it can be advanced superiolaterally and fixed with suture anchors making sure the knee has full extension.

Comments

- The popliteus fibular ligament is not addressed in our procedure for several reasons. First, it is only a branch of the popliteus tendon and is the weakest of all the structures. Secondly, in those patients whom we did add a popliteofibular ligament reconstruction, we found no clinical differences in our results.
- Postoperatively we utilize a spring loaded knee brace (Dynasplint), maintaining full extension and allow progress weight bearing. The brace is utilized to help contain excessive posterolateral knee rotation.

Before Surgery: Overview of Goals, Milestones, and Guidelines[1]

GUIDING PRINCIPLES OF POSTOPERATIVE REHABILITATION

- Diminish pain and swelling in the early phases.
- Never overstress the healing tissue.
- Dynasplint brace for 6 weeks to minimize stress on the healing soft tissues.
- Gradual return to function through progressive ROM, WB and strengthening exercises.
- Control forces onto the lateral and posterolateral corner.

Goals

- Diminish pain and swelling
- Normalize range of motion
- Activate quadriceps
- Protect posterolateral corner structures of the knee

Management of Pain and Swelling

- Elastic wrap or knee sleeve to reduce swelling

Exercises

- Ankle pumps
- Passive knee extension (gradual progression)
- Passive knee flexion to tolerance
- Straight leg raises (three-way, flexion, abduction), pillow squeezes
- Quadriceps setting
- Closed kinetic chain exercises: minisquats, lunges, step-ups

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Electrical muscle stimulation to quadriceps during voluntary quadriceps exercises (4 to 6 hours per day)

Neuromuscular Dynamic Stability Exercises

- Eliminate quad avoidance gait
- Retro stepping drills

[1]*Prehabilitation, if appropriate, is described in the Nonoperative Rehabilitation section of this chapter.*

Cryotherapy/Elevation

- Apply ice 20 minutes of every hour, and elevate leg with knee in full extension (knee must be above heart)

Patient Education

- Review postoperative rehabilitation program.
- Review instructional video (optional).
- Select appropriate surgical date.

Phase I: Immediate Postoperative Period (days 0 to 14)

Goals

- Decrease pain and swelling through cryotherapy, PROM, and electrotherapeutic modalities.
- Obtain immediate extension to 0°.
- Instruct on gait training while in locked brace in brace and weight-bearing as tolerated.
- Normalize patella mobility.
- PROM to 90° flexion.

Clinical Pearl

During this phase, it is imperative to obtain full knee extension immediately while limiting hyperextension, which may put unwanted stresses on the healing tissues. Also, the patient must avoid active hamstring activity for 8 weeks. Finally, a Dynasplint brace is used during ambulating to prevent posterior tibial sag.

Protection

- The knee is protected by placing it in a Dynasplint brace locked at 0°.
- Immediate weight-bearing is allowed to tolerance.
- The patient typically ambulates in crutches for 2 to 3 weeks to decrease stress on the healing structures.

Management of Pain and Swelling

- The patient is instructed to ice and elevate the extremity for 20 minutes every hour throughout the first 2 weeks or until adequate swelling control is attained. Icing should be performed in full knee extension to prevent a flexion contracture from forming. A vasopneumatic compressive device (Figure 35-7) may be utilized to simultaneously decrease swelling and pain.
- A compression sleeve or ace wrap may be utilized to keep swelling to a minimum.
- Analgesics and antiinflammatory medications may be utilized to decrease pain and swelling.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- The rehabilitation specialist may begin patellar mobilizations immediately to tolerance.

TIMELINE 35-2: **Postoperative Rehabilitation After Posterolateral Corner Repair or Reconstruction**

PHASE I (Immediately Postoperative, weeks 0 to 2)

Week 1

Day 1

- Protection: brace/immobilizer (Dynasplint) applied to knee, locked at 0°of flexion for ambulation and sleeping
- Weight bearing: two crutches, weight bearing as tolerated
- Exercises:
  - Ankle pumps
  - Overpressure into passive knee extension
  - Active and passive knee flexion (90° by Week 2
  - Straight leg raises (flexion, adduction); *no* abduction
  - Quadriceps isometric setting
  - Hamstring stretches
  - Closed kinetic chain exercises: weight shifts
- Muscle stimulation: use muscle stimulation during active muscle exercises (4 to 6 hours per day)
- Passive motion: as needed, 20° to 60° (as tolerated and as directed by physician) maintain anterior tibial force during passive knee flexion
- Ice and evaluation: ice 20 minutes out of every hour and elevate with knee in full extension

Days 2 to 4

- Protection: EZ Wrap brace/immobilizer, locked at 0° extension for ambulation
- Weight bearing: two crutches, weight bearing as tolerated
- Range of motion
  - Remove brace, perform range of motion exercises 6 to 8 times per day
  - Perform frequent bouts of ROM to regain knee flexibility
- Exercises:
  - Gentle overpressure into extension
  - Emphasize restoring knee extension
  - Patellar mobilization
  - Ankle pumps
  - Straight leg raises, pillow squeezes
  - Minisquats and weight shifts
  - Quadriceps isometric setting
- Muscle stimulation: electrical muscle stimulation to quads (6 hours per day)
- Passive motion: 20° to 70° with anterior tibial force
- Ice and evaluation: ice 20 minutes out of every hour and elevate leg with knee in full extension

Days 5 to 7

- Protection: brace/immobilizer, locked at 0° extension for ambulation and unlocked for sitting, etc.
- Weight bearing: two crutches, weight bearing as tolerated
- Range of motion: remove brace to perform range of motion exercises 6 to 8 times per day, knee flexion 75° by day 5, approximately 80° by day 7
- Exercises:
  - Multi-angle isometrics at 90° and 60° of flexion (knee extension)
  - Knee extension (90° to 40°)
  - Patellar mobilization (5 to 8 times daily)
  - Ankle pumps
  - Straight-leg raises, pillow squeezes
  - Minisquats and weight shifts as tolerated
  - Quadriceps isometric setting
  - Proprioception and balance activities
- Neuromuscular training/proprioception:
  - OKC passive/active joint repositioning at 90°, 60°
  - CKC squats and weight shifts
- Muscle stimulation: electrical muscle stimulation (continue 6 hours daily)
- Passive motion: 0° to 90°, as needed
- Ice and elevation: ice 20 minutes of every hour and elevate leg with knee full extension

*At the end of week two, recheck with MD to determine whether extension can be progressed faster.

TIMELINE 35-2 Postoperative Rehabilitation After Posterolateral Corner Repair or Reconstruction (Continued)

	PHASE II (Early Rehabilitation, weeks 2 to 4)	
Week 2	**Week 2***	**Week 3**

• Protection: brace/immobilizer, locked at 0° extension for ambulation
• Weight bearing: two crutches, partial weight bearing to weight bearing as tolerated
• Range of motion: remove brace to perform range of motion exercises 6 to 8 times per day, knee flexion 90° by day 14
• Exercises:
  • Multi-angle isometrics at 90° and 60° (knee extension)
  • Knee extension 90° to 40°
  • Patellar mobilization (5 to 8 times daily)
  • Ankle pumps
  • Straight leg raises, pillow squeezes
  • Minisquats and weight shifts
  • Quadriceps isometric setting
  • Proprioception and balance activities
• Neuromuscular training/proprioception:
  • OKC passive/active joint repositioning at 90°, 60°
  • CKC squats and weight shifts
• Muscle stimulation: electrical muscle stimulation (continue 6 hours daily)
• Passive motion: 0° to 90°, as needed
• Ice and elevation: ice 20 minutes of every hour and elevate leg with knee full extension
	• Protection: Continue locked brace for ambulation
	• Weight bearing: As tolerated (continue with crutches 3 to 4 weeks postop)
	• Passive Range of Motion: Self-ROM stretching (6 to 8 times daily)
	• Exercises:
	  • Muscle stimulation to quadriceps exercises
	  • Isometric quadriceps sets
	  • Straight Leg raises (4 planes)
	  • Leg Press (0° to 60°)
	  • Knee extension 90° to 40°
	  • Half squats (0° to 40°)
	  • Weight shifts
	  • Front and side lunges
	  • Uni-cam bicycle (low intensity cycling)
	  • Proprioception training
	  • Passive range of motion from 0° to 90°
	  • Patellar mobilization
	  • Well leg exercises
	  • Progressive resistance extension program—start with 1 lb., progress 1 lb. per week
	• Proprioception/Neuromuscular Training
	  • OKC passive/active joint repositioning 90°, 60°, 30°
	  • CKC joint repositioning during squats/lunges
	• Swelling control: Ice, compression, elevation
		• Protection: Maintain locked brace (some patients use ROM brace for ambulation)
		• Passive Range of Motion: Continue range of motion stretching and overpressure into extension (ROM should be 10° to 110°)
		• Exercises:
		  • Continue all exercises as in week two
		  • Passive Range of Motion 0° to 105°
		  • Bicycle for range of motion stimulus and endurance (emphasize ROM on bike)
		  • Pool walking program (if incision is closed)
		  • Eccentric quadriceps program 40 to 100 (isotonic only)
		  • Lateral lunges (straight plane)
		  • Front Step Downs
		  • Lateral Step-Overs (cones)
		  • Progress Proprioception drills, neuromuscular control drills
		  • Frequent bouts of ROM exercises

TIMELINE 35-2 Postoperative Rehabilitation After Posterolateral Corner Repair or Reconstruction (Continued)

PHASE III (Progressive Strengthening, weeks 4 to 10)

Weeks 4 to 5

- Protection: No immobilizer or brace, may use knee sleeve to control swelling/support
- Range of Motion
  - Self-ROM (four to five times daily using the other leg to provide ROM), emphasis on maintaining 0° passive extension
  - PROM 10° to 105° at 4 weeks
- KT 2000 Test: 20 lb. anterior and posterior test)
- Exercises:
  - Progress isometric strengthening program
  - Leg press (0° to 100°)
  - Knee extension 90° to 40°
  - Hip abduction and adduction
  - Hip flexion and extension
  - Lateral step-overs
  - Lateral lunges (straight plane and multi-plane drills)
  - Lateral step-ups
  - Front step-downs
  - Wall squats
  - Vertical squats
  - Standing toe calf raises
  - Seated toe calf raises
  - Biodex Stability System (Balance, Squats, etc.)
  - Proprioception Drills
  - Bicycle
  - Pool Program (Backward Running, Hip and Leg Exercises)
- Proprioception/Neuromuscular Drills
  - Tilt board squats (perturbation)
  - Passive/active reposition OKC
  - CKC repositioning on tilt board with sports RAC
  - CKC lunges with sports RAC

Weeks 6 to 7

- Protection: No immobilizer or brace, may use knee sleeve to control swelling/support
- Range of Motion
  - Self-ROM (four to five times daily using the other leg to provide ROM), emphasis on maintaining 0° passive extension
  - PROM 10° to 105° at 4 weeks
- KT 2000 Test: 20 and 30 lb. anterior and posterior test
- Exercises:
  - Continue all exercises from Weeks 4 to 5
  - Pool running (forward) and agility drills
  - Balance on tilt boards
  - Progress to balance and ball throws
  - Wall slides/squats
  - PROM 0° to 125°

Weeks 8 to 9

- Protection: No immobilizer or brace, may use knee sleeve to control swelling/support
- Range of Motion
  - Self-ROM (four to five times daily using the other leg to provide ROM), emphasis on maintaining 0° passive extension
  - PROM 10° 105 ° at 4 weeks
- KT 2000 Test: 20 and 30 lb. anterior and posterior test
- Exercises:
  - Continue all exercises from Weeks 4-7
  - Leg press sets (single leg) 0° to 100° and 40° to 100°
  - Wall squats
  - Perturbation training
  - Walking program
  - Bicycle for endurance
  - Biodex stability system
  - PROM 0° to 135°



FIGURE 35-7. Commercial vasopneumatic compression device used after surgery to decrease pain and swelling.

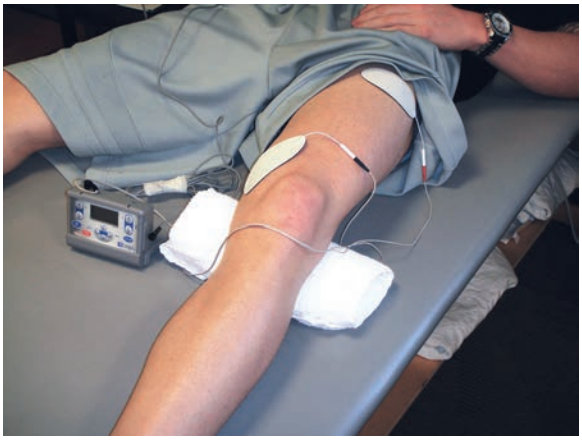

FIGURE 35-8. Neuromuscular electrical stimulation to the quadriceps musculature to improve muscle activation during straight leg raises.

- Also, gentle manual passive range of motion of the knee may be initiated to neuromodulate pain and aid in collagen alignment of the healing ligamentous tissue.
- PROM is allowed to 90° for the first 2 weeks.

Soft Tissue Techniques

- Scar mobilizations may be performed once the sutures are removed and adequate tissue healing has occurred.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Gentle calf and hamstring stretching may be performed to aid in maintaining full knee extension.

Other Therapeutic Exercises

- Neuromuscular electrical stimulation (NMES) (Figure 35-8) to the quadriceps are initiated immediately while performing straight leg raises during active flexion, abduction, and adduction. The patient may progress resistance ankle weights as strength returns and the patient displays good quadriceps control.
- Limited weight-bearing activities may be incorporated as a weight shift to improve neuromuscular control but

TIMELINE 35-2 Postoperative Rehabilitation After Posterolateral Corner Repair or Reconstruction (Continued)

Week 10	PHASE IV (Advanced Activity, weeks 10 to 16)		PHASE V (Return to Activity Weeks 16 and Beyond)
	Weeks 10 to 13	Weeks 14 to 16	

• KT 2000 Test: 20 and 30 lb. anterior and posterior test
• Isokinetic test: Concentric knee extension/flexion at 180 and 300/second
• Exercises:
  • Continue all exercises from Weeks 6 to 9
  • Continue stretching drills
  • Progress strengthening exercises and neuromuscular training
	• Exercises:
	  • May initiate running program week 12 if good quad control and ROM
	  • May initiate light sport program (golf)
	  • Continue all strengthening drills
	  • Leg press
	  • Wall squats
	  • Hip abd/adduction
	  • Hip flex/ext
	  • Knee extension 90° to 40°
	  • Hamstring curls (initiate at week 12)
	  • Standing toe calf
	  • Seated toe calf
	  • Step down
	  • Lateral step ups
	  • Lateral lunges
	  • Neuromuscular training
	  • Lateral step-overs cones
	  • Lateral lunges
	  • Tilt board drills
		• Progress program
		• Continue all drills above
		• May initiate lateral agility drills
		• Backward running
			• KT 2000, Isokinetic, and functional Tests before return
			• Exercises:
			  • Continue strengthening exercises
			  • Continue neuromuscular control drills
			  • Progress running and agility program
			  • Progress sport-specific training
			  • Running/cutting/agility drills
			  • Gradual return to sport drills
			6-Month Follow to up
			• Isokinetic test
			• KT 2000 test
			• Functional test
			12-Month Follow to up
			• Isokinetic test
			• KT 2000 test
			• Functional test

still need to monitor forces along the lateral and posterior knee.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Quadriceps, hip abductors, adductors, extensors, calf, peroneals

Sensorimotor Exercises

- Weight shifting onto a stable surface may be initiated immediately then progressed to a weight shift onto a foam surface to further challenge the neuromuscular control system.

Open and Closed Kinetic Chain Exercises

- See above.

Techniques to Increase Muscle Strength, Power, and Endurance

- At this phase, activation of the quadriceps is the primary principle through the use of NMES.

Neuromuscular Dynamic Stability Exercises

- The patient may begin controlled balance activities beginning with a weight shift onto the involved extremity and progressing to a weight shift onto a foam or unstable surface.

Functional Exercises

- At this stage, the patient is instructed to ambulate in the Dynasplint locked at 0° while using axillary crutches. A lateral heel wedge may be utilized for a genu varum knee to decrease stress through the lateral joint line and open up the medial joint line to decrease contact stress forces.

Milestones for Progression to the Next Phase

- Full passive knee extension
- Good quadriceps control with SLR and quad set
- Good patellar mobility
- Minimal joint effusion
- Flexion PROM to 90°
- Independent ambulation in crutches

Phase II: Earl Rehabilitation (weeks 2 to 3 postoperatively)

Goals

- Progress to independent ambulation without crutches
- Initiate weight-bearing strengthening exercises

- Improve quadriceps strength to ≥ 60% of contralateral side
- Discharge Dynasplint brace at 6 weeks postoperative
- Gradual increase to full passive knee extension
- Gradually increase knee flexion
- Diminish swelling and pain
- Muscle control and activation
- Restore proprioception/neuromuscular control
- Normalize patellar mobility

Clinical Pearl

Progress to full PROM over the first 6 weeks following the surgery. The rehabilitation specialist should continue to protect the healing structures through progressive weight-bearing activities and the Dynasplint brace.

Protection

- Crutches may be discontinued by 3 weeks postoperatively as long as the patient displays good quadriceps control and feels confident about the extremity.

Management of Pain and Swelling

- Moist heat, cryotherapy, and vasopneumatic compression devices may be utilized to control pain and inflammation. Typically, the patient is weaning off of the narcotic pain medications and has begun utilizing nonsteroidal antiinflammatory (NSAIDs) medication.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Patellar mobilizations may be performed as needed. Manual PROM of the tibiofemoral joint is progressed to >125° by the end of this phase.

Soft Tissue Techniques

- Cross-friction massage may be utilized to break up adhesions at the incision sites.
- Soft tissue mobilization techniques may be used to decrease muscular tone of the quadriceps and hamstrings if this restricts the patient's ability to achieve flexion and extension PROM.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Gentle gastrocnemius and soleus towel stretching may be performed with special care to avoid hamstring stretching.

Other Therapeutic Exercises

- Continue with a progressive resistance exercises program including SLRs, Leg Press (0° to 60°), minisquat (0° to 40°), and step downs to improve quadriceps control.



FIGURE 35-9. Single leg stance on foam to further challenge the patient's dynamic stability.

- Total ankle strengthening may be incorporated using resistance bands in all four directions to maintain strength before advancing balance drills.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Quadriceps
- Hip abductors, adductors, extensors, external rotators
- Gastroc-soleus complex
- Core stabilization

Sensorimotor Exercises

- Balance onto unstable surfaces

Open and Closed Kinetic Chain Exercises

- Bicycle (depending on ROM)
- Continue resisted SLRs with NMES
- Leg Press (0° to 60°)
- Multi-hip (abduction, abduction, extension, flexion)
- Clams
- Seated hip ER/IR
- Sidelying planks with hip abduction 30-second hold
- Prone planks with hip extension 30-second hold

Techniques to Increase Muscle Strength, Power, and Endurance

- See above

Neuromuscular Dynamic Stability Exercises

- Single leg stance on unstable surface (Figure 35-9)
- Gentle perturbation training

Functional Exercises

- Progressive gait training
- Normalize gait
- Eccentric quadriceps control on step-downs

Milestones for Progression to the Next Phase

- Active ROM 0° to 115°
- Quadriceps strength 60% > contralateral side (isometric test at 60° knee flexion)
- Unchanged KT Test bilateral values (+1 or less)
- Minimal to no full joint effusion
- No joint line or patellofemoral pain

Phase III: Progressive Strengthening (weeks 4 to 10 postoperatively)

Goals

- Minimal to no joint effusion
- PROM 0° to 110°
- Minimal pain
- No joint line pain
- Restore full knee range of motion (0° to 125°)
- Improve lower extremity strength
- Enhance proprioception, balance, and neuromuscular control
- Improve muscular endurance
- Restore limb confidence and function

Clinical Pearl

The patient will restore full PROM without pain in this stage and progressive strengthening of the entire lower extremity. If full ROM is not attained, low load long duration stretching should be utilized to slowly stretch out the scar tissue (collagen), which will help to regain the lost motion.

Protection

The patient progresses from the Dynasplint to a knee sleeve or hinged knee brace while walking because of the continued weakness of the lower leg musculature.

Management of Pain and Swelling

- The patient may take NSAIDs as needed to control the mild pain and inflammation that may persist.
- A compression sleeve may be utilized to control or minimize knee joint effusion as the patient's activity level increases.

Techniques for Progressive Increase in Range of Motion

Manual Therapy and Soft Tissue Techniques

- The rehabilitation specialist should continue to mobilize the patella, and progress knee flexion and extension ROM.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Quadriceps and hamstring static stretching may be initiated to improve overall flexibility.

Other Therapeutic Exercises

- Leg press
- Lateral lunge (straight plane)
- Lateral step-down
- Front step-down
- Multi-axis hip (four directions)
- Lunges
- Wall squat
- Proprioception drills on a Biodex stability system

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Quadriceps
- Total hip musculature
- Gastrocnemius
- Core stabilization

Sensorimotor Exercises

- Balance onto unstable surfaces
- Dynamic stabilization drills
- Neuromuscular control drills

Open and Closed Kinetic Chain Exercises

- See above

Techniques to Increase Muscle Strength, Power, and Endurance

The patient is instructed to progress resistance for each exercise along with working on timed bouts to improve endurance. Cardiovascular exercises including cycling, elliptical training, and swimming may be utilized as well.

Neuromuscular Dynamic Stability Exercises

- Tilt board squats
- Single leg balance onto unstable surfaces
- Perturbation training while on unstable surfaces (Figure 35-10)

Functional Exercises

- Progressive walking program

Milestones for Progression to the Next Phase

- Full PROM
- Satisfactory clinical examination
- >4/5 MMT throughout LE
- AROM 0 to 125° or greater
- Quad strength 75% of contralateral side, knee extension flexor:extensor ratio 70% to 75%
- No change in KT values (comparable with contralateral side, within 2 mm)
- No pain or effusion

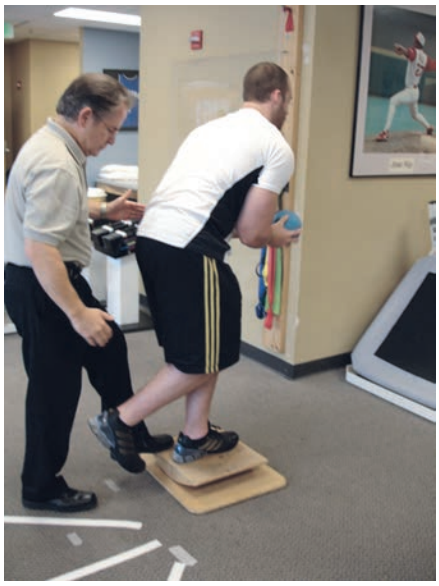

FIGURE 35-10. Perturbation training on a tilt board to enhance dynamic stability and neuromuscular control.

- Satisfactory clinical exam
- Satisfactory isokinetic test (values at 180°)
  - Quadriceps bilateral comparison 75%
  - Hamstrings equal bilateral
  - Quadriceps peak torque/body weight 65% at 180°/s (males) and 55% at 180°/s (females)
  - Hamstrings/quadriceps ratio 66% to 75%
- Hop Test (80% of contralateral leg)
- Subjective knee scoring (modified Noyes System) 80 points or better

Phase IV: Advanced Activity (weeks 10 to 16 postoperatively)

Goals

- Normalize lower extremity strength
- Enhance power and endurance
- Improve neuromuscular control
- Initiate sports-specific drills

Clinical Pearls

It is imperative that the patient continues to improve strength, power, and endurance while maintaining knee homeostasis. The rehabilitation specialist may want to consider an unloader brace to decrease medial knee joint forces. A lateral heel wedge or custom orthotic in the patient's shoe may be used to control varus loading in the knee joint, as well. Sports-specific drills may be initiated toward the end of this phase including a running program that slowly progresses straight-line running distances.

Management of Pain and Swelling

- NSAIDs as needed
- The patient may continue to wear a compression sleeve with daily activities and should ice after activities

Techniques for Progressive Increase in Range of Motion

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Complete lower extremity stretching may be performed. Consideration for dynamic stretching may be performed before exercises while the athlete may perform a static stretching program after exercising.
- Manual soft tissue may be performed as needed to address limitations or delayed onset muscle soreness after exercise progression.

Other Therapeutic Exercises

- Total leg strengthening may be performed to enhance strength, power and endurance.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- At this stage, the athlete may continue to progress quadriceps and hip strengthening. Hamstring strengthening should be initiated; however, the rehabilitation specialist should continue to monitor for posterolateral knee pain.

Sensorimotor Exercises

- Balance activities are progressed to include more dynamic movements to simulate the athlete's sport. Perturbation training may be used to create a postural disturbance upon the patient to further challenge dynamic stability and neuromuscular control.

Open and Closed Kinetic Chain Exercises

- Total lower body and core strengthening emphasizing dynamic movements and single leg isolation activities
  - Leg Press (0° to 100°)
  - Multi-axis hip
  - Initiate isolated hamstring strengthening at 8 weeks postoperative
  - Step downs
  - Forward and lateral lunges
  - Forward and lateral step downs
  - Sidelying clams
  - Hip ER/IR
  - Bridging
  - Plank with hip abduction and extension
  - Sport cord resistance movements

Techniques to Increase Muscle Strength, Power, and Endurance

- See above.

Neuromuscular Dynamic Stability Exercises

- See above.



FIGURE 35-11. Antigravity treadmill used to decrease stress on the knee joint while allowing the patient to progress through a running program.

Plyometrics

- Plyometrics may be initiated on the leg press utilizing half of the patient's body weight as an initial starting point.
- Progression to box jumps may begin if the patient displays good quadriceps control and no pain.

Functional Exercises

- The patient may initiate a running program in a pool or antigravity treadmill (Figure 35-11) as symptoms allow.
- Lateral movement drills may be incorporated if the patient displays adequate dynamic stability and neuromuscular control.

Milestones for Progression to the Next Phase

- Full ROM
- Unchanged KT 2000 Test (within 2.5 mm of opposite side)
- Isokinetic test that fulfills criteria
- Quadriceps bilateral comparison (80% or greater)
- Hamstring bilateral comparison (110% or greater)
- Quadriceps torque/body weight ratio (55% or greater)
- Acceleration rate at 0.2 seconds (80% of quads peak torque)
- Hamstrings/quadriceps ratio (70% or greater)
- Proprioceptive test (100% of contralateral leg)
- Functional test (85% or greater of contralateral side)
- Satisfactory clinical exam
- Subjective knee scoring (modified Noyes System) (90 points or better)

Phase V: Return to Activity (weeks 16 to 22 postoperatively)

Goals

- Full ROM
- Pain free
- No effusion present
- Isokinetic testing:
  - Bilateral quadriceps comparison within 85%
  - Bilateral hamstrings within 110%
  - Hamstrings/quadriceps ratio within 70%
  - Quadriceps torque: body weight ratio ≥ 65%
- Satisfactory clinical examination
- Gradual return to full-unrestricted sports
- Achieve maximal strength and endurance
- Normalize neuromuscular control
- Progress skill training

Clinical Pearl

In this phase, the patient gradually returns to full, unrestricted sports activities while continually building upon the previous exercises that focus on strength, power, and endurance.

Management of Pain and Swelling

- As needed. See above.

Techniques for Progressive Increase in Range of Motion

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Dynamic stretching may be utilized before activities followed by a comprehensive static stretching program once activities have been completed.

Other Therapeutic Exercises

- At this point, a total body strengthening program and core stability program is progressed to further challenge the patient's dynamic stability and neuromuscular control.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Quadriceps
- Hamstrings
- Hip musculature
- Calf musculature
- Core stabilizers

Sensorimotor Exercises

- Biodex Stability System (balance, squats, etc.)

Open and Closed Kinetic Chain Exercises

- Leg press (0° to 100°)
- Knee extension 90° to 40°

- Hip abduction and adduction
- Hip flexion and extension
- Lateral step-overs
- Lateral lunges (straight plane and multi-plane drills)
- Lateral step-ups
- Front step-downs
- Hamstring-Romanian dead lifts (RDLs)
- Wall squats
- Vertical squats
- Standing toe calf raises
- Seated toe calf raises

Plyometrics

- Box jumps
  - Double legged
  - Single legged
  - Two boxes
  - Jump roping
  - Sport cord lateral hop onto foam with ball toss

Functional Exercises

- Interval running program beginning with straight line and progressing to a cutting program at predetermined intervals
- Plyometrics
- Sport-specific drills depending on the patient's sport, position, and demands

Sport-Specific Exercises

- Lateral cariocas
- Figure 8s
- Shuttle runs
- Interval sprinting program
- Specific sport drills and activities

Milestones for Progression to the Next Phase

- See below

Criteria for Return to Sport

General

- Full ROM
- Pain free
- Isokinetic testing:
  - Quadriceps torque to body weight ratio ≥ 65%
  - Hamstrings/quadriceps ratio within 70%
  - Bilateral comparison of quadriceps within 90%
  - Bilateral hamstrings within 100%
  - Acceleration rate at 0.2 seconds (80% of quads peak torque)
- Satisfactory clinical examination
- Completion of sport-specific program
- Clearance by MD

Sport-Specific

- A running program that involved starting and stopping on command may be used to determine return to play
- Lateral shuffles, cariocas, and timed shuttle runs can determine lateral function and cutting abilities.

After Return to Sport

Continuing Fitness or Rehabilitation Exercises

- Continue with total body strengthening and stretching program
- Aerobic conditioning program
  - Biking
  - Swimming
  - Elliptical training
  - Interval sprinting

Exercises and Other Techniques for Prevention of Recurrent Injury

- Plyometric jumping working on landing techniques
- Hip abductor/extensor/external rotation strengthening
- Perturbation training to further enhance dynamic stability and neuromuscular control

Evidence

Geeslin AG, LaPrade RF: Outcomes of treatment of acute Grade-III isolated and combined posterolateral knee injuries. *J Bone Joint Surg Am* 93:1672–1683, 2011.

This prospective study analyzed the outcomes of 29 grade III posterolateral knee injuries treated with an anatomic repair or reconstruction within 6 weeks of injury. At an average of 2.4 years following treatment, the mean IKDC and Cincinnati Knee Rating scores improved significantly along with lateral compartment gapping as determined by varus stress radiographs. (Level IV evidence)

LaPrade RF, Wentorf FA, Fritts H, et al: A prospective magnetic resonance imaging study of the posterolateral and multiple ligament injuries in acute knee injuries presenting with a hemarthrosis. *Arthroscopy* 23:1341–1347, 2007.

This prospective MRI study evaluated 331 consecutive acute (within 30 days) knee injuries with a hemarthrosis at a large, metropolitan imaging facility with six sites. The incidence of a posterolateral knee injury with an acute hemarthrosis was 9.1%. The authors also determined that most PCL and posterolateral corner injuries occur in combination with other ligament injuries. (Level IV evidence)

LaPrade RF, Johansen S, Engebretsen L: Outcomes of an anatomic posterolateral knee reconstruction: surgical technique. *J Bone J Surg Am* 93(Suppl 1):10–20, 2011.

This study aimed to document the clinical stability and functional outcomes on posterolateral reconstruction surgery. This two-center study looked at 64 patients with chronic grade 3 posterolateral instability. A significant improvement was noted on the IKDC scores for varus opening at 20°, external rotation at 30°, reverse pivot shift, and single leg hop at an average of 4.3 years from surgery. (Level III evidence)

Stannard JP, Brow SL, Farris SL, et al: The posterolateral corner of the knee: Repair versus reconstruction. *Am J Sports Med* 33:881–888, 2005.

This cohort study evaluated the repair (n = 39) versus reconstruction (n = 25) of acute posterolateral corner injuries in 63 patients with 64 injuries. The authors showed that the repaired knee showed inferior results on laxity and failure rates. They went on to recommend the use of a reconstruction rather than a primary repair in patients who sustain a posterolateral corner tear. (Level II cohort study)

Multiple-Choice Questions

QUESTION 1. During Phase I of rehab of a PLC injury, it is imperative to:

A. Obtain full knee flexion immediately
B. Maintain non–weight-bearing status for the first 3 weeks to limited stress to the healing tissues
C. Obtain full knee extension, while limiting hyperextension
D. Ice the knee for 20 minutes every hour throughout the first 2 weeks with the knee flexed to avoid overstressing the tissues

QUESTION 2. Progression from the Dynasplint to a knee sleeve or hinged brace occurs in which phase of rehab?

A. At the end of Phase I (week 2)
B. Mid Phase II (around week 4)
C. Phase III (6 to 10 weeks)
D. Beginning of Phase V (14 weeks)

QUESTION 3. Criteria for return to sport include all of the following except:

A. Bilateral quadriceps strength within 90% on isokinetic testing
B. Pain free, full ROM
C. Completion of sport-specific program
D. Hamstring/quadriceps ratio within 100%

QUESTION 4. This should be avoided for 8 weeks of therapy in rehab for a PLC injury:

A. Active hamstring activity
B. Active quadriceps activity
C. Active gastrocnemius activity
D. All of the above

QUESTION 5. If full PROM has not been restored during Phase III of rehab, this can be used to regain the lost motion:

A. Quick thrust grade V manipulations of the tibiofemoral joint
B. Low-load long-duration stretching
C. Continued strengthening of the primary muscles surrounding the joint will help regain the lost ROM
D. None of the above, if full ROM has not been restored by this point it is unable to be restored

QUESTION 6. All of these are activities the patient should be doing in Phase III (weeks 6 to 10) except:

A. Single leg balance on unstable surfaces with perturbation training
B. Plyometric exercises
C. Progressive walking program
D. Multi-hip machine in four directions (abduction, adduction, extension, flexion)

Answer Key

QUESTION 1. Correct answer: **C** (see Phase I Clinical Pearl)

QUESTION 2. Correct answer: **C** (see Phase III Protection)

QUESTION 3. Correct answer: **D** (see Criteria for Return to Sport)

QUESTION 4. Correct answer: **A** (see Phase I Clinical Pearl)

QUESTION 5. Correct answer: **B** (see Phase III Clinical Pearl)

QUESTION 6. Correct answer: **B** (see Phase III)

BEYOND BASIC REHABILITATION: RETURN TO RUGBY LEAGUE AFTER POSTEROLATERAL CORNER KNEE RECONSTRUCTION WITH AUTOGRAFT

John Maguire, MBBS, FRACS, MSM, FAOA, and Steven Sartori, B Physio, FPCP

ASPECTS OF RUGBY LEAGUE THAT REQUIRE SPECIAL ATTENTION IN REHABILITATION

- High-grade, posterolateral corner (PLC) knee injury requiring autograft reconstruction is a rare injury in rugby league. It is a challenging problem for medical staff to return players to rugby league at an elite level, particularly if there is a concurrent anterior cruciate ligament (ACL)/PCL injury, or high-grade articular cartilage injury.
- Surgical stabilization and high-level active knee control are required to avoid knee varus and extension stress during pivoting and cutting maneuvers. These are inherent in most football codes, not to mention direct contact injuries.
- Rugby league is a contact sport played mainly in Australia, New Zealand, Pacific Islands, France, and throughout the United Kingdom. It is a multidirectional ball running game requiring power, agility, speed, repeat high intensity sprinting, and endurance. The game duration is 80 minutes, with 40 minute halves, and little stoppage time.
- There are limited player interchanges so player endurance is paramount especially in key positions such as halfback, fullback and hooker. There are often multiple players engaged in the tackle. The tackle involves contact, including wrestling and grappling. An individual player may make up to 60 tackles per game.
- No hard bracing or helmets are allowed thus limiting the use of knee bracing. Some soft bracing, padded headgear, and taping is allowed.
- Rugby league has a high overall rate injury rate, averaging between 60 and 80 injuries per 1000 player hours. Up to 75% of an elite club's senior roster of 35 players will sustain at least one injury per season, which will result in missed game time during the season.
- Each team on average will have six players unavailable for first grade games every week. Knee injuries account for 15.3% of total injuries.
- The most common mechanism of knee injury in elite rugby league occurs during tackling, in particular when being tackled.[1]
- In 2012, the National Rugby League Injury Surveillance reported a total of 16 ACL injuries throughout the 16 national clubs. This accounted for 20.5% of total knee injuries reported and resulted in 259 missed games in total.[2]
- PCL injuries for 2012 totaled 7, accounting for 9.0% of total knee injuries resulting in only 29 missed games.
- There were no isolated PLC, or combined PLC/cruciate injuries reported in the National Rugby League (NRL) 2012 injury surveillance report.[2]
- As with other high-speed contact pivoting sports, returning from PLC injury, in this case specifically PLC auto graft reconstruction, is only possible with excellent surgical planning and technique.
- Close communication between physical therapist/athletic trainer and surgeon are required. Excellent training routines and sensible return to sport considerations are required. Particular attention to all aspects of strength, power, neuromuscular, agility, reactive, and speed training is necessary, and involves constant monitoring and feedback to the athlete to avoid knee varus and extension stress to the graft.

Introduction

Literature

- This is a rare injury, with little or no data relating to return to competition in all football codes in Australia, at the elite professional level.
- With an increasing body of evidence emphasizing neuromuscular knee control in injury prevention and rehabilitation[3-5] and with feedback to the athlete being instantaneously available with the use of video, force plates, and muscle stiffness testing, there is an evidence based approach to rehabilitation which is functionally based, rather than time based, and provides extra objective insight to inform clinical decision-making processes.
- Traditional strength testing, including either isokinetic (if available) or other strength indices, accepted neuromuscular testing (e.g., hop tests) and field-based agility testing are still utilized and are required to help clinical decision-making regarding safe return to sport.

Advanced Rehabilitation Program

- There are other monitoring variables which can contribute to clinical decision making. These can include subjective well-being data (e.g., knee pain rating/10) and objective maximum voluntary contraction (MVC) dynamometry. These are recorded daily, and may assist

in session planning for the next day, or week, in an attempt to avoid over-training, or concurrent soft tissue injury especially in the later stages of intense sport specific training.
- Adductor MVC testing (squeeze test) has been shown to be reliable and predictive of groin pain in elite level Australian Rules football players.[6,7] MVC testing can also be carried out on other muscle groups and may give a daily indication of whether progression is safe.
- As can be seen there are many things to consider before a return to sport following this severe and challenging injury. The following protocols will demonstrate what we do with our players at an elite level in Rugby League in Australia.

Phase I: Advanced Strength and Conditioning Programs

- The commencement of advanced strength and conditioning is in the late stage of rehabilitation from 6 months.
- The following text is written with the assumption that the athlete has successfully completed the previous rehabilitation milestones as listed in the Rehabilitation Timeline, specifically that there has been demonstrated objective advanced proprioceptive control (e.g., star excursion test/Y balance test), single leg hop with positional knee control, normal running biomechanics (video assessment), and minimal joint effusion post exercise.
- A time-frame-based rehabilitation protocol without functional milestones, especially neuromuscular and strength markers, is not recommended. This has been shown to be associated with increased reinjury risk.[8,9] It should also be mentioned that early consideration of combined injury also needs to be taken into account well before the athlete enters the advanced phases of rehabilitation. Rehabilitation for an isolated PLC reconstruction will differ from a combined ACL/PLC injury, or combined PCL/PLC injury. Other concomitant procedures such as tibial osteotomy and articular cartilage repair/restorative procedures will also change some parameters of rehabilitation, and may also influence the decision of whether the athlete will be able to return to their preinjury level of sport, or even return to sport at all.
- For example, return to play rates in National Football League (NFL) after ACL reconstruction have been shown to be lower than previously perceived with 63% of NFL athletes returning to NFL game play.[10]
- Return to play rates in elite rugby league are similar to this figure at 66% (authors' own data). Combined cruciate/PLC reconstruction return to play rates at elite level are not well- known.
- The primary influences of rehabilitation for these procedures in the early phases are dictated by biological tissue healing times and involve weight-bearing status, range of motion (ROM) parameters, open kinetic chain (OKC) restrictions, and bracing use. Many of these parameters are variable depending on the surgeon's instructions, and the procedures performed.
- There is a paucity of high level evidence base for many rehabilitation parameters, however there is a growing evidence base for the use of OKC knee extension in ACL rehabilitation after 12 weeks postoperatively between 90° and 60° ROM without demonstrated graft stress/joint laxity.[11-15]
- This in particular influences a combined ACL/PLC injury since OKC knee extension can be initiated relatively early, and assist in quadriceps strengthening compared to CKC exercises alone.[11,13,15] OKC knee extension for combined ACL/PLC injuries should therefore be limited to 90° to 60° until late stage rehabilitation; however, the optimal time to resume full range OKC extension remains unclear.[14,15] OKC knee extension for combined PCL/PLC injuries should be limited to 0° to 60°,[15,16] and combined ACL/PCL/PLC should be limited to 60° to 30°.[15,16]
- Isolated PLC and PCL/PLC combined injuries have not traditionally used OKC knee flexion until later stage rehabilitation for similar fears of graft stress/joint laxity incurred,[4,17] however, there needs to be further quality research to quantify this, as has been performed with ACL rehabilitation.
- Similarly, bracing and weight-bearing parameters need to be further investigated in relation to PLC injury and combined cruciate/PLC injury in relation to graft stress and induced joint laxity.
- Traditionally rehabilitation following lateral side ligament repair is more conservative than following ACL reconstruction, however Kinzer et al. demonstrated excellent outcomes following ACL/lateral side knee reconstruction utilizing contralateral patella tendon graft with their Knee Symmetry Model, not involving the use of postoperative bracing, or limiting either ROM or weight-bearing status.[8]
- Until a wider level evidence base is established, then rehabilitation limitations for combined PCL/PLC and isolated PLC injuries should remain conservative.

Periodization

- Advanced strength and conditioning programs can include an initial continued linear periodization program from the previous rehabilitation phase where training load is primarily concerned with progressive muscle hypertrophy and endurance (high volume/low intensity), rather than aspects of power and strength.
- Progression to an undulating/nonlinear periodization once there is an adequate strength base will allow recovery periods between more intense strength training periods, variation to reduce training adaptation plateau, and allow changes in velocity and resistance to pursue power and strength emphasis without compromising technique.[18]
- Undulating/nonlinear programs have been shown to increase strength and motor performance in healthy, young trained athletes. There is little literature available on injured athletes.[18,19]
- A short duration linear periodization could also be used, however, it would have to progress into a strength/power phase to be appropriate.[19] There is subjective evidence that a nonlinear periodization program is

beneficial in most rehabilitation phases because they will offer the ability to train more than one parameter (e.g., hypertrophy, strength, endurance, power) at a time, while still emphasizing one of them in a particular phase.[19]

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- CKC exercises have been traditionally preferred in rehabilitation due to their demonstrated ability to produce quadriceps and hamstring group cocontraction, increase joint proprioception, and increase joint compression,[5,15] however, there is evidence demonstrating increased tibial translation and graft stress at angles greater than 60 degrees.[4,5,13,15,17]
- CKC quadriceps exercises should therefore be limited to those parameters in all combined and isolated PLC injuries until at least 4 months postoperatively.[4,17]
- CKC hamstring exercises in mid stance and terminal stance positions, with progression to eccentric control are important in later stage rehabilitation to control unwanted thrust into knee hyperextension.[4]
- Evidence supporting the implementation of strength and conditioning principles into specific late stage athletic rehabilitation programs is lacking. General consensus includes the progression from high volume/low intensity hypertrophy and endurance training into a strength/power phase, and eventually a specific power phase depending on the sports requirements.[19]
- Similar recommendations are made with regard to conditioning programs tailoring the explosive speed/endurance/repeat high intensity sprinting ability, and the energy system requirements of the sport.[19]
- Specific game performance requirements can be measured using global positioning system (GPS) and heart rate data and are integrated into late-stage training prescription to simulate game-specific loading.[20] For example, GPS data indicate that rugby league players will perform one bout of repeated high intensity loading every 5 minutes on average, but may be as high as every 2 to 3 minutes. One repeated high intensity effort bout will consist of 7 to 13 efforts (sprints/contacts/wrestle), with efforts lasting 7 to 8 seconds. Recovery between efforts can be as short as 5 seconds.[20] Conditioning training in late phase rehabilitation will require high-intensity repeat bouts of exercise with little recovery to physically and mentally prepare

TIMELINE 35-3: **Return to Rugby League after PLC Autograft Reconstruction (Isolated)**

Phase I: PRELIMINARY POSTOPERATIVE REHABILITATION (weeks 0 to 16 postoperatively)

Weeks 1 to 2

- Touch Weight Bearing (TWB) independent transfers/mobility
- Pain control
- Edema control: cryotherapy, elevation, compression
- Quadriceps setting/straight leg raises (SLR) in brace locked in full extension
- Quadriceps E-stimulation
- Ankle pumps
- Passive range of motion (PROM) and active assisted range of motion (AAROM) exercises aiming for 90° knee flexion/0° extension by end of week two
- Manual patella-femoral mobilizations
- Core (lumbo-pelvic and hip) stabilization exercises

Weeks 3 to 6

- PWB to full WB as tolerated (use pain as a guide)
- PROM/AAROM exercises aiming for 120° knee flexion/full extension by end of Week 6
- Quadriceps setting/SLR with EMG biofeedback

Weeks 7 to 12

- Weight bearing as tolerated
- Gait retraining, remaining PWB until normal gait pattern/SLR without extension lag
- Discontinue brace once normal gait pattern
- Progressive quadriceps resistance using TheraBand or weights as appropriate
- Stationary bike (submaximal once ROM achieved)
- Swimming: no fins/kick/flip turn/breaststroke
- Co-contraction of quadriceps/hamstrings in weight bearing with EMG biofeedback
- Centre of gravity (COG) weight shift/low level balance-proprioception
- Manual therapy: soft tissue techniques/joint mobilization as appropriate
- Single leg stance exercises
- Progress core exercises and hip stabilization

Weeks 13 to 16

- FWB normal gait pattern/No virus thrust
- Closed kinetic chain (CKC) leg press to a maximum of 70 feet flexion
- OKC knee extension 90° to 60° with ACL involvement/90–0° with PCL/sagittal plane only with MCL, FCL, or PLC involvement
- No OKC resisted knee flexion
- Eccentric/concentric hamstring CKC (e.g., bridging)
- CKC squat rack/squat machine not exceeding 70′ feet flexion
- CKC progression including single leg stance/resistance
- Resistance stationary cycle
- Swimming no flip turns
- Elliptical machine (submaximal)
- Stretching of tight musculotendinous/neural structures as appropriate (avoiding knee hyperextension/varus positioning)
- Progressive core/hip stabilization (floor-based core)
- Progressive balance/proprioceptive exercises from static to dynamic/add unstable base of support (BOS) (e.g., wobble board/BOSU step/squat)

the athlete for eventual return to that particular sport.

Olympic Lifts Used in the Training Program

- Submaximal Olympic lifting such as squatting (Figure 35-12), dead lifting, power clean, snatch and power press can be initiated in this phase, with initial emphasis on technique and knee alignment. Increased resistance loading can be progressively added once demonstrated correct technique is achieved. Verbal, mirror, and video feedback can be useful to assist in teaching correct technique.
- The objective is to increase training adaptation with velocity and resistance variables during this phase as a building block into the final power phases.[19] Higher load eccentric hamstring exercises (e.g., Nordic/Russian deadlift—Figure 35-13) should continue to be progressed to control unwanted knee extension forces.

Training Principles Used in the Design of the Program

- Program design during the final phases of rehabilitation will incorporate multiple training principles of progression, overload, variation, player position individualization, and game-specific demands.



FIGURE 35-12. Front squat—Olympic lift.

TIMELINE 35-3 Return to Rugby League after PLC Autograft Reconstruction (Isolated) (Continued)

PHASE II: ADVANCED STRENGTH AND CONDITIONING (weeks 16 to 24 postoperatively)	PHASE III: PERFORMANCE ENHANCEMENT (months 6 to 8 postoperatively)	PHASE IV: SPORT to SPECIFIC TRAINING (weeks 9 to 12 postoperatively)
• Progressive interval walking program including bodyweight supported walking (e.g., AlterG) • Resistance cycling including road cycling • Progressive CKC leg press/squat • Progressive OKC knee extension • Progressive CKC eccentric hamstring control (e.g., slide board bridge) • Commence OKC knee flexion/including PCL involvement • Commence weight-bearing eccentric hamstring exercises (Russian Dead Lift/no Nordic) • Progressive plyometric/agility exercises: supported jumping, jumping, bounding, hopping with feedback +/– video/neutral knee alignment/soft controlled landing into knee flexion avoiding knee extension/lumbo-pelvic control/trunk control • Advanced proprioceptive drills including hopping/landing onto unstable BOS • Advanced core/pelvic strengthening including limb movement/trunk rotation/single leg stance • Commence progressive interval running program including video feedback/gait analysis/bodyweight support running/once demonstrating single leg stance control with repeated squat • Continue swimming/alternate NWB conditioning on nonrunning days	• Advanced strengthening including progressive quadriceps/hamstring exercises, submax Olympic lifts, eccentric hamstring/gluteal exercises, OKC and CKC exercises (see Figures 35-10 to 35-13) • Progressive running including straight-line interval speed drills/repeat interval conditioning drills/endurance-distance running with demonstrated normal biomechanics • Advanced plyometric drills without pivoting/cutting (e.g., single leg hop/landing/bounding; see Figure 35-14) • Advanced core/lumbo-pelvic exercise • Advanced proprioceptive drills (e.g., hop and land with rotation onto BOSU) • Continued alternate low load conditioning on nonrunning days	• Sport specific strength exercises including Olympic lifts (e.g., squat, hang clean, clean press) • Maximal sprint drills/repeat interval sprinting • Agility drills including pivoting/cutting with demonstrated (video) neutral knee alignment and avoiding cutting in knee extension (e.g., W,Z,T pattern between poles; see Figure 35-15) • Repeated hop/jump/landing drills including rotational directions with abovementioned alignment (as per text) • Sport-specific conditioning and training drills (see Figure 35-16) • Contact/wrestle training once the abovementioned is demonstrated



FIGURE 35-13. Nordic high load eccentric hamstring exercise.



FIGURE 35-14. Weighted single leg squat—combined closed chain lower limb/trunk control/open chain shoulder/balance exercise.

- The final sport-specific phase of training will continue to adopt most of these principles, but will become more tailored to game-specific and positional demands. For example, the total distance and speed of running for an outside back during a game may be more than that of a forward/back row player, but the forward/back row player will have an increased number of collisions/tackles requiring more strength/power. This will alter the strength and conditioning program for individual players.

Application of Acute Training Variables

- Strength training typically involves a load of 80% to 100% of one maximal repetition (1RM), utilizing one to six repetitions with 3 to 5 minutes recovery. The calculation of 1RM for the rehabilitating athlete can be difficult, but most elite clubs will have this information preinjury, or can be calculated utilizing loading charts.[19]
- Power training requires a primary component of velocity of movement at a reduced load with longer recovery, utilizing one to six repetitions with resistance loads of 30% to 65% of 1RM. During the later stages, power training may be manipulated into shorter recovery periods, with higher load to simulate actual game loads.[18,19]
- Once there is an established strength base (e.g., squat 1.5 times body weight [see Figures 35-14 and 35-15]), plyometric training is progressed during this phase to enhance neuromuscular and power adaptations.[18] Progression from bilateral to single limb bounds, jumps and hops can occur with feedback regarding trunk, lumbopelvic, and knee positioning. Feedback may involve video, force plate/ground reaction force, or muscle stiffness/velocity measures.
- Training loads vary, however four to six sets of five to eight repetitions, with 30 to 90 seconds recovery time, two to four times per week is typically introduced.[21]



FIGURE 35-15. Weighted overhead squat—combined closed chain lower limb/trunk control/open chain shoulder exercise.

Total foot contacts per session can vary between 20 and 50,[18,21] but is typically symptom based.

- Safe timing of plyometric training (Figure 35-16) is important and can usually be done early in the training session before fatigue. Although plyometric training is critical to ensure neuromuscular adaptation, advanced proprioceptive exercises (not involving cutting/pivoting) should still continue in an attempt to minimize the risk of reinjury, or contralateral leg injury (Table 35-1).
- Through the more advanced phases of training, data monitoring, including MVC, pain rating, general soreness, and specific muscle tightness rating will assist in forward planning conditioning/agility/neuromuscular components of training. Noted changes may occur after increasingly heavy resistance training, and may

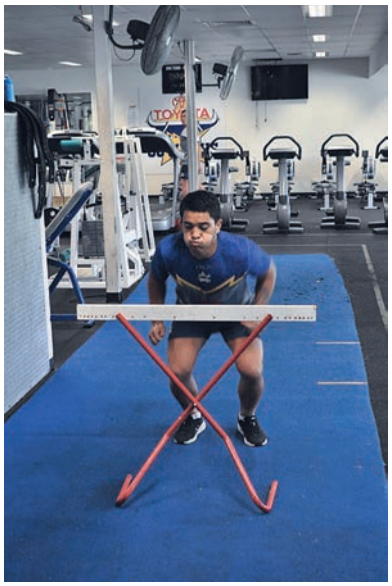

FIGURE 35-16. Plyometrics power jump-land.

Table 35-1 North Queensland Cowboys 2013 Weights Periodization Plan

Phase 1	Phase 2	Phase 3
Hypertrophy	Strength/power	(Specific)
Lower weights	Lower weights	Whole body
Front squats 5×8	Squats 5×4	Front squats 5×5
Zirchers 3×10	Deadlifts 1×5, 3×3	RDLs 3×6
Clean pulls (hang) 5×5	Three hurdles > prowler	Split squats 3×6
Reverse lunges 3×8	DB step-ups 3×6	Split jerks 4×5
One-leg DB RDLs 3×8	RDLs 3×6	Bench rows 3×8
Abs		Wted chins 3×10 > ABS

place other musculotendinous structures at risk of acute strain injury due to fatigue, or load-induced tendinopathy. Planning high-intensity running after heavy resistance training is not recommended, and should be performed on alternate days.

Phase II: Performance Enhancement Training Techniques

Periodization

- As previously mentioned, a functional progression including neuromuscular markers is preferred over a traditional time-based model in determining when the athlete will progress safely into more advanced phases of rehabilitation.
- The primary goal of the performance enhancing phase is to restore muscular strength, endurance, power, cardiovascular endurance, and neuromuscular control/balance/proprioception. It also involves the introduction of progressive pivoting and cutting.
- Strength and conditioning parameters continue toward full restoration of specific strength and power utilizing a continuing nonlinear periodization model. Technical errors should have been corrected in the previous phase by using feedback measures.
- Variables of speed, resistance, recovery time, and exercise type are interchanged to avoid training adaptation plateau. Cycling through weekly or longer periods of variation can be used to maximize training adaptation.

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- Milestones for progression into this phase include no joint effusion post exercise, normal running biomechanics at higher straight line speed, demonstrated strength testing of quadriceps/hamstrings 85% to 100% (isokinetic, relative strength index, limb symmetry index), hop testing symmetry (including single limb vertical jump height), single repeated jump-land with neutral knee/lumbo-pelvic control, force plate jump symmetry, and surgeons clearance/KT arthrometer/stress radiography.

Olympic Lifts Used in the Training Program

- All Olympic lifting continues with progressive resistance and speed.

Training Principles Used in the Design of the Program

- Conditioning sessions outlined in the previous phase continue to replicate game data. Game data illustrate repeat high intensity work bouts with minimal recovery ratios are required, with some positional differences.
- Maximum speed, over-speed, and speed-resistance training can be initiated with the aim of restoring normal sprint mechanics and increasing athletic performance. Care should be taken in weekly planning of these sessions in relation to acute soft tissue injury, and utilizing monitoring data as previously mentioned.
- Plyometric training (Figure 35-16) including single leg jump-land/depth jumps/bounding/repeat jump-land continue from the previous phase. Progression into rotational jumps and landing technique, decelerating bounds utilizing resistance bands, and advanced proprioceptive training landing on an unstable base can be introduced, and landing-knee position feedback given. Force plate data measuring single leg jump vertical ground reaction forces, and measured height need to be symmetrical to reduce reinjury risk, or contralateral limb injury risk.[9]
- The main component of this phase is introducing agility-based drills containing cutting/pivoting maneuvers (Figure 35-17) with feedback (video) in regards to knee and lumbopelvic control. Initial drills are slow speed, single direction change, noncontested drills to allow focus on knee positioning. Progression to higher speed, multidirectional changes and reactive drills, and



FIGURE 35-17. Agility/cutting Z drill.

eventually game simulated contested drills with multiple players are introduced. Positional specific drills can also be introduced, which simulate game-related data.[21] Throughout each progression, specific feedback on knee control is required.

Phase III: Sport-Specific Training

Periodization

- The final phase of sport-specific training is characterized by specific activities that emphasize returning the athlete to full game- and position-related function, and progressive integration into open reactive/multidirectional team drills and contact training. Emphasis is placed on successful return to previous specific functional levels, and prevention of reinjury.
- Milestones to progress into this phase are previously mentioned. These include strength testing, neuromuscular testing, ground reaction force testing, and clinical monitoring (e.g., effusion).
- Demonstrated excellent neuromuscular control of the knee and trunk during landing, cutting and pivoting is required and closely monitored, including control under fatigue.
- Psychological evaluation may be required if the athlete expresses a lack of confidence, or undue anxiety about injury risk. Final return to sport testing is required before medical clearance to sport, and involves several other functional tests. Listed below are functional tests that are used before clinical decision making.

Program Design/Performance Training Program

- Whilst there is a minimal specific evidence base for injured athletes in strength and conditioning principles during their rehabilitation phases, the final phase of training should incorporate established training principles, in this case of highly trained, healthy, young male footballers. Elements of power, strength, eccentric, plyometric, neuromuscular, sprint, and repeat high intensity training are required for rugby league, and most other football codes.
- Whilst strength and power training follows a game- and position-specific continuing overload-undulating/nonlinear program until maximum strength gains are symmetrical to preinjury levels, there is focus placed on periodized maximal strength, and maximal power phases. This may involve changing variables to shorter recovery periods with high load/low repetition to simulate actual game loads.
- During this phase, the injured athlete should have full integration into a normal preseason training schedule (assuming that the athlete is returning to sport at seasons start), whilst maintaining ongoing extra rehabilitation elements. These rehabilitation elements may include monitored strength/power deficits, but more importantly include continuing high-level neuromuscular/proprioceptive training, including training these elements under fatigue and in uncontrolled/reactive drills. Ongoing feedback regarding knee/lumbopelvic/trunk control is required.
- FIFA 11+, or similar proven preventative programs, can be incorporated into a regular dynamic warmup for the entire squad as an ongoing pretraining, and pregame ritual.[22]
- Monitoring, testing, and feedback of these elements continue after successful return to sport is made for a minimum period of 1 to 2 years, but should continue indefinitely if there are documented lapses of any element.
- Conditioning drills have game-specific focus on repeat high intensity bouts of exercise with high work/low recovery ratios. Maximal sprinting/return running drills containing 7 to 13 efforts lasting 7 to 8 seconds each effort, every 2 to 3 minutes continue, with as little as 5 seconds recovery between efforts. Distance covered with each effort vary between 6 and 10 m for front row forwards, and more than 21 m for outside backs and wide running forwards.[20]
- Preinjury data can be used to determine when the athlete approaches their preinjury cardiovascular endurance levels.
- Skill training under fatigue after conditioning drills is utilized to enhance ball handling skills, and decision-making in defensive and offensive game simulation. Attention and monitoring of active knee control during periods of fatigue is another clinical indicator of readiness to return to play.
- Movement based testing which is position specific has also been used as a clinical indicator of return to play readiness in NFL athletes returning from ACL reconstruction.[21]
- Contact and uncontrolled wrestling training are the final components of the returning athlete into full training, and represents uncontrolled blunt trauma risk to the knee in any direction.
- Maximal strength and functional testing is required to commence this sub-phase. As previously mentioned

hard bracing is not permitted in rugby league, which places high importance on excellent active knee control. Taping and soft bracing may enhance proprioceptive feedback, but will not offer rigid protection to knee hyperextension or varus joint moments sustained during contact training.
- Successful completion of a minimum of 3 to 4 weeks of full contact training is recommended before clearance to return to competitive games.

Sports Performance Testing

General Information

- General history
- Subjective questionnaires—online wellbeing/soreness scoring
- Medical history—current status, medications, and history
- Sports injury history—all previous injury history
- Surgical history—all surgical history
- Chronic conditions/medication
- Genetic conditions—hypermobility

Specific Tests

- Objective tests as per above text
- Physiological assessments—GPS heart rate data/maximum aerobic speed
- Body composition tests—weight and body fat composition
- Static/dynamic postural assessments—static star excursion test
- Dynamic muscle performance testing—hop/jump land/ground reaction force/video
- Movement performance testing—gait analysis/position specific testing
- Sport-specific testing—open training
- Others—MVC

Specific Criteria for Progression to the Next Stage to Determine Readiness for Rugby League

- As per text

Specific Criteria for Release to Unsupervised Complete Participation in Rugby League

- Objective criteria to release an athlete to commence competitive return to sport include no joint effusion after exercise sessions, normal running/sprinting/pivoting/cutting biomechanics including monitoring under fatigue, strength testing of quadriceps/hamstrings 90% to 100% (isokinetic, relative strength index, limb symmetry index), hop testing symmetry (including single limb vertical jump height), single repeated jump-land with active knee control (including monitoring under fatigue), force plate/ground reaction force jump symmetry, surgeons clearance (including KT arthrotometer/stress radiography), position-specific movement testing, and asymptomatic completion of open skills/contact training over at least 3 to 4 weeks. See Figure 35-18 for an example of a return to training program.

Recommended Ongoing Exercises

- Monitored strength/power deficits
- High level neuromuscular training
- Lumbo-pelvic control
- Regular monitoring (GRF—jump and hop tests and video)

Evidence

Heijne A, Werner S: Early versus late start of open kinetic chain quadriceps exercises after ACL reconstruction with patella tendon or hamstring grafts: A prospective randomized outcome study. *Knee Surg Sports Traumatol Arthrosc* 15:402–414, 2007.

A randomized controlled study comparing 68 patients' outcomes after ACL reconstruction. Patients were randomly allocated to early (4th postoperative week) and late (12th postoperative week) start of OKC quadriceps exercises in both patella tendon and hamstring tendon subgroups. Preoperative and postoperative measures of ROM, anterior knee laxity, postural sway, thigh muscle torques, and anterior knee pain were evaluated. Early OKC with hamstring tendon graft showed a significantly increased anterior knee laxity over time (Randomized controlled trial; Level II evidence).

Kinder A, Jenkins W, Urch S, et al: Rehabilitation following knee dislocation with lateral side injury: Implementation of the knee symmetry model. *N Am J Sports Phys Ther* 5:155–165, 2010.

A prospective case series of 21 patients with knee dislocation and lateral side injury, implementing the Knee Symmetry Model of rehabilitation involving symptomatic restoration of ROM and weight-bearing progression rather than a timeframe-based approach. Outcome data and subjective knee scores (International Knee Documentation Committee and modified Noyes survey scores) showed excellent long-term stability, normal ROM and strength, and a high level of function (Case series; Level IV evidence).

Lunden J, Bzdusek P, Monson J, et al: Current concepts in the recognition and treatment of posterolateral corner injuries of the knee. *J Ortho Sports Physical Ther* 40:502–516, 2010.

A current expert opinion based review of concepts of rehabilitation of posterolateral corner injuries (Diagnosis/therapy; Level V evidence).

Myer G, Martin L, Ford K, et al: No association of time from surgery with functional deficits in athletes after anterior cruciate ligament reconstruction: Evidence for objective return to sport criteria. *Am J Sports Med* 40:2256–2263, 2012.

A prospective study of 33 athletes with unilateral ACL reconstruction cleared by a physician to return to sport, measuring unilateral force development (vertical jump height) and absorption (vertical ground reaction force) deficits. Symmetry deficits persist in athletes after return to sports and are independent of time after reconstruction (Case series; Level IV evidence).

Reimen M, Lorenz D: Integration of strength and conditioning principles into a rehabilitation program. *Int J Sports Phys Ther* 6:241–253, 2011.

A current expert opinion based review of concepts of strength and conditioning principles in rehabilitation of injured athletes (Level V evidence).

Coaching Session: Skills Rehab

Start: 10/01/13 7:00:00am

End: 10/01/13 8:00:00am

Venue: TBA

Major Objective:

	Group	Exercise/Drill	Time	Duration	Drill Objective	Players - Modified	Coaches
1	All	Mapping Drill/3 plays	7:00am	10mins	Communication / spacing		
2	All	Leg Swings	7:10am	5mins	Physical preparation		
3	Forwards	Attack - Position Specific	7:15am	20mins	Carry - lean into contact		
					- 2 on 1 Def shooting		
					- 1Bs 2 vs 3 pads with Rooster option		
					- Ruck Plays- wedge / snap / 12 / Viking / Block		
					- Static then rolling thru pads		
4	Backs	Attack - Position Specific	7:15am	20mins	- Long passing		
					- 3 v 3 kick returns		
					Kickers:		
					- 1 leg to step thru / numbers grid		
					Add pad		
					Catchers:		
					Throw routine: hands high / chest mark / lying on ground		
					- Pad work		
					All: Kickers thru poles to 1,2,3,4.		
					- catchers get interference		
					- contested grabs 1 v 1		
5	All	5 v 4 - Defence	7:40am	10mins	Use whistle	Shoulder Boys- Mod skills	
					Get fwd / nominate		
6	All	Kick ChaseGame	7:50am	15mins	Rules:	1 v 2, 1 v 3, 2 v 3	
					- kick inside own 1/2 for 20m tackle 1pt		
					- inside 10m tackle 2pts	Shoulder Boys- Mod skills	
					- kick in opposition 1/2 for repeat set 3pts		
					- 4pts for a try		

Coaching Session: Conditioning

Start: 22/01/13 7:00:00am

End: 22/01/13 8:00:00am

Venue: DFS 1

Major Objective:

	Group	Exercise/Drill	Time	Duration	Drill Objective	Players - Modified	Coaches		
1	**Full Training**	**Conditioning**	**7:00am**	**6mins**	**6 x 10m Returns in 36sec go on 1min**				
					Group 1 - 32m				
					Group 2 - 31m x 8 in 6sec go on 12sec				
					Group 3 - 30m Start off ground				
					6 x 10m Returns in 36sec				
					Total 488m				
					2min recovery				
2	**Full Training**	**Conditioning**	**7:00am**	**8mins**					

FIGURE 35-18. A sample return to training program.

					Group 1											
					Back 4m, Fwd 20m hit ground, back 10m hit ground,											
					sprint 20m in 15sec, jog back to start go on 35sec											
					Group 2											
					Back 3m, Fwd 20m hit ground, back 10m hit ground											
					sprint 20m in 15sec, jog back to start go on 35sec											
					Group 3											
					Back 2m, Fwd 20m hit ground, back 10m hit ground											
					sprint 20m in 15sec, jog back to start go on 35sec											
					Total 516m											
					3min recovery											
3	Full Training	Conditioning	7:00am	7mins	Up 10m hit ground back 10m then up 10m hit ground											
					then sprint back											
					Group 1 - 26m											
					Group 2 - 24m											
					Group 3 - 22m											
					x 8 in 15sec walk back to start go on 30sec											
					Total 464m											
					3min recovery											
4	Full Training	Conditioning	7:00am	8mins	MAS x 4 With Football											
					Group 1 - 83m and 16m return											
					Group 2 - 78m and 14m returns											
					Group 3 - 73m and 12m returns											
					6 x 10m returns in 36sec go on 1min											
					MAS x 4 With Football											
					Group 1 - 83m											
					Group 2 - 78m No Returns											
					Group 3 - 73m											
					Total 884m											
					3min recover y											
5	Full Training	Conditioning Games	7:00am	8mins	Games with Coaches:											
					- partner offside touch											
					- two games											
6	Full Training	Conditioning	7:00am	29mins	Repeat in reverse but no game											

Training Groups										
Full Training		Blue Team	Pink Team	Green Team	Orange Team					

FIGURE 35-18, CONT'D

Risberg M, Lewek M, Synder-Mackler L: A systematic review for anterior cruciate ligament reconstruction: how much and what type? *Phys Ther Sport* 5:125–145, 2004.

A systematic review of 33 RCTs in relation to the effectiveness of various rehabilitation programs that have been used for ACL injuries in adults, including open and closed kinetic chain exercises (Systematic review RCTs; Level I evidence).

Wilkins S: Rehabilitation of the multiple ligament injured knee. *Tech Knee Surg* 10:2–10, 2011.

A current expert opinion based review of rehabilitation of the multiple ligament injured knee (Level V evidence).

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14. Heijne A, Werner S: Early versus late start of open kinetic chain quadriceps exercises after ACL reconstruction with patella tendon or hamstring grafts: a prospective randomized outcome study. *Knee Surg Sports Traumatol Arthrosc* 15:402–414, 2007.
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18. Fleck S, Kraemer W: *Designing resistance training programs*, Illinois, 2004, Human Kinetics.
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20. Gabbett T: Sprinting patterns of national rugby league competition. *J Strength Condit Res* 26:121–131, 2012.
21. Verstegen M, Falsone S, Orr R, et al: Suggestions from the field for return to sports participation following ACL reconstruction: American football. *J Orth Sports Phys Ther* 42:337–344, 2012.
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Multiple-Choice Questions

QUESTION 1. Which choice of stage progression is recommended for late stage rehabilitation PLC reconstruction in athletes?

A. Timeline progression only
B. Functional progression including milestone testing
C. Surgeons clearance only
D. Strength testing only

QUESTION 2. Which testing criteria are not recommended to provide medical clearance to competitive contact sport?

A. Strength testing (isokinetic, relative strength index, limb symmetry index)
B. Hop testing
C. Positional specific movement testing
D. None of the above

QUESTION 3. What exercises are recommended that the athlete continues after returning to sport?

A. Strength deficits
B. Neuromuscular training
C. Cutting/pivoting with knee position feedback
D. All of the above

QUESTION 4. Which loads must be avoided during postsurgical rehabilitation for PLC injury?

A. Flexion
B. Valgus loading
C. Varus loading and hyperextenion
D. None of the above

Answer Key

QUESTION 1. Correct answer: **B** (see Phase I: Advanced Strength and Conditioning Programs)

QUESTION 2. Correct answer: **D** (see Phase I: Sport Performance Testing)

QUESTION 3. Correct answer: **D** (see Phase III: Sport-Specific Training)

QUESTION 4. Correct answer: **C** (see Introduction)

Chapter 36



Leg Pain in the Athlete: Stress Fractures, Medial Tibial Stress Syndrome, and External Compartment Syndromes

INTRODUCTION

Timothy S. Mologne, MD, and Kari Sturtevant, DPT

Epidemiology

- Leg pain is a common complaint in athletes.
- There is no disparity between men and women, except stress fractures are more common in women.
- Leg pain can be seen in athletes in all sports, but is especially common in endurance sports, particularly running.

Pathophysiology

Intrinsic Factors

- Excessive foot pronation combined with repetitive impact activity
- Hormonal imbalance
- Female endurance athletes (anorexia, amenorrhea, osteopenia)[1,2]
- Poor nutrition
- Metabolic disorders
- Abnormal anatomical relationship between the popliteal artery and fascia and muscles in the popliteal fossa (popliteal artery entrapment syndrome)

Extrinsic Factors

- Overuse
- Acute increase in duration and intensity of training without appropriate conditioning
- Repetitive loading
- Improper footwear
- Repetitive running on hard surfaces

Classic Pathological Findings

- Inflammatory process of the periosteum and tendinous attachments of the soleus, flexor digitorum longus, and deep crural fascia along the posteromedial aspect of the distal two thirds of the tibia: medial tibial stress syndrome[3]
- Imbalance in bone turnover with more bone resorption than bone production: stress fracture[2]
- Muscle ischemia related to: chronic compartment syndrome[4]
- Entrapment of the popliteal artery by medial displacement of the artery by the medial head of the gastrocnemius muscle: popliteal artery entrapment syndrome[5]
- Entrapment of various motor and sensory nerves in the leg and ankle: nerve entrapment syndrome
- Bone formation in the interosseous ligament between the tibia and fibula following an ankle or tibial fracture: tibiofibular synostosis
- Fascial defect in the lateral leg compartment at the site of the superficial branch of the peroneal nerve becoming superficial: muscle herniation with possible associated chronic exertional compartment syndrome[4]

Clinical Presentation

History

- Activity-related aching pain along the posteromedial aspect of the distal two thirds of the tibia: posteromedial tibial stress syndrome
- Activity-related pain on the tibia: stress fracture
- Leg aching during or after exercise that usually occurs after the same duration of exercise. The pain does not resolve immediately after rest: chronic exertional compartment syndrome
- Possible postexercise paresthesias: chronic exertional compartment syndrome
- Cramping pain and paresthesias with exercise, which are relieved with rest: popliteal artery entrapment syndrome

Physical Examination

- Diffuse tenderness to palpation along the distal two thirds of the posteromedial aspect of the tibia: medial tibial stress syndrome
- Pain in the posteromedial tibia with toe raises and resisted plantar flexion: medial tibial stress syndrome
- More focal tenderness along the tibia with possible swelling in the same area: stress fracture
- Increased pain with a bending or twisting force is applied to the tibia: stress fracture
- Physical examination is usually normal in patient with chronic exertional compartment syndrome, but may demonstrate firm, tense leg compartments and possible paresthesias in a specific nerve distribution, depending on the compartment and pressures in the compartment that contains the nerve.
- The physical examination is usually normal in patients with popliteal entrapment syndrome. With the knee extended, pulses may diminish or obliterate with passive ankle dorsiflexion or active plantar flexion. Pulse may be best assessed with Doppler ultrasound.

Imaging and Other Diagnostic Studies

- Radiographs of the leg
- Bone scan (may be helpful in medial tibial stress syndrome and stress fractures) (Figure 36-1)
- Magnetic resonance imaging (MRI; helpful for stress fractures, medial tibial stress syndrome, and exertional compartment syndrome) (Figure 36-2)
- Arteriogram in cases of suspected popliteal artery entrapment syndrome and in patients thought to have vascular claudication
- Leg compartment pressure measurements at rest and 1 and 5 minutes after exercise (diagnostic for exertional compartment syndrome)[4]
- Doppler ultrasound may be used to assess ankle pulses in the workup for suspected popliteal artery entrapment syndrome.

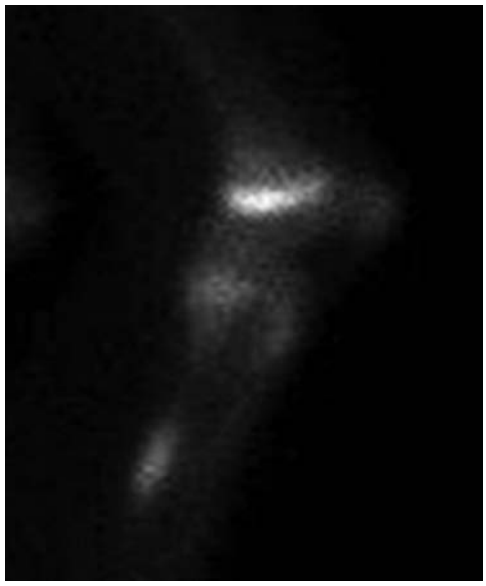

FIGURE 36-1. Bone scan showing mild increased uptake along the posteromedial aspect of the distal third of the tibia in an elite runner diagnosed with posteromedial tibial stress syndrome.

Differential Diagnosis

- Medial tibial stress syndrome
- Tibial stress fracture
- Chronic exertional compartment syndrome
- Popliteal artery entrapment syndrome
- Nerve entrapments
- Gastroc-soleus strain
- Plantaris tear
- Ruptured Baker's cyst
- Tibiofibular synostosis
- Fascial defect with muscle herniation

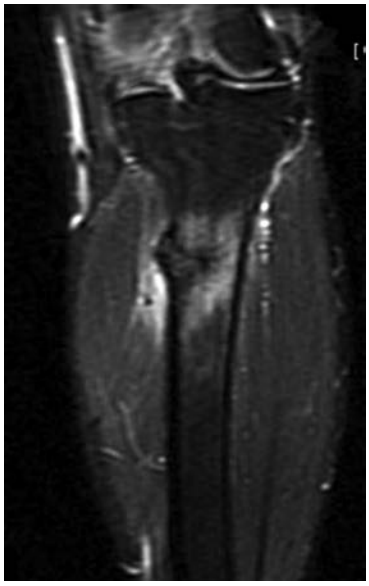

FIGURE 36-2. Magnetic resonance image of a stress fracture of the proximal medial tibia.

- Lumbosacral disc herniation with radiculopathy
- Vascular claudication (elder athletes with possible peripheral vascular disease)
- Neurogenic claudication from spinal stenosis

Treatment

Nonoperative Management

- REST
- Cross-training
- Decrease in training intensity and duration
- Change in training surface
- Nonsteroidal antiinflammatory agents
- Ice
- Heel cord stretching
- Orthotics for excessive foot pronation
- Education on gradual progression in training and conditioning

Guidelines for Choosing Among Nonoperative Treatments

- Virtually all causes of leg pain in athletes, with the exception of chronic exertional compartment syndrome and popliteal artery entrapment syndrome, are treated conservatively as an initial step.

Surgical Indications

- At least 4 months of rest and activity modification with recurrence of symptoms once activities and sports activities are restarted (medial tibial stress syndrome)
- Stress fractures of the anterior tibial cortex that remain symptomatic and show signs of delayed or nonunion despite 6 months of treatment
- Chronic exertional compartment syndrome is not effectively managed with nonsurgical treatments except rest and activity modifications. Surgery is the best option to allow athletes to return to their respective sports.
- Claudication symptoms in patients found to have popliteal artery entrapment syndrome
- Persistent symptoms related to specific nerve compressions that do not respond to conservative treatment.

Evidence

Bennell K, Matheson G, Meeuwisse W, et al: Risk factors for stress fractures. *Sports Med* 28(2):91–122, 1999.

This article is a literature review on stress fractures and concludes that although stress fractures result from repetitive loading, no clear association has been determined between stress fractures and the duration or intensity of training. Menstrual disturbances, caloric restriction, lower bone density, muscle weakness, and leg length differences are risk factors for stress fracture. (Level X evidence)

Mubarak S, Gould R, Lee Y, et al: The medial tibial stress syndrome. A cause of shin splints. *Am J Sports Med* 10:201–205, 1982.

This case series of 12 patients with posteromedial leg pain found normal compartment pressure measurements. Mild increased uptake on a bone scan was present in two of eight patients (25%). Biopsy material of the affected area in two patients treated surgically with a deep posterior compartment fasciotomy is described as showing inflammation and vasculitis. (Level X evidence)

Pedowitz R, Hargens A, Mubarak S, et al: Modified criteria for the objective diagnosis of chronic compartment syndrome of the leg. *Am J Sports Med* 18:35–40, 1990.

This retrospective study evaluated 45 patients diagnosed with chronic compartment syndrome. A fascial herniation of muscle was found in 46%. The authors defined intramuscular compartment pressure criteria to diagnose an chronic exertional compartment syndrome of the leg as (1) a pre-exercise pressure greater than or equal to 15 mmHg; (2) a 1-minute postexercise pressure of great than or equal to 30 mmHg; or (3) a 5-minute postexercise pressure greater than or equal to 20 mmHg. (Level X evidence)

Pell R, Khanuja H, Cooley R: Leg pain in the running athlete. *J Am Acad Orthop Surg* 12(6):396–404, 2004.

This review article outlines and discusses the evaluation and management of various causes of leg pain in runners. (Level X evidence)

Stager A, Clement D: Popliteal artery entrapment syndrome. *Sports Med* 28(1):61–70, 1999.

This review article discusses the pathoanatomy, demographics, and clinical presentation of patients with exercise-induced leg pain caused by entrapment of the popliteal artery along the posterior aspect of the knee. (Level X evidence)

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Multiple Choice Questions

QUESTION 1. Intrinsic factors contributing to leg pain in the athlete include:

A. Poor nutrition
B. Being female
C. Abnormal hormone balance
D. All of the above

QUESTION 2. Which of the following scenarios is *least* likely to result in leg pain?

A. A 42-year-old male runner who recently increased his miles run per week from 25 to 35 and improved his pace from a 10-minute mile to an 8-minute mile
B. A 26-year-old woman training for an ironman who now has infrequent menstrual cycles and is concerned about her weight and body image
C. A 32-year-old female cyclist who recently purchased a new road bicycle, had it custom fit, and has now increased her mileage per week by 10% with similar intensity
D. A 21-year-old man with a history of medial tibial stress fractures who has recently returned to running with old shoes and displays moderate pronation while running

QUESTION 3. Which of the following is *not* a surgical indication?

A. Conservative treatment has failed to relieve specific nerve compressions.
B. Following 4 months of treatment, stress fractures of the anterior tibial cortex remain symptomatic.
C. Following 4 months of rest and activity modification, familiar symptoms are experienced once sport activities are resumed.
D. Claudication symptoms persist in a patient with popliteal artery entrapment.

QUESTION 4. Which of the following injuries is *not* initially treated conservatively?

A. Chronic exertional compartment syndrome
B. Tibiofibular synostosis
C. Medial tibial stress fracture
D. Decreased sensation in the area of the leg consistent with the superficial fibular nerve

QUESTION 5. Which of the following diagnostic images would be useful for an athlete with complaints of leg pain?

A. MRI
B. Radiograph
C. Doppler ultrasound
D. CT myelogram

Answer Key

QUESTION 1. Correct answer: **D** (see Pathophysiology: Intrinsic Factors)

QUESTION 2. Correct answer: **C** (see Pathophysiology)

QUESTION 3. Correct answer: **B** (see Treatment: Surgical Indications)

QUESTION 4. Correct answer: **A** (see Treatment: Guidelines for Choosing Among Nonoperative Treatments)

QUESTION 5. Correct answer: **D** (see Clinical Examination: Imaging and Other Diagnostic Studies)

NONOPERATIVE REHABILITATION OF MEDIAL TIBIAL STRESS SYNDROME

Mark F. Reinking, PT, PhD, SCS, ATC, and L. Tyler Wadsworth, MD

GUIDING PRINCIPLES OF NONOPERATIVE REHABILITATION OF MEDIAL TIBIAL STRESS SYNDROME

- Let the athlete's leg pain guide the return to activity
- Gradual return to athletic activity
- Address entire kinetic chain biomechanics

Phase I (weeks 0 to 2): Acute Phase

Protection

- If the athlete has medial tibial pain with walking ambulation, crutches should be used until the athlete can walk without pain.

Management of Pain and Swelling

- Icing and electrical stimulation can be used to control pain complaints.
- Some athletes report improvement in pain with use of a compressive sleeve worn over the leg, although there is no evidence to support or refute use of this approach.

Techniques for Progressive Increase in Range of Motion

If the athlete shows impairments of range of motion (ROM) at the ankle, the clinician needs to identify if the limitation is a result of muscle length, joint limitation, or both. The appropriate intervention would be selected based on that differential.

Manual Therapy Techniques

- If joint ROM limitations, joint mobilization should be applied appropriately in terms of grade and direction.

Soft Tissue Techniques

- The muscles that have been named as potential contributors to medial tibial stress syndromes (MTSS) include soleus, posterior tibialis, flexor digitorum longus, and flexor hallices longus.[1-5]

- Newsham[6] demonstrated a decrease in MTSS pain using manual techniques to reduce hypertonicity in the deep posterior compartment of the leg.
- Callison[7] presented evidence that the addition of acupuncture to a standard rehabilitation program for medial tibial stress syndrome significantly decreased pain and medication use.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Gastrocnemius and soleus stretching as indicated by muscle length testing

Other Therapeutic Exercises

- Relative rest from the offending weight-bearing activities is important in Phase I. Decrease the volume of impact weight-bearing exercise by at least 50%.
- Add low-impact cross-training (pool running, cycling, elliptical machine) to maintain cardiorespiratory fitness.

Activation of Primary Muscles Involved

- Newsham[6] recommended restoring muscle balance of the toe flexors and extensors using exercise to facilitate toe extension and short foot exercises to improve the strength of the foot intrinsics. If other muscle weakness of the crural muscles was identified in the initial examination, this should be addressed.

Sensorimotor Exercises

- No evidence to support this for MTSS, but if the athlete's ground-based training is altered because of leg pain, these exercises can minimize loss of sensorimotor performance. Begin with static balance exercises such as single leg stand on floor with eyes open and progress to less stable surface and eyes closed.

Open and Closed Kinetic Chain Exercises

- Avoid any impact loading that is painful. If the athlete can perform closed kinetic chain exercises without leg pain, then these should not be restricted.

Techniques to Increase Muscle Strength, Power, and Endurance

- Niemuth[8] identified hip abductor muscle weakness in a group of recreational runners with lower limb overuse injuries.
- Address any muscle imbalances in the lower kinetic chain. This should be based on careful manual muscle testing and observational gait analysis.

Milestones for Progression to the Next Phase

- Pain-free walking ambulation
- Minimal pain to palpation along posteromedial tibial crest

Phase II (weeks 3 to 4): Rehabilitation Phase

Orthotics

- Consideration should be given for orthotic fabrication based on lower extremity movement patterns and function.
- Some evidence suggests that an excessively pronated foot may increase the risk for MTSS.[9]
- Other evidence suggests both over the counter and custom foot orthotics decrease pain in athletes with MTSS.[10,11]
- Orthotic decision making is based on athlete preference, foot type, sport activity, and arch taping trial.

Management of Pain and Swelling

- Icing after exercise

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Same as described in Phase I, but progressing to more aggressive joint techniques if ROM impairment persists.

Soft Tissue Techniques

- Same as described in Phase I.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Same as described in Phase I.

Sensorimotor Exercises

- Progress athlete to higher demand static balance exercise including single leg stand on unstable surface with upper extremity challenges including diagonal movements, resisted upper extremity exercise, Bodyblade, and rebounder.

Open and Closed Kinetic Chain Exercises

- Progress resistance from Phase I and add multiplanar closed chain movements in Phase II, including multidirectional lunges, lunge with trunk rotation, squats with upper extremity diagonal patterns.

Techniques to Increase Muscle Strength, Power, and Endurance

- Adjust exercise dosage appropriate to functional demand of impaired muscles.

Plyometrics

- If athlete is pain free with all ground based exercises, begin early plyometric training[12] with mini-trampoline

double leg hops, double leg drop squats, and double leg decline squats. These exercises must be pain free and performed no more than 3 times/week on alternate days.

Functional Exercises

- Begin progression to return to running progression with a walk-jog-run progression. See sample progression in Box 36-1.
- An athlete who has mild tenderness to palpation and symptoms that do not worsen with weight-bearing exercise can progress training as tolerated.

Criteria for Abandoning Nonoperative Treatment and Proceeding to Surgery or Other More Invasive Intervention

- Positive compartmental pressure study: Athletes who show persistence of leg pain with weight-bearing activities and inability to progress through return to running progression should be tested for chronic exertional compartment syndrome.

Milestones for Progression to the Next Phase

- No pain with palpation along posteromedial tibial crest
- Minimal to no pain with early plyometrics and walk-jog-run progression. An athlete who is doing most training in the pool may be allowed to return to competition but continue with functional progression during training time.

Phase III (weeks 4 to 8): Functional Training Phase

Management of Pain and Swelling

- Icing after running

Sensorimotor Exercises

- Progress athlete to dynamic balance activities using BOSU ball, slide board, balance beam.

Open and Closed Kinetic Chain Exercises

- Progress the challenge, intensity and speed of the multiplanar closed chain exercises introduced in Phase II.

Plyometrics

- Progress to higher level plyometric exercises including ankle hops on floor (double to single leg), depth jumps, box jumps, squat jumps, tuck jumps, and bounding.

Functional Exercises

- Continue with walk-jog-run progression.

Milestones for Progression to Advanced Sport-Specific Training and Conditioning

- Completion of functional progression
- Performance of all plyometric exercises without tibial pain

TIMELINE 36-1: **Nonoperative Rehabilitation of Medial Tibial Stress Syndrome (MTSS)**

PHASE I (weeks 0 to 2)	PHASE II (weeks 3 to 4)	PHASE III (weeks 4 to 8)
• Weight bearing as tolerated • Icing and interferential electrical stimulation for pain control • Joint mobilizations as indicated • Soft tissue mobilization/myofascial techniques to medial crural tissues • Gastrocnemius and soleus stretching as indicated • Cross-training activities • Short foot exercises • Hip muscle strengthening (lateral rotators, abductors) as indicated • Nonimpact balance exercises • Hike	• Pain-free walking ambulation • Orthotic fabrication as indicated • Icing and interferential electrical stimulation following exercise • Joint mobilizations as indicated • Soft tissue mobilization/myofascial techniques to medial crural tissues • Gastrocnemius and soleus stretching as indicated • Cross-training activities • Short foot exercises • Hip muscle strengthening (lateral rotators, abductors) as indicated • Nonimpact higher demand balance exercises • Multiplanar nonimpact closed kinetic chain exercises • Initiate early plyometric exercise • Initiate walk-jog-run functional progression	• Walk-jog-run progression • Icing and interferential electrical stimulation following exercise • Gastrocnemius and soleus stretching as indicated • Hip muscle strengthening (lateral rotators, abductors) as indicated • Higher demand dynamic balance exercises • Increase training volume of multiplanar closed kinetic chain exercises • Plyometric sequence

BOX 36-1 Walk-Jog-Run Progression

Rules of Progression:

- Stretching: gastroc, soleus, hamstring, quad, IT band before and after run (2 × 30 seconds each).
- If you have pain during run, slow to a brisk walk and complete the workout time. *Do not* proceed to the next step until you are able to perform that level without pain.
- Cross-training options: pool running, elliptical trainer, stationary cycling, swimming
- Minor shin soreness after running may occur but should dissipate within 1 to 2 hours. If not, do not progress to the next step!
- Perform weeks 1 to 2 on a treadmill, and then progress to overground exercise.
- *Do not run through pain!*

1 DAY	DISTANCE/MODE	INTENSITY	2 TIME	COMPLETED
1	Walk 3 min	4.0 MPH	14 min	
	Jog 2 min	6.0 MPH		
	Walk 3 min	4.0 MPH		
	Jog 3 min	6.2 MPH		
	Retro Walk 3 min	2.7 MPH		
2	X-Train			
3	Walk 2 min	4.0 MPH	15 min	
	Jog 3 min	6.2 MPH		
	Walk 4 min	4.0 MPH		
	Jog 3 min	6.2 MPH		
	Retro Walk 3 min	2.8 MPH		
4	X-Train			
5	Walk 2 min	4.0 MPH	15 min	
	Jog 3 min	6.2 MPH		
	Walk 3 min	4.0 MPH		
	Jog 4 min	6.4 MPH		
	Retro Walk 3 min	2.8 MPH		
6	X-Train			
7	Day Off			
8	Walk 2 min	4.0 MPH	16 min	
	Jog 4 min	6.2 MPH		
	Walk 2 min	4.0 MPH		
	Jog 5 min	6.4 MPH		
	Retro Walk 3 min	2.8 MPH		
9	X-Train			
10	Walk 2 min	4.0 MPH	17 min	
	Jog 5 min	6.4 MPH		
	Walk 2 min	4.0 MPH		
	Jog 5 min	6.7 MPH		
	Retro Walk 3 min	2.8 MPH		
11	X-Train			
12	Walk 2 min	4.0 MPH	19 min	
	Jog 6 min	6.4 MPH		
	Walk 2 min	4.0 MPH		
	Jog 6 min	6.7 MPH		
	Retro Walk 3 min	2.8 MPH		
13	X-Train			
14	Day off			
15	Jog 8 min	6.5 MPH	19 min	
	Walk 3 min	4.0 MPH		
	Jog 8 min	7.0 MPH		
16	X-Train			
17	Jog 10 min	6.5 MPH	21 min	
	Walk 2 min	4.2 MPH		
	Run 1 min	8.0 MPH		
	Jog 8 min	7.0 MPH		
18	X-Train			
19	Jog 12 min	6.5 MPH	24 min	
	Walk 2 min	4.2 MPH		
	Run 2 min	8.5 MPH		
	Jog 8 min	7.0 MPH		

Continue

BOX 36-1 Walk-Jog-Run Progression_cont'd

1 DAY	DISTANCE/MODE	INTENSITY	2 TIME	COMPLETED
20	X-Train			
21	Day Off			
22	Jog 10 min	6.5 MPH	25 min	
	Run 5 min	8.5 MPH		
	Jog 10 min	7.0 MPH		
23	X-Train			
24	Jog 10 min	6.5 MPH	27 min	
	Run 7 min	8.5 MPH		
	Jog 10 min	7.0 MPH		
25	X-Train			
26	Jog 8 min	6.5 MPH	30 min	
	Run 5 min	8.0 MPH		
	Jog 8 min	7.0 MPH		
	Run 5 min	8.5–9.0 MPH		
	Jog 4 min	6.5 MPH		
27	X-Train			
28	Day Off			

Week 5: Run on consecutive days; gradually increase mileage.
Week 6: Resume full training as long as pain free.

Criteria for Abandoning Nonoperative Treatment and Proceeding to Surgery or Other More Invasive Intervention

- Persistence of pain with weight-bearing activities
- Inability to complete functional progression to running secondary to pain

Specific Criteria for Return to Sports Participation: Tests and Measurements

- Pain-free running on successive days
- No pain with palpation along the posteromedial tibial border (MTSS)

Evidence

Eickhoff CA, Hossain SA, Slawski DP: Effects of prescribed orthoses on medial tibial stress syndrome in collegiate cross country runners. *Clin Kines* 54(4):76–80, 2000.

One hundred sixty-four collegiate cross-country athletes completed a survey on the effect of presecribed foot orthoses for medial tibial stress syndrome. Overall, 88% of athletes with MTSS symptoms reported a favorable effect from orthotic use. (Level IIb evidence)

Galbraith RM, Lavallee ME: Medial tibial stress syndrome: conservative treatment options. *Curr Rev Musculoskelet Med* 2(3):127–133, 2009.

This narrative review summarizes the published literature regarding conservative treatment options for medial tibial stress syndrome. (Level V evidence)

Herring KM: A plyometric training model used to augment rehabilitation from tibial fasciitis. *Curr Sports Med Rep* 5(3):147–154, 2006.

This methodological paper proposes a plyometric training model to incorporate into the rehabilitation of atheltes with medial tibial stress synrome (tibial fasciitis). Although the authors suggested that this model be subject to research, no evidence of the effectiveness of the model was presented in the paper. (Level V evidence)

Loudon JK, Dolphino MR: Use of foot orthoses and calf stretching for individuals with medial tibial stress syndrome. *Foot Ankle Spec* 3(1):15–20, 2010.

This prospective cohort study included 23 runners with symptoms of MTSS. All participants received interventions, including off-the-shelf foot orthotics and calf stretching. Of the 23 runners, 15 had a 50% reduction of pain in 3 weeks of intervention. The duration of MTSS symptoms was a significant factor that was associated with intervention effectiveness. The authors recommended that treatment for runners with MTSS may include off-the-shelf orthotics and calf stretching. (Level IIb evidence)

Moen MH, Rayer S, Schipper M, et al: Shockwave treatment for medial tibial stress syndrome in athletes: a prospective controlled study. *Br J Sports Med* 46(4):253–257, 2012.

This prospective observation trial included 42 athletes from two sports medicine clinics diagnosed with MTSS by the same sports medicine specialist. All athletes form one clinic were treated with a graded running progression, and the athletes at the second clinic also performed the graded running progression and received extracorporeal shockwave therapy (ESWT). These athletes received a total of five ESWT treatments in 9 weeks. The authors found that the subjects in the ESWT group returned to runner sooner than those who performed the running progression only. (Level IIb evidence)

Moen MH, Tol JL, Weir A, et al: Medial tibial stress syndrome: A critical review. *Sports Med* 39(7):523–546, 2009.

This systematic review provided a summary of the literature on medial tibial stress syndrome, including etiology, biomechanics, histology, examination, imaging, risk factors, therapy, conservative and surgical treatment, and prevention. (Level IIIa evidence)

Newsham K: A neuromuscular intervention for exercise related medial leg pain. *J Sport Rehabil* 21(1):54–62, 2012.

The quasi-experimental, nonequivalent control group study evaluated the effectiveness of a neuromuscular intervention for exercise related medial leg pain (ERMLP). Thirteen athletes with ERMLP symptoms were divided into a treatment group (N = 7) and a control group (N = 6). The treatment group received manual therapy to decrease trigger poin pain in medial leg and retraining of toe extensors and flexors. The treatment group exhibited decreased ERMLP pain with activity, and an increase in their algometer pressure threshold. (Level IV evidence)

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Multiple Choice Questions

QUESTION 1. Which of the following muscles has not been implicated in the etiology of medial tibial stress syndrome?

A. Soleus
B. Posterior tibialis
C. Flexor hallicus longus
D. Anterior tibialis

QUESTION 2. Early plyometric exercises such as ankle bounces on a mini-trampoline should be introduced in which rehabilitation Phase?

A. I
B. II
C. III
D. IV

QUESTION 3. When an athlete has persistent medial leg pain that is not responding to nonsurgical intervention, the most appropriate action is which of the following?

A. Casting of the foot and ankle
B. Continue with functional return to running progression
C. Compartmental pressure testing
D. Nerve conduction velocity testing

Answer Key

QUESTION 1. Correct answer: **D** (see Phase I)

QUESTION 2. Correct answer: **B** (See Phase II)

QUESTION 3. Correct answer: **C** (see Phase II)

NONOPERATIVE REHABILITATION OF TIBIAL STRESS FRACTURE

Mark F. Reinking, PT, PhD, SCS, ATC, and L. Tyler Wadsworth, MD

GUIDING PRINCIPLES OF NONOPERATIVE REHABILITATION

- Determine whether the stress fracture is at a high- or low-risk location.
- Allow adequate protection and time for clinical healing (and radiographic healing as indicated).
- Let the athlete's leg pain guide the return to activity.
- Gradual return to athletic activity.

Phase I (weeks 0 to 2–6): Acute Phase

Protection

- In the leg, the tibial plateau, proximal posteromedial tibia, medial distal tibial diaphysis, and fibular stress fractures are considered low risk.
- Stress fractures of the anterior mid-tibia and medial malleolus have a high risk of nonunion, recurrence, and fracture completion.
- For high-risk stress fractures of the anterior mid-tibia and medial malleolus, immobilization and non–weight

bearing are required and some athletes may require surgical treatment.

- Low-risk stress fractures have a low potential for nonunion or fracture completion, or other complication. Athletes with low-risk stress fractures may be allowed to continue limited participation if they are willing to accept the risk of prolonged symptoms and fracture extension or progression to complete fracture.
- If the athlete with a low-risk stress fracture has tibial pain with ambulation, crutches with or without fracture brace should be used until the athlete can walk without any increase in pain or discomfort. A pneumatic air brace is used for athletes who tolerate weight-bearing without increase in discomfort and has been shown to reduce time to unrestricted activity in low-risk stress fractures.[1]
- Underlying causes for stress fracture should be elicited, including rapid increases in training volume and/or intensity, history of menstrual irregularity in female athletes, nutritional inadequacy (especially the intake of total calories and calcium), condition and type of running shoes.
- Documented risk factors for recurrent stress fractures include high longitudinal arch of the foot, leg-length inequality, excessive forefoot varus, and high weekly training mileage.[2]
- Consideration should be given to testing vitamin D levels, as low vitamin levels have been linked to an increased risk for stress fracture.[3] Treatment of nutritional inadequacies is important but there is no evidence that routine treatment with calcium or vitamin D in individuals who are not deficient accelerates stress fracture healing.

Management of Pain and Swelling

- Icing and electrical stimulation can be used to control pain complaints.
- Analgesics should not be used to allow weight-bearing activity, but patients who have pain can be treated with analgesics. Although there is some concern regarding potential interference of bone healing caused by nonsteroidal antiinflammatory drugs (NSAIDs), there is no evidence to date to support or disprove this theory.
- There are no controlled trials of electromagnetic field or ultrasonic bone stimulation in treatment of low-risk stress fractures showing improvement in healing rates when these technologies are used.[4] However, treatment of stress fractures of the anterior mid-tibia with pulsed electromagnetic fields is widely employed despite limited evidence specific to stress fracture.

Techniques for Progressive Increase in Range of Motion

Only activities that do not cause pain progression are allowed during this stage for low-risk stress fractures, and no pain is permitted in high-risk stress fractures. If the athlete shows impairments of ROM at the ankle, the clinician needs to identify if the limitation is a result of muscle length, joint limitation, or both. The appropriate intervention would be selected based on that differential

Manual Therapy Techniques

- If joint ROM limitations, joint mobilization should be applied appropriately in terms of grade and direction.

TIMELINE 36-2: **Nonoperative Rehabilitation of Low-Risk Tibial Stress Fracture**

PHASE I (weeks 1 to 2)	PHASE II (weeks 3 to 4)	PHASE III (weeks 4 to 8)
• Only pain-free weight bearing advised • Pneumatic brace may be used to allow pain-free weight-bearing activities • Icing and interferential electrical stimulation for pain control • Joint mobilizations as indicated • Soft tissue mobilization/myofascial techniques to medial crural tissues • Gastrocnemius and soleus stretching as indicated • Cross-training activities such as pool running as tolerated • Short foot exercises • Hip muscle strengthening (lateral rotators, abductors) as indicated • Nonimpact balance exercises • Hike	• Pain-free walking ambulation in pneumatic brace • Orthotic fabrication as indicated • Icing and interferential electrical stimulation following exercise • Joint mobilizations as indicated • Soft tissue mobilization/myofascial techniques to medial crural tissues • Gastrocnemius and soleus stretching as indicated • Cross-training activities may include non-impact activities such as pool running, elliptical trainer, StairMaster, stationary cycling • May introduce walk-jog-run progression if this does not exacerbate pain • Short foot exercises • Hip muscle strengthening (lateral rotators, abductors) as indicated • Nonimpact higher demand balance exercises • Multiplanar nonimpact closed kinetic chain exercises • Initiate walk-jog-run functional progression	• Walk-jog-run progression • Icing and interferential electrical stimulation following exercise • Gastrocnemius and soleus stretching as indicated • Hip muscle strengthening (lateral rotators, abductors) as indicated • Higher demand dynamic balance exercises • Increase training volume of multiplanar closed kinetic chain exercises • Plyometric sequence

Soft Tissue Techniques

- Address co-existing soft tissue comorbidities including medial tibial stress syndromes (MTSS) and myofascial trigger points.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Gastrocnemius and soleus stretching as indicated by muscle length testing.

Other Therapeutic Exercises

- Relative rest from any painful weight-bearing activities is important in Phase I.
- Pool running can be employed to maintain cardiorespiratory fitness if this can be done without exacerbating the athlete's pain.

Activation of Primary Muscles Involved

- Non–weight-bearing, pain-free range of motion exercises of the hip, knee, ankle, and foot can be performed daily to preserve joint range of motion and soft-tissue length.

Sensorimotor Exercises

Begin with static balance exercises such as single leg stand on floor with eyes open and progress to eyes closed when athlete can maintain balance for 20 to 30 seconds. Athlete should then be progressed to less stable surfaces (foam, BOSU Ball, DynaDisc), first with eyes open and then with eyes closed.

Open and Closed Kinetic Chain Exercises

- Only pain-free closed kinetic chain exercises are allowed in Phase I. Open kinetic chain exercises targeted at muscle weakness identified in the initial examination is permitted unless painful at the fracture location. No impact loading exercises are allowed in this Phase.

Techniques to Increase Muscle Strength, Power, and Endurance

- Niemuth[5] identified hip abductor muscle weakness in a group of recreational runners with lower limb overuse injuries. Address any muscle imbalances in the lower kinetic chain that can be treated without exacerbating stress fracture pain. This should be based on careful manual muscle testing and observational gait analysis.

Milestones for Progression to the Next Phase

- Pain-free walking ambulation
- No tenderness to palpation or percussion, negative provocative maneuvers (hop test, pain on tuning fork examination, pain with fulcrum testing) is allowed for high-risk stress fractures on physical examination.

Phase II (weeks 2 to 12): Rehabilitative Phase

Protection

- Pneumatic air brace for weight-bearing activities as needed.
- Only activities that do not worsen pain are allowed.

Orthotics

- Consideration should be given for orthotic fabrication based on lower extremity movement patterns and function.
- There is no evidence that over-the-counter or custom foot orthotics are useful in secondary prevention of stress fracture in athletes, although there is a high degree of acceptance and satisfaction among runners who use orthotics.

Management of Pain and Swelling

- Care should be taken not to allow exercise progression through pain with stress fracture.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Same as described in Phase I but progressing to more aggressive joint techniques if ROM impairment persists.

Soft Tissue Techniques

- Same as described in Phase I.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Same as described in Phase I.

Sensorimotor Exercises

- Begin with static balance exercises such as single leg stand on floor with eyes open and progress to less stable surface and eyes closed.
- Progress athlete to higher demand static balance exercise, including single leg stand on unstable surface with upper extremity challenges, including diagonal upper body movements, resisted upper extremity exercise, BodyBlade, and elastic rebounder.

Open and Closed Kinetic Chain Exercises

- Avoid any impact loading that is painful. If the athlete can perform closed kinetic chain exercises without leg pain, then these should not be restricted.

- Add multiplanar closed chain movements in Phase II, including multidirectional lunges, lunge with trunk rotation, squats with upper extremity diagonal patterns.

Techniques to Increase Muscle Strength, Power, and Endurance

- Niemuth[5] identified hip abductor muscle weakness in a group of recreational runners with lower limb overuse injuries.
- Address any muscle imbalances in the lower kinetic chain. This should be based on careful manual muscle testing and observational gait analysis.

Plyometrics

- May introduce if athlete is pain free with all ground based exercises. Begin early plyometric training (no evidence for plyometrics in treatment of stress fracture) with mini-trampoline double leg hops, double leg drop squats, and double leg decline squats. These exercises must be pain free and performed no more than three times/week on alternate days.

Functional Exercises

- Begin transition to land running with a walk-jog-run progression.
- Generally the athlete resumes running or weight-bearing training at no more than 50% of the volume that he or she was doing at the time of injury onset, although this recommendation is based on expert opinion rather than controlled trials.
- Weight-bearing activities should be limited to an exposure that does not increase symptoms.
- It is commonly recommended to increase weekly weight-bearing exposure by approximately 10% per week, although this rate of progression has not been tested in clinical trials.
- It is important that weight-bearing training be reduced or deferred if symptoms increase.

Milestones for Progression to the Next Phase

- Pain-free early plyometrics and walk-jog-run progression
- No tenderness to palpation or percussion, negative provocative maneuvers (hop test, pain on tuning fork examination, pain with fulcrum testing) on physical examination is allowed for high-risk stress fractures.

Phase III (weeks 4 to 16 or longer): Functional Training Phase

Protection

- Pneumatic air brace for weightbearing activities as needed until pain free with all activities for 1 to 2 weeks.

Management of Pain and Swelling

- Care should be taken not to allow activity progression to worsen pain with stress fracture.

Sensorimotor Exercises

- Progress athlete to dynamic balance activities (whole body movement) using jumping/hopping to and from BOSU ball, slide board movements, balance beam exercise.

Open and Closed Kinetic Chain Exercises

- Progress the challenge, intensity and speed of the multiplanar closed chain exercises introduced in Phase II.

Plyometrics

- Progress to higher level plyometric exercises including ankle hops on floor (double to single leg), depth jumps, box jumps, squat jumps, tuck jumps, and bounding.

Functional Exercises

- Continue with walk-jog-run progression

Milestones for Progression to Advanced Sport-Specific Training and Conditioning

- Completion of functional progression
- Performance of all plyometric exercises without tibial pain

Criteria for Abandoning Nonoperative Treatment and Proceeding to Surgery or More Intensive Intervention

- Anterior mid-tibia and medial malleolus stress fracture not responding to nonsurgical care or showing signs of non-union. In high-performance and elite athletes, early surgical treatment should be considered because this may lead to a more rapid return to competition and a lower risk for recurrence.
- Assess compliance in athletes who remain symptomatic from low-risk stress fractures beyond 8 to 12 weeks of treatment. Consider evaluation or re-evaluation for nutritional insufficiencies and other causes of osteopenia.

Specific Criteria for Return to Sports Participation: Tests and Measurements

- Pain-free running on successive days
- Athletes with low-risk stress fractures may be allowed to participate if they have full range of motion, full

strength, and can perform the demands of their sport without gait changes.
- No tenderness to palpation or percussion, negative provocative maneuvers (hop test, pain on tuning fork examination, pain with fulcrum testing) on physical examination is allowed for high-risk stress fractures.

Evidence

Arendt D, Griffiths H: The use of MR imaging in the assessment and clinical management of stress reactions of bone in high-performance athletes. *Clin Sports Med* 16:292–306, 1997.

A widely cited reference proposing a grading scale based on MRI appearance and along with prognostic and return-to-play recommendations. (Level V evidence)

Burgi AA, Gorham ED, Garland CF, et al: High serum 25-hydroxyvitamin D is associated with a low incidence of stress fractures. *J Bone Miner Res* 26(10):2371–2377, 2011.

Vitamin D levels were measured in incoming military recruits. Six hundred female recruits diagnosed with stress fracture of the tibia or fibula within the first 180 days of service were matched for age, race, and length of service and vitamin D levels compared, along with BMI and state of residence at time of entry into military service. Recruits in the highest quintile of vitamin D levels had half the risk for stress fracture. (Level IIIb evidence)

Kaeding CC, Yu JR, Wright R, et al: Management and return to play of stress fractures. *Clin J Sport Med* 15(6):442–447, 2005.

Excellent review of high- and low-risk stress fractures, treatment algorithm, and return-to-play recommendations. (Level V evidence)

Matheson GO, Clement DB, McKenzie DC, et al: Stress fractures in athletics: a study of 320 cases. *Am J Sports Med* 15:46–58, 1987.

This is one the largest early series of stress fractures in athletes. Physical findings, risk factors, prognosis, and radiographic and scintigraphic changes are discussed in this pre-MRI era study. (Level IV evidence)

Nattiv A, Loucks AB, Manore MM, et al: American College of Sports Medicine position stand. The female athlete triad. *Med Sci Sports Exerc* 39(10):1868, 2007.

The ACSM position stand reviews the current understanding of the complex interaction among exercise volume, energy availability, and current treatment recommendations. (Level IIa evidence)

Swenson EI, DeHaven KE, Sebastianelli WJ, et al: The effect of a pneumatic leg brace on return to play in athletes with tibial stress fractures. *Am J Sports Med* 25(3):322–328, 1997.

Athletes with stress fractures treated with a pneumatic leg brace returned to light activities in a median 7 days vs. 21 days in unbraced athletes in this randomized trial, and experienced symptom resolution with full activities in 21 ± 2 days in braced athletes vs. 77 ± 7 days. (Level Ib evidence)

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Multiple Choice Questions

QUESTION 1. Which of the following features is not characteristic of a high-risk stress fracture?

A. High risk of fracture recurrence
B. High degree of pain
C. High risk of nonunion
D. High risk of fracture completion

QUESTION 2. Which intervention has been shown to decrease time to return to play for athletes with tibial stress fracture?

A. Vitamin D supplementation
B. Calcium supplementation
C. Pneumatic leg brace
D. High-dose nonsteroidal antiinflammatory drugs

QUESTION 3. Which of the following is not a risk factor for tibial stress fracture?

A. Leg-length inequality
B. Running on asphalt
C. Rapid training progression
D. Athletic menorrhea

QUESTION 4. Which of the following activities is not appropriate for Phase I rehabilitation?

A. Plyometrics
B. Hip abductor strengthening
C. Stretching exercises for the gastrocnemius and soleus
D. Pool running that does not exacerbate pain

Answer Key

QUESTION 1. Correct answer: **B** (see Phase I)

QUESTION 2. Correct answer: **C** (see Phase I)

QUESTION 3. Correct answer: **C** (see Phase I)

QUESTION 4. Correct answer: **A** (see Phase I)

POSTOPERATIVE REHABILITATION AFTER TREATMENT OF EXERTIONAL COMPARTMENT SYNDROMES

Dana Curtis Covey, MD, MSc, CAPT, MC USN, and Shane A. Vath, CDR, MSC USN

Introduction

- Exertional compartment syndrome is compartmental pain and swelling caused by exercise, and that is relieved with rest. There are two types:
  - *Chronic exertional compartment syndrome* (CECS) is a less emergent form in which symptoms recur with repetitive exertional activities, and is the most common type seen in athletes.
  - The second type, *acute compartment syndrome*, can also occur in athletes secondary to direct trauma or may develop from pre-existing CECS.
- The leg is the most common site of exertional compartment syndrome. In CECS, the diagnosis is usually confirmed by measuring compartment pressures before and after exercise. Fasciotomy is the definitive treatment.

Indications for Surgical Treatment

- A history and physical examination consistent with exertional compartment syndrome
- Failure of conservative treatment
- One or more of the following criteria for compartment pressure readings; with the greater the number of criteria, the higher the level of confidence[1]
  - Pre-exercise pressure 15 mmHg or greater
  - One minute post-exercise pressure 30 mmHg or greater
  - Five minute post-exercise pressure 20 mmHg or greater
- The Stryker catheter is the device most widely used for intra-compartmental pressure testing and is placed into one of four compartments (in the case of leg involvement), both pre- and postexercise

Brief Summary of Surgical Treatment

Major Surgical Steps

- Major technique steps in open compartment fasciotomy[2,3] for treatment of CECS of the leg:
  - First, have a thorough knowledge of compartmental anatomy
  - Identify the involved compartment(s) to be released
  - For an anterior or lateral compartment release, an incision is made in line with the leg midway between the tibia and fibula. The anterior intermuscular septum is identified. A horizontal fasciotomy incision is made the length of the compartment in front of the septum to release the fascia of the anterior compartment, and behind it to release the lateral compartment. Take care to avoid injury to the superficial peroneal nerve. Each involved compartment should be released completely
  - To release the superficial or deep posterior compartments, a horizontal incision is made 1 to 2 cm posterior to the posteromedial border of the tibia is made being cognizant of the location of the saphenous vein and nerve. The fascia overlying the gastrocnemius and soleus muscles (superficial posterior compartment) is divided along its length. Fasciotomy of the deep posterior compartment is next accomplished by retracting the gastrocnemius-soleus complex to expose the flexor digitorum longus in the deep posterior compartment. Its fascia should be incised along its length, and the soleus bridge should be released as well, taking care to avoid injury to the posterior tibial artery and vein.

Factors That May Affect Rehabilitation

Anesthetic

- Regional or general anesthesia

Surgical

- Open versus subcutaneous versus endoscopic fasciotomy

Other Surgical Techniques and Options

- Subcutaneous fasciotomy technique[4]
- Endoscopic technique of fascial release[5]

Before Surgery: Overview of Goals, Milestones, and Guidelines[1]

- Before surgery, conservative treatment methods for treatment of CECS can be tried. These include:
  - Reducing training intensity
  - Discontinuing the activity causing symptoms
  - A period of rest, after which exercise may slowly increase
  - Ice and nonsteroidal antiinflammatory medications (NSAIDs)
  - Orthotics to correct foot position during running
  - Avoidance of running on hard surfaces
  - Changing footwear
  - Altering running mechanics

[1] *Prehabilitation, if appropriate, is described in the Nonoperative Rehabilitation section of this chapter.*

- Deep tissue massage, ultrasound, and stretching before exercise

GUIDING PRINCIPLES OF POSTOPERATIVE REHABILITATION

- Document pre- and postexercise compartment pressures.
- Release only the involved compartment(s).
- Understand the anatomy and surgical technique for each compartment.
- Ensure a complete fascial release of the involved compartment.
- Avoid neurovascular injury by adequately visualizing the fascia being incised.

Phase I (days 0 to 14): Immediate Postoperative Period

Clinical Pearl

Following compartment release patients will often experience paresthesias in the nerve distribution of the involved compartment(s) or distributions of other peripheral nerves owing to the surgical procedure and resulting lower extremity edema. Sensory and motor disturbances should be noted. Progressive improvements should occur as swelling resolves and healing progresses. Patients should be provided education regarding gradual return of nerve function and encouraged to inform their treating surgeon if a gradual improvement does not occur or symptoms progressively increase.

Goals

- Minimize and reduce postoperative pain, inflammation, and swelling of the involved lower extremity to limit scar formation.
- Educate athlete on importance of RICE (rest, ice, compression, elevation) and gentle motion respecting pain to reduce swelling and pain.
- Provide progressive stress to soft tissue to encourage functional scar formation that does not restrict compartment(s) or otherwise limit function.

Protection

- Crutches and weight bearing as tolerated.
- Avoid activities that increase swelling, such as: prolonged positions/activities with limb in dependent position, heat, restrictive clothing or poorly applied wraps over or proximal to swelling.

Management of Pain and Swelling

- Oral pain medications
- Therapeutic modalities for pain and swelling
- Cryotherapy to aid in reducing pain, inflammation, and swelling
- Compression to involved extremity. Tubular compression doubled over the foot and ankle increases likelihood of proper application. Simplicity of application improves compliance for daily use.
- Patient education: Use pillows or bolsters to elevate leg above the level of the heart to reduce pressure and swelling. Perform ankle pumps to encourage venous return.
- Retrograde massage may be employed intensity and duration appropriate to wound healing if swelling persists despite performing other management instructions and techniques.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- ROM: Precautions: "respect pain." Provide patient guidance on intelligent progression: range of motion, repetitions, sets, and frequency to regain normal hip, knee, ankle, and foot motion. Activity extremes can result in prolonged pain and swelling. Appropriately caution patient regarding extremes of inactivity/activity and association with prolonged pain and swelling. This can lead to over scarring, which may reduce functional outcome.
- PROM: Manual range of motion of ankle, knee, and hip can be performed early in rehabilitation but patient progression to active motion is encouraged. This enables more frequent independent mobilization.

Soft Tissue Techniques

- Inspect incision site. After wound is well healed following staple/suture removal gentle desensitization and mobilization techniques consistent with wound healing can be initiated to reduce pain, promote mobility, and reduce adhesions.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Seated calf towel stretch with knee extended and knee flexed.
- Seated → quadruped toe down stretch with addition of inversion and eversion force as tolerated (Figure 36-3).
- Seated heel slide with foot flat to encourage ankle dorsiflexion/plantarflexion and knee/hip motion.

Other Therapeutic Exercises

- Perform upper body low intensity cardiovascular activities such as upper body ergometer (UBE) or resistance training. Consider duration of time spent with legs in dependent position. Adjust based on athlete's response.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Heel slides
- Four-way hip SLR on plinth
- Supine double → single leg hip bridging



FIGURE 36-3. Quadruped toe-down stretch.

- Ankle dorsiflexion/plantarflexion supine with leg elevated
- Ankle alphabet
- Progress to light four-way ankle resistance exercises as tolerated.

Sensorimotor Exercises

- Progress crutch ambulation weight bearing as tolerated while encouraging normal gait. Use pain, swelling and function to guide progression. Wean from crutch use for household → community ambulation.
- Weight shifting: Standing on involved leg with support as needed keep foot flat step forward/backward and side/side.

Open and Closed Kinetic Chain Exercises

- As listed in the preceding

Techniques to Increase Muscle Strength, Power, and Endurance

- Main goal during this phase is to reduce swelling, pain, and promote healing while minimizing negative effects of reduced activity/mobility.

Functional Exercises

- Gait training to encourage normal gait pattern with increased tolerance for weight bearing and decreased pain. Encourage WBAT while minimizing reproduction of pain.

Milestones for Progression to the Next Phase

- Minimal soft tissue swelling of involved extremity.
- Demonstrate ability to independently ambulate100 feet with minimal gait deviations and 2/10 or less pain.
- Demonstrate ability to ambulate at least 75% weight bearing with crutches community distances (2000 feet) without pain.

Phase II (postoperative weeks 2 to 4)

Clinical Pearl

Response following surgical compartment release is highly variable. Ensure that the athlete's subjective input and objective findings correlate before higher level progression. Rehabilitation should match clinical presentation, emphasizing intelligent progression from lower to higher load activities with continued assessment and adjustment based on response. Use caution when returning to higher load activities: hill walking, ambulation in shoes with elevated heel, eccentric or plyometric loading of involved compartment(s), and especially running or other activity that produced the preoperative symptoms. These activities may cause a drastic increase in limb pain and swelling, resulting in extended healing and delayed return to sports activities. Ensure that the athlete is educated to improve compliance and limit inappropriate independent progression of activities. Avoid reproducing preoperative symptoms during rehabilitation.

Goals

- Unassisted ambulation without gait deviations for ¼ mile or 5 minutes
- Full pain-free range of motion and strength of foot and ankle

TIMELINE 36-3: **Postsurgical Rehabilitation After Surgical Treatment of Exertional Compartment Syndromes**

PHASE I (postoperative weeks 0 to 2)	PHASE II (postoperative weeks 2 to 4)
• Crutches, WBAT • Gait training • Inspect incision • PT modalities • ROM: Hip, knee, ankle, foot • Stretch: gastroc/soleus/toe down • RICE • Patient education	• Progress to unassisted ambulation • PT modalities: cryotherapy • Scar/soft tissue mobilization • Bicycle → elliptical • Walking program • AROM • Initiate strengthening • Active functional exercise • Wobble board • Early sport-specific training

- Scar healed with good mobility and minimum discomfort
- Continue to manage swelling, minimize scar formation, and maximize progressive return to function.
- Appropriately stress soft tissue to ensure functional scar formation that does not restrict compartment(s) or limit function.

Protection

- Crutches/cane should only be used for walking if the individual is experiencing pain or swelling. Encourage reduced use of assistive devices if minimal pain, swelling, and good function.

Management of Pain and Swelling

- Oral pain medications are continued as needed for pain and swelling.
- Therapeutic modalities for pain and inflammation are continued as needed.
- Cryotherapy with compression is continued to aid in reducing pain and swelling, especially following exercise/activity.
- Tubular compression is continued as needed to manage swelling of the extremity.
- Patient education: As swelling resolves, increase time spent with the extremity in dependent positions. Use elevation and ankle pumps when required to reduce swelling with decreasing frequency.
- Retrograde massage may be employed intensity and duration appropriate to wound healing if swelling persists despite performing other management instructions and techniques.
- If swelling continues, inquire regarding daily activities/exercise and adjust as appropriate.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- ROM: Precautions: "respect pain." Continue guiding the athlete on intelligent progression: range of motion, repetitions, sets, and frequency to regain full pain free ankle and foot motion. Progress activity/exercise level but continue to caution the athlete regarding extremes of inactivity/activity and association with prolonged pain and swelling. During this phase activity extremes can still increase pain and swelling and produce overscarring, reducing functional outcome. Progress loads from low to high with increasing speed and power: isometric, concentric, eccentric, plyometric.
- PROM: This should only be performed if the patient lacks full motion. Active motion and exercise encourages more functional and higher loads to tissues.

Soft Tissue Techniques

- Continue using scar desensitization and mobilization techniques as needed consistent with wound healing to promote mobility and reduce adhesions.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Pre-exercise:
  - Active stretching: Standing on involved extremity with foot flat step forward/backward at angles and side to side stepping in front/behind opposite leg
- Post-exercise:
  - Standing calf stretch, increasing slant board angle with knee extended and knee flexed
  - Quadruped toe down stretch with increasing downward pressure and angle of inversion and eversion as tolerated (see Figure 36-3)

Other Therapeutic Exercises

- Increase intensity and duration of upper body cardiovascular activities such as upper body ergometer or resistance training. Continue resistance training specific to sport and transition to lower extremity cardiovascular training based on athlete response to more intense activity with legs in dependent position.
- Short bouts of low intensity low resistance stationary bicycle can be utilized to encourage self-mobilization of involved lower extremity. Following anterior or lateral compartment, release progression to toe clip use based on symptoms. Increase duration, intensity, and resistance of stationary bicycle to provide progressive stress to soft tissue, based on athlete response.
- Progressively add elliptical trainer.
- When nonpainful with stationary bicycle/elliptical and unassisted community walking, begin walking program (Box 36-2) documenting: pace, distance, and the athlete's response (pain, swelling). Progress the program based on the athlete's response. The program can be

TIMELINE 33-3 Postsurgical Rehabilitation After Surgical Treatment of Exertional Compartment Syndromes (Continued)

PHASE III (postoperative weeks 4 to 6)	PHASE IV (postoperative weeks 6 to 10)	PHASE V (postoperative weeks 10 to 12)
• Normal unassisted ambulation • PT modalities as needed • Scar/soft tissue mobilizations as needed • Elliptical/bike as desired • Active/passive stretching • Walking program → walk/run program • Progress strengthening • Active functional exercise: increase speed/power • Plyometric shuttle exercises • Sport-specific drills • Cryotherapy following exercise	• PT modalities as needed • Elliptical/bike for high-intensity training • Active/passive stretching • Walking program → walk/run progression • Strengthening as needed • Plyometric shuttle • Sport-specific drills • Sprint progression	• Continue run progression • Manage as needed

BOX 36-2 Progressive Walking/ Running Program*

Step 1: Walk on treadmill, progressing up to 20 minutes at a comfortable pace
Step 2: Walk for 5 minutes
Then jog for 1 minute, walk for 4 minutes × three cycles (total of 15 minutes)
Walk for 5 minutes at a comfortable pace.
Step 3: Walk for 5 minutes
Then jog for 2 minutes, walk for 3 minutes × three cycles (total of 15 minutes)
Walk for 5 minutes at a comfortable pace.
Step 4: Walk for 5 minutes
Then jog for 3 minutes, walk for 2 minutes × three cycles (total of 15 minutes)
Walk for 5 minutes at a comfortable pace.
Step 5: Walk for 5 minutes
Then jog for 4 minutes, walk for 1 minute × three cycles (total of 15 minutes)
Walk for 5 minutes at a comfortable pace.
Step 6: Walk for 5 minutes
Jog for 15 minutes
Walk for 5 minutes
Step 7: Walk for 5 minutes
Jog for 20 minutes
Walk for 5 minutes
Step 8: Warm up
Progress your running distance and intensity as tolerated
Cool down

*This program is to be performed three times per week. *Do not* walk or run past the point of "pain" (although discomfort or soreness is OK).

progressed rapidly if the athlete is asymptomatic. Stop the program if preoperative symptoms are reproduced and return to bicycle/elliptical.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Ankle Isolator: Dorsiflexion, plantarflexion, inversion, eversion
- Ankle resistance band exercises: Dorsiflexion, plantarflexion, inversion, eversion

Sensorimotor Exercises

- Weight shifting: Standing on involved/uninvolved leg: supported → unsupported on a flat surface → elevated surface keep foot flat step forward/backward and side/side. (An elevated surface promotes increased ankle motion and loads.)
- Perform exercises to begin loading in a more functional manner. Increase range of motion, distance, speed, and power with exercises over time.
  - High knees with hip/knee flexion with ankle dorsiflexion; hip/knee extension with ankle plantarflexion
  - Side stepping with squat add resistance band as able
  - Grapevine stepping
  - Side stepping with squat → hop.
  - Walking lunges
- Seated → standing balance/wobble board supported → unsupported: clockwise/counterclockwise; forward/backward; side/side; angles

Techniques to Increase Muscle Strength, Power, and Endurance

- Per preceding, increasing sets, reps, speed, power based on symptoms

Neuromuscular Dynamic Stability Exercises

- Can begin single leg rebounder on flat stable surface → soft or uneven surfaces as desired

Plyometrics

- Plyometric shuttle: Begin double leg jumping and progress to single leg as able.

Functional Exercises

- Per the preceding

Sport-Specific Exercises

- Once scar is healed and there are minimal symptoms, the athlete can begin sport-specific training with the exception of running, impact activities, or other activities that produced symptoms before surgical release.
- Pool exercises: Once incision well healed can begin swimming, pool walking/running in deep → shallow water.

Milestones for Progression to the Next Phase

- No soft tissue swelling or mild intermittent swelling of involved extremity following exercise. Swelling should resolve prior to the next exercise session.
- Demonstrate ability to ambulate at least ¼ mile or 5 minutes with normal gait and 2/10 or less pain.
- Scar healed with good mobility, minimal tenderness causing no limitation of foot and ankle motion.

Phase III (postoperative weeks 4 to 6)

Clinical Pearl

Resolution of pain and swelling and return to function following surgical release is variable. Progress athletes to eccentric, plyometric, impact, sport-specific activities, and running in an intelligent manner based on subjective report, objective findings, and response to exercise. The athlete should stop activities as soon as preoperative symptoms begin or if they produce prolonged postexercise pain greater than about 2 hours. As healing progresses, a gradual or rapid increase in exercise tolerance with

decreasing symptoms of pain and swelling during or postexercise is expected. If the patient experiences prolonged pain following exercise and/or function is not improving, then the athlete's exercise program should be evaluated to determine aggravating activity(ies) and adjusted appropriately.

Goals

- Walk 12 minutes or more at moderate pace with 2/10 or less pain.
- Appropriately stress soft tissue to ensure functional scar formation that does not restrict compartment(s) or limit function.
- Perform sport-specific training, progressively adding jumping, lower extremity plyometrics, and progressive running activities.
- Progress to walk run program when able to walk 20 minutes with 2/10 or less leg pain that resolves within about 2 hours postexercise (see Box 36-2).

Management of Pain and Swelling

- Continue previous treatment methods as needed based on athlete's symptoms and response.
- Cryotherapy should be performed following exercise sessions to control pain and swelling.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- As clinically indicated

Soft Tissue Techniques

- Only perform scar desensitization and mobilization techniques if scar is sensitive, painful, adhesed, or limits mobility or function. Transverse friction massage may be used to improve soft tissue mobility/extensibility of the leg.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Continue active stretching before exercise as desired and static stretching following exercise
  - Pre-exercise as desired:
    - Active stretching on elevated surface: standing on involved/uninvolved extremity with foot flat step forward/backward at angles and side/side stepping in front/behind opposite leg. Standing calf stretch increasing slant board angle with knee extended and knee flexed.
  - Post-exercise:
    - Standing calf stretch increasing slant board angle with knee extended and knee flexed.
    - Toe down stretch on hands and knees increasing downward pressure and inversion/eversion force.

Other Therapeutic Exercises

- Continue resistance training specific to sport and increase lower extremity cardiovascular training based on athlete's response.
- Perform stationary cycling if appropriate to sport or if athlete's desires higher intensity cardiovascular training. Increase duration, intensity, and resistance of stationary bicycle as desired.
- Continue elliptical trainer based on athlete desire and ability to tolerate progression to walk/run program.
- When able to progress to 20 minutes of continued walking with 2/10 pain or less and minimum swelling or duration of post exercise pain begin progression to walk/run program. Document: pace, distance and the athlete's response (pain intensity/duration, swelling). Adjust or stop program based on response.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Continue as needed.
- Ankle Isolator may be continued as needed, progress weight, reps and sets: dorsiflexion, plantarflexion, inversion, eversion.
- Ankle resistance band exercises may be continued as needed, progress weight, reps, sets: dorsiflexion, plantarflexion, inversion, eversion.

Sensorimotor Exercises

- Weight shifting may be continued as needed.
- Continue functional exercises as needed increasing range of motion, distance, speed, power with exercises over time.
  - High knees with hip/knee flexion with ankle dorsiflexion; hip/knee extension with ankle plantarflexion
  - Side stepping with squat add resistance band as able
  - Grapevine stepping
  - Side stepping with squat → hop
  - Walking lunges
  - Ladder drills specific to sport
- Balance/wobble board may be continued as needed, add weight as able: standing minimal support clockwise/counterclockwise; forward/back; side/side; angles.

Open and Closed Kinetic Chain Exercises

- Exercises listed in the preceding

Neuromuscular Dynamic Stability Exercises

- Single leg rebounder on flat stable surface → soft surfaces as desired.

Plyometrics

- Plyometric shuttle progress to single leg jumping with higher resistance and greater reps.
- Perform sport specific drills increasing duration and intensity as appropriate without reproducing leg pain

or producing prolonged post exercise pain for greater than 2 hours.

Sport-Specific Exercises

- Begin plyometrics and sprinting without increasing pain or swelling. Use caution with return to contact/collision activities due to potential for blunt injury or re-aggravation of soft tissue.

Milestones for Progression to the Next Phase

- Walking 12 minutes or more at moderate to fast pace with 2/10 or less pain.

Phase IV (postoperative weeks 6 to 10)

Clinical Pearl

Return to running should be gradual and progressive in nature to provide gradual stress to lower extremities without increased pain or reduced function owing to irritation of legs or other overuse injury. The program should be performed every other day so symptoms can be assessed on rest days. Desire gradual increase in tolerance to exercise and running with reducing symptoms. If pain or symptoms are increasing and function declining, then the athlete should be rested until there is a return to baseline. Athletes should cease running at the onset of preoperative symptoms. Endurance runners are typically eager to return to running and often ignore symptoms. Supervised run progression on a treadmill or indoors can help mitigate the urge to run despite symptom reproduction.

Goals

- Progress to walk run program when able to walk 20 minutes with 2/10 or less leg pain that resolves within about 2 hours postexercise (see Box 36-2).
- Running distances as tolerated without reproduction of preoperative symptoms or swelling with minor postexercise pain that resolves within about 2 hours.

Management of Pain and Swelling

- Cryotherapy can be performed following exercise sessions to reduce any pain or swelling.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- As clinically indicated

Soft Tissue Techniques

- Perform previous treatment as indicated.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Perform active warm up before running/exercise as desired.
- Following exercise perform static stretching
  - Standing calf stretch with forefoot elevated with knee extended and knee flexed.
    - Toe down stretch on hands and knees increasing downward pressure and inversion/eversion force (Figure 36-3).

Other Therapeutic Exercises

- Continue previous phase exercises/progression.
- Continue resistance training specific to sport and increase lower extremity cardiovascular training based on athlete's response.
- Perform stationary cycling if appropriate to sport or if athlete's desires higher intensity cardiovascular training while progressing back to running. Increase duration, intensity, and resistance of stationary bicycle as desired.
- Continue elliptical trainer based on athlete desire and ability to tolerate progression to walk/run program.
- Progress to walk/run program (see Box 36-2) when able to walk 20 minutes with 2/10 or less leg pain that resolves within about 2 hours postexercise and athlete has minimal swelling. Document: pace, distance and the athlete's response (pain: intensity/duration, swelling). Adjust program based on response.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Perform exercises from previous phase as needed. Main focus is to return to running and sport-specific activity.

Sensorimotor Exercises

- Perform as needed.

Plyometrics

- Continue plyometric shuttle progression as needed.
- Continue to progress sport specific drills increasing duration and intensity as appropriate without reproducing leg pain.

Sport-Specific Exercises

- Continue plyometric and sprinting progression being aware of any increase in pain or swelling. Progress to contact/collision activities.

Evidence

Detmer DE, Sharpe K, Sufit RL, et al: Chronic compartment syndrome: diagnosis, management and outcomes. *Am J Sports Med* 13(3):162–170, 1985.

This is a case series of 100 patients with chronic exertional compartment syndrome who received fasciotomy for

treatment. At follow-up, 90% of patients had resolution or significant improvement of their symptoms at a median of 4.5 months postoperatively. Operative and postoperative complications occurred in 11 patients.

Houglum P: Soft tissue healing and its impact on rehabilitation. *J Sport Rehabil* 1:19–39, 1992.

This is an overview of the chemical and cellular activity involved in soft tissue healing, with emphasis on aspects that can be affected by rehabilitation. Guidelines are presented for a rehabilitation program based on the physiological effects of the healing process. A rehabilitation program must be carefully coordinated with the timing of tissue healing and designed in a logical sequence to permit successful rehabilitation of the injured athlete.

Mouhsine E, Garafalo R, Moretti B, et al: Two minimal incision fasciotomy for chronic exertional compartment syndrome of the lower leg. *Knee Surg Sports Traumatol Arthrosc* 14:1093–1097, 2006.

This study reports results following a minimal double incision fasciotomy for CECS. Eighteen athletes with CECS of the leg underwent a minimal double incision fascial release a mean of 4 months after onset of symptoms. At 2-year follow-up, all had resumed preinjury levels athletic activity. Complications occurred in 2 of the 11 patients who underwent to bilateral fasciotomy in that they had a sensation of leg weakness for an average period of 3 months.

Mubarak SJ, Owen CA: Double-incision fasciotomy technique of the leg for decompression in compartment syndrome. *J Bone Joint Surg Am* 59:184, 1977.

This paper describes the surgical anatomy of the compartments of the leg and describes a technique using anterolateral and posteromedial incisions for access to all four compartments of the leg for fascial release.

Pedowitz RA, Hargens AR, Mubarak SJ, et al: Modified criteria for the objective diagnosis of chronic compartment syndrome of the leg. *Am J Sports Med* 18(1):35–40, 1990.

This is a retrospective study of 131 patients who were evaluated for possible chronic exertional compartment syndrome (CECS). Forty-five were diagnosed as having CECS. Given an appropriate history and physical examination, one or more of the following intramuscular pressure criteria were diagnostic of CECS: a pre-exercise pressure 15 mmHg or greater; a 1-minute postexercise pressure 30 mmHg or greater; a 5-minute postexercise pressure 20 mmHg or greater.

Schubert A: Exertional compartment syndrome: review of the literature and proposed rehabilitation guidelines following surgical release. *Int J Sports Phys Ther* 6(2):126–141, 2011.

This article summarizes literature regarding CECS and proposes scientifically based guidelines for rehabilitation following compartment release. A literature search was performed and there were no specific guidelines following surgical for rehabilitation after compartment release for lower extremity CECS. Guidelines are proposed for rehabilitation following compartment release with rationale based on tissue healing, muscle loading, and scar tissue formation. (Level X evidence)

Verleisdonk EJ, Schmitz RF, van der Werken C: Long-term results of fasciotomy of the anterior compartment in patients with exercise-induced pain in the lower leg. *Int J Sports Med* 25(3):224–229, 2004.

This prospective study describes the results of fasciotomy in patients with exercise-induced pain in the lower leg from suspected chronic exertional compartment syndrome. Tissue measurements were performed in 114 patients. In 56 patients (106 compartments) increased tissue pressure was found (greater than 50 mmHg measured immediately after exercise, or greater than 30 mmHg if the pressure before exercise greater than 20 mmHg, or if the pressure 5 minutes after exercise is still greater than 30 mmHg). Two years postoperatively, patients were evaluated by questionnaire and 87% had significant reduction in symptoms. Eighteen patients not found to have increased tissue pressure also participated. In these patients, a fasciotomy was performed based on typical history, despite normal or slightly increased intramuscular pressures, and 12 patients (24 compartments) were asymptomatic after surgery. Fasciotomy in patients with CECS in the leg resulted in marked symptom reduction in most of patients.

Wittstein J, Moorman CT, Levin LS: Endoscopic compartment release for chronic exertional compartment syndrome. *Am J Sports Med* 38(8):1661–1666, 2010.

This is a case series of nine patients (14 legs) with chronic exertional compartment syndrome who underwent endoscopic compartment release with the assistance of a balloon dissector. Eight of nine patients were able to return to their preoperative athletic activities. The only complications were hematomas that resolved in two patients.

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Multiple Choice Questions

QUESTION 1. What is the main goal immediately following surgical compartment release?

A. Protect healing fascia
B. Ambulate without crutches
C. Manage pain and swelling to limit scar formation
D. Increase mobility of incision site

QUESTION 2. Patients' physical response following surgical compartment release is best described as:

A. Highly consistent
B. Highly variable
C. Immediate improvement
D. Rarely experience swelling

QUESTION 3. After the athlete has returned to running, the running should be progressed when the athlete has:

A. Reduced exercise tolerance with increased pain
B. Pain that limits ability to increase exercise
C. Constant pain that does not limit exercise
D. Increased tolerance to exercise with reduced pain

QUESTION 4. A running program should be initiated:

A. 6 weeks following surgery
B. When the incision site is healed
C. When patient can tolerate walking 20 minutes with minimal pain/swelling
D. 12 weeks following surgery

Answer Key

QUESTION 1. Correct answer: **C** (see Week 0 to 2)

QUESTION 2. Correct answer: **B** (see Week 2 to 4)

QUESTION 3. Correct answer: **D** (see Week 6 to 10)

QUESTION 4. Correct answer: **C** (see Week 6 to 10)

BEYOND BASIC REHABILITATION: RETURN TO RUNNING AFTER STRESS FRACTURE OF THE TIBIA

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Introduction

ASPECTS OF RUNNING THAT REQUIRE SPECIAL ATTENTION IN REHABILITATION

- Hip strength and lower limb control with closed chain activities
- Correction of faulty running biomechanics
- Graduated return to running program

Incidence

- Running has become increasingly popular in recent years. It is a quick, practical, low cost form of exercise leading to rapid gains in cardiovascular fitness.
- Although the positive effects of running are numerous, participants are at high risk of running-related overuse injuries.
- Epidemiologic studies of runners report that up to 79% of runners incur an overuse injury within any given year.[1,2] Of novice runners, 20% to 34% become injured within the first 13 weeks of training.[3]
- The most common site of running related injury is the knee, followed by the lower leg, foot, and upper leg.[2]
- According to Bennell et al.[1] stress fractures occur in 21% of elite track and field athletes.
- The overall incidence of stress fracture is 0.70 per 1000 hours of training. The tibial is the most common site for stress fractures in runners, accounting for 46% of all stress fractures. The distance running population is most likely to experience stress fractures, accounting for 31.6% of total fractures.[1]
- During a 12-month period, 60% of track and field athletes who sustained a fracture had a previous history of this diagnosis This high recurrence rate suggests a continuation of risk factors such as: "abnormal biomechanics, excessive training, and low bone density."[1]

Risk Factors for Stress Fracture

- The multifactorial nature of running related injuries and high recurrence rate poses a challenge for effective rehabilitation and safe return to sport.
- It is generally understood that running-related injuries are a result of an amalgamation of intrinsic and extrinsic factors that surpass a runner's individual capacity to withstand them. Established risk factors include[4,5]:
  - Weekly mileage or intensity (training errors)
  - Faulty biomechanics
  - Strength deficits
  - History of previous injury
- Those that increase their mileage rapidly or train more than 40 miles per week are approximately three times more likely to sustain injury.[1]
- A significant correlation between previous running injury and risk of future injury have been reported.[1,2]

Training Errors

- Hreljac et al.[6] reported that up to 60% of running related injuries are a result of training errors.
- A clear mechanisms of overuse injury includes the abrupt increase in physical activity, which may be a function of the type of load applied, its peak magnitude, loading rate and/or the total doseage.[7]
- Mechanical loading is associated with microdamage of the bone.[7]
  - When stressed below the threshold of injury with adequate time to rest between sessions, bone remodels and adapts, typically resulting in greater ability to bear stress without injury.[6]

- If the body cannot successfully repair this microdamage, it will accumulate and ultimately result in fracture of the bone.[8]
- The periosteum of the bone does not mature until about 20 days after the remodeling process begins, thus leaving the bone temporarily weakened during this time.[9] This period is known as the "weak third week," or the third week after the onset of a new or increased activity.[9]
  - Continued stress applied to remodeling bone during this time may lead to accelerated breakdown of the cortex, thus it is at this time that a stress fracture is most likely to develop.[10]

Biomechanics

- In a prospective study, Davis et al. concluded that runners with higher peak positive acceleration of the tibia and higher vertical ground reaction forces were at greater risk of developing a tibial stress fracture.[11]
- Milner et al. found that female runners with a history of tibial stress fracture demonstrated greater instantaneous and average vertical loading rates compared with healthy controls.[7] Authors concluded that tibial stress fractures may be most related to loading rates.[7]
- In a systematic review of the literature on the relationship between the history of tibial stress fracture and ground reaction forces and loading rate, Zadpoor et al. concluded that the magnitude of ground reaction forces was not significantly different between the stress fracture group and controls.[7] However, the vertical loading rate (average and instantaneous) of the two groups was significantly different.[12]
- Increased peak rearfoot eversion and peak hip adduction may also be risk factors for tibial stress fracture.[13] Increased hip adduction and internal rotation in single limb stance forces the knee joint center to migrate medially relative to the foot resulting in dynamic knee valgus, an increase in tibial internal rotation and increased foot pronation.
  - Increased dynamic valgus changes the magnitude and direction of forces throughout the lower limb during closed chain tasks and increases the risk of lower limb stress fracture.

Strength and Endurance

- Niemuth et al.[14] studied hip strength of 30 injured recreational runners compared with 30 uninjured recreational runners. They concluded that the injured lower limb demonstrated significantly weaker hip abductors compared with the contralateral limb. Hip external rotators on the injured side were weaker than the uninjured side, but the difference was not statistically significant. Hip muscle strength of the control group was similar to hip muscle strength of the uninjured limb of the injured athletes. These results suggest a relationship between hip muscle weakness and overuse injuries in the recreational runner.
- Local muscle fatigue is known to influence loading rate of impact during running; Christina et al.[15] found that the loading rate of impact peak force was higher in post-fatigue runs compared to pre-fatigue runs. Thus, building endurance should be an important component of rehabilitation after lower leg stress injury.

Literature

- Stress fractures can be classified into low-risk and high-risk stress fractures.
- The most common type of tibial stress fractures occurring in runners is a low-risk posteromedial cortex (compression side) stress fracture, a low-risk fracture.[16]
- A less common type of stress fracture is the longitudinal stress fracture, also a low-risk stress fracture.[16]
  - Following a low-risk tibial stress fracture, runners ought to refrain from running and impact exercise until symptoms resolve—typically 6 to 8 weeks.
- Fractures occurring on the anterior or tension side of the tibial shaft are considered high-risk fractures. These have a propensity to delayed and nonunion fractures, thus internal fixation is frequently warranted.[16]
- The timelines in this section are based on return to running following a low-risk fracture. The same principles apply for high-risk fractures, although typical return to sports is at 4 months.[17]

Phase I (weeks 1 to 6): Advanced Strength and Conditioning Programs

- Rehabilitation can commence shortly after diagnosis of stress fracture.
- During this time frame, the athlete is at risk of significant decreases of cardiovascular and muscular function. It is recommended that he or she continues aerobic exercise with the use of modalities that off-load the lower limbs such as deep-water running, swimming, bicycling and even antigravity treadmill training.
  - A study by Liem et al.[18] suggests parameters for deep water running and antigravity treadmill training and provides sample workouts.
  - With antigravity treadmill training, the transition to land running can typically occur more quickly because the runner already has been acclimating to lower limb loading.
    - The initial attempt at land running should not occur until the runner has reached approximately 85% to 90% BW with antigravity treadmill training.[18]
- Muscle strength and endurance can be maintained and improved with trunk stabilization exercises and resistance training.
- Phase I focuses on correction of muscle imbalances, increasing muscular endurance and obtaining good lower limb control with closed chain, low-impact tasks.
- Progression beyond low impact activities occurs in Phase II at 6 to 8 weeks.

Neuromuscular Control/Strength

- A treatment program is progressed in a systematic manner from isolated muscle recruitment and

neuromuscular control to endurance, functional training, and return to running is most logical.

- Much of the existing evidence for strength training stems from research demonstrating greater weakness in injured runners compared with noninjured controls.[19]
  - Resistance exercises for the proximal hip girdle and lower limbs are incorporated with the goal of strength development and improvement in bone mineral density.[18]
  - Proximal hip and trunk strength is necessary for control of distal segments during closed chain activities. Therefore it is important to continue with strengthening and neuromuscular control exercises until the resolution of faulty biomechanics (as opposed to symptom resolution solely) to decrease risk of future injury.
- Factors such as poor neuromuscular control and lower limb proprioception have also been shown to contribute to faulty lower limb biomechanics.
  - A treatment program aimed at strengthening the weak muscles and neuromuscular re-education to control the pelvis and femur in the frontal and transverse planes thus play an important role in rehabilitation.
  - Because dynamic hip stability cannot exist without stability of the pelvis, exercise programs aimed at rehabilitation of the lower limb need to address dynamic trunk stability with a well-rounded core stabilization program.
  - Physical therapy treatment for rehabilitation of lower limb muscle imbalances need to address isolated muscle recruitment/strengthening as well as neuromuscular control.
- Strength training has also been shown to improve factors associated with running performance, such as running economy, which is how well an athlete uses oxygen at a particular running velocity.[20]

The gluteus medius and gluteus maximus play strategic roles in the control of the lower limb during running. Strengthening of these muscles has demonstrated improvement in these common running overuse injuries.[21]

- Key exercises for isolating and strengthening the gluteal musculature include:
  - Clam with Thera-Band (Figure 36-4)
    - Place Thera-Band around thighs just proximal to knees.
    - Lie on side with knees bent approximately 60° with shoulders, hips, and feet in line.
    - Without rolling backward, lift top knee while pivoting on heels.
    - Perform three sets of 10-20.
  - Bridge with leg extension (Figure 36-5).
    - Lie on back with arms above head and knees bent as in Figure 36-5.

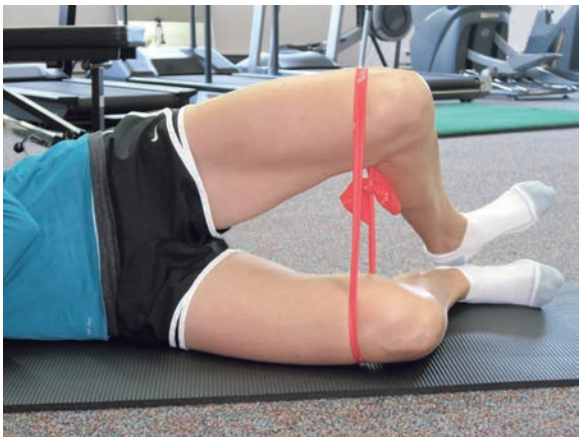

FIGURE 36-4. Clam exercise with Thera-Band resistance.



FIGURE 36-5. Bridge with leg extension. Maintain level hips by exaggerating gluteus maximus contraction in stationary leg before leg extension.

TIMELINE 36-4: **Return to Running After Stress Fracture of the Tibia**

PHASE I (weeks 1 to 6)	PHASE II (week 6) Successful Return to Running

• Aerobic exercise (pool running, swimming, bicycle)
• Strengthening of gluteus maximus, gluteus medius, and core musculature
• Neuromuscular control to eliminate the dynamic valgus tendencies
• Normalize lower extremity flexibility
• General strength training
• Patient education regarding factors leading to stress fracture and how to avoid same mistake in the future
• Criteria to progress to next phase:
  • Exemplary lower extremity control with all closed chain exercises used in Phase I
  • No pain with exercises
	• Aerobic exercise (pool running, swimming, bicycle)
	• Continue with Phase I strength and neuromuscular control exercises
	• Begin plyometrics with focus on lower extremity control and soft landing
	• Running gait retraining
	• Gradual increase of running mileage
	• Patient education regarding training programs and risk of future injury

- Lift hips off ground so that trunk and thighs are in a straight line.
- Exaggerate hip extensor contraction in stabilizing limb, extend opposite knee in a controlled manner, flex knee back to original position.
- Alternate sides.
- Perform two to three sets to fatigue or form failure.

- Side walk with Thera-Band[22] (Figure 36-6).
  - Place Thera-Band loop around ankles.
  - In a squatted position, step sideways across room, repeat the opposite direction.
  - Avoid lateral trunk movement.
  - Exaggerating a hip flexed position will best recruit the gluteus maximus.
  - Perform to fatigue or form failure.
- Single leg sit to stand[22] (Figure 36-7).
  - Find a surface that is mid-thigh height.
  - Step forward with one leg 6 to 8 inches.
  - Balance on that leg, squat down exaggerating hip flexion to lightly tap lower buttock on surface. (If you have pockets, aim to tap the bottom of the pocket on the surface.)
  - Return to upright position.
  - Exaggerating hip flexion best recruits gluteal muscles.
  - Focus on good foot and knee control.
  - Perform two to three sets of 10-20.
- A systematic approach to lower limb neuromuscular control includes an exercise progression focusing on proper alignment of the lower limbs: foot pointed forward, arch maintained, patella facing forward and hips level. The criterion for progression to more difficult exercises is proper technique with more simple exercises. The exercise progression includes:
  - Single leg stance
  - Single leg mini squat
  - Single leg side step down

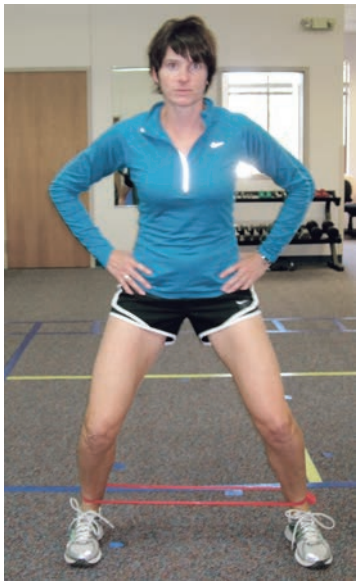

FIGURE 36-6. Thera-Band side stepping exercise. Maintain squatted position, feet pointed forward, knees pointed forward or slightly out. Perform approximately 15' one direction, and then back the other direction. Continue to fatigue.



FIGURE 36-7. Single leg sit to stand for gluteus medius and maximus strengthening and lower extremity control: Stand on one foot, 6 to 8 inches away from a surface that is mid-thigh height. Slowly squat down and reach back with hips to lightly tap the surface and stand back up. Maintain foot forward, knee forward position. Perform three sets of 10.

  - Single leg balance on uneven surfaces (add perturbations and/or ball toss to increase challenge)
- Address flexibility and ROM deficits found in evaluation in Phase I.
  - Manual therapy techniques and flexibility training should be directed at addressing deficits in range of motion and soft tissue extensibility; this is important because these limitations impart greater stress to adjacent bones.
  - At initial contact during the running gait cycle, hip flexion, knee flexion, ankle dorsiflexion, and subtalar pronation help dissipate forces and keep the center of mass low.[23]
    - Restrictions in the soft tissue that influences these joints can limit the lower limb's ability to accommodate ground reaction forces.
    - Postural muscles such as the gastroc-soleus complex (primarily soleus), rectus femoris, iliopsoas, tensor fascia lata, hamstrings, short thigh adductors, quadratus lumborum, piriformis, and sartorius, are commonly tight in runners;[24] however, each runner presents with unique impairments and a treatment plan that is tailored the individual's needs should be developed.
    - The gastroc-soleus complex is especially important when considering tibial stress fractures. A tight and shortened gastroc-soleus complex can lead to increased traction on the tibial cortex, which can result in medial tibial stress syndrome.[24] If repetitive traction persists, a stress fracture may subsequently develop.

Periodization

- Linear

Program Design/Performance Training Program

- Repetitions: 8 to 15
- Sets: two to three
- Rest interval: 60 to 90 seconds
- Intensity: 40% to 60%
- Training frequency: Strength three to four times per week, neuromuscular control daily

Phase II (weeks 6 until return to running): Sport-Specific Training

- Continue to focus on mastering neuromuscular control, strength and endurance of the hip and core musculature, as well as initiation of gait retraining.
- Plyometric exercises and Olympic lifts are introduced in this phase because these modes of training develop the runner's series elastic component (SEC). The SEC uses potential energy, producing the same force with less energy demand, thus improving running economy.

Gait Retraining

- Gait retraining to reduce lower limb loading rates has shown promise, but has not reduced tibial stress fracture incidence.[18] Studies have shown that subjects can change their running gait to lessen vertical force impact peaks and vertical force loading rates, and that these gait changes can be maintained at 1 month.[23]
- Changes to running biomechanics have been reported in as few as three training sessions.[25,26]
- Crowell et al. demonstrated that gait retraining over eight sessions with real-time visual feedback (accelerometer taped to the anterior medial shin with information displayed on a computer monitor) and verbal cueing resulted in decreased ground reaction forces.[26] Benefits were maintained at 1-month follow up.[26] It is recommended that feedback be progressively decreased for optimal learning and carryover.
- Gait retraining should include verbal and visual cues with an accelerometer, if available, to correct faulty biomechanics identified during the video gait assessment.
  - It is recommended that cues be given in a systematic manner because it is difficult for the athlete to focus on more than one aspect of the running gait and respond to more than one cue.
  - A common biomechanical fault is excessive femoral internal rotation and foot over-pronation. Cues to correct these deviations may include focusing on keeping the knees facing forward and apart, maintaining the arch of the foot, or pushing off the tip of the big toe as opposed to the inside edge of the big toe. Trial and error help determine which cues work best for each athlete.
- Heiderscheitt et al. conducted a laboratory study to determine the effects of cadence manipulation on lower limb joint kinematics and kinetics, concluding that as cadence increases, step length decreases.[27]
  - An increase in cadence by 10% of the runner's preferred cadence leads to decrease center of mass vertical excursion and decreased braking impulse; this is thought to lessen the likelihood of tibial stress fracture.[27]
  - It is recommended that runners manipulate their cadence with the use of a metronome for training. It is possible to download a metronome file as an mp3 and upload it to an mp3 player.

Return to Running

- Address training errors and gradual return to running:
  - Discuss volume of training program and any changes made to the training program in the months before tibial stress fracture. Educate the runner about sensible increases to the training volume and intensity.
  - Treatment and return-to-running decision making is based on the site of the injury and its corresponding potential for healing and risk of significant complication.
  - Most stress fractures heal uneventfully with relative rest and activity modification, however, low-risk does not equate to no risk for those with a stress fracture.
  - A treatment plan should always be tailored to the individual's goals, with discussion of the risks and benefits of continued participation versus absolute or relative rest.
  - Gradual increase in activity should begin after the athlete is pain free and the site is not tender.
- Attempts to quantify graduated training programs through clinical research have not been successful. Despite the lack of research supporting graduated running programs and reduced injury, clinical experience leads one to recommend that a 10% increase per week of training volume OR similar increase in intensity is appropriate to reduce the risk of running-related injury.
  - Several return to running programs have emphasized alternating between days of running and starting at a level between one-third and one-half of the athlete's normal distance and pace.[28-30]
  - It is recommended that the return to run program commence with 5 to 7 minutes of running every second day for the first week and progress weekly provided the athlete is running symptom free.
- Introduction to running following injury is a balance between the dosage and frequency of load applied to the body and the body's ability to adapt.
- It is imperative that biomechanical abnormalities be minimized before the reintroduction of running follow tibial stress fracture.

Periodization

- Undulating

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- Training continuum
- Training with optimum posture

- Sensorimotor and balance training
- Core training
- Cardiorespiratory training
- Training for optimum muscle balance
- Training for optimum muscle functional strength
- Neuromuscular dynamic stability exercises
- Plyometric training
- Functional training
- Sport-specific training

Training Principles Used in the Design of the Program

- Principle of progression
- Principle of individualization

Application of Acute Training Variables

- Rehabilitation exercises
  - Continue with Phase I exercises, with a focus of high-repetition and low-resistance exercises to build endurance.
- Plyometrics
  - Repetitions:
    - Beginner: 80 to 100 contacts. Intermediate: 100 to 120 contacts. Advanced: 120 to 140 contacts.[31] Aim for eight contacts per set for high intensity exercises. Watch for form failure; if form fails, give the athlete additional rest or reduce the number of repetitions or sets for that day.
  - Sets: two to three per exercise
  - Rest interval: 1:10 to 1:5 work/rest ratio
  - Training frequency: two to three times per week
  - Training volume: higher volume of lower level at the beginning and progress to higher intensity using lower volume.
  - Specific exercises used in the training:
    - Low level
      - Jumping rope
      - Ankle bounces
    - Intermediate level
      - Jumping jacks
      - Barrier jumps (front-back and side-side)
      - Bounding in place
      - Ski jumps
    - High level
      - Tuck jumps
      - Squat jumps
      - Broad jumps
      - Run into bounding
      - Skips for height
      - Double leg → single leg box jumps
      - Scissor kicks
      - Split lunge jumps
      - Power skipping
      - Single leg hops
      - Zig zag hops
      - Depth jumps
- Olympic lifts
  - These exercises are recommended for the elite college runner and not necessarily recreational and age group competitors unless properly coached.
    - Repetitions: three to five
    - Sets: two to three
    - Rest interval: 2 to 5 minutes
    - Intensity: 30% to 40%
    - Repetition tempo: N/A
    - Training frequency: two times per week
    - Training volume: two to four exercises
    - Specific exercises used in the training
      - Snatch
      - Clean and jerk
      - Power clean
      - Hang clean
      - Jump squats
- General weight lifting for strength
  - Repetitions: 10 to 25
  - Sets: two to three
  - Rest interval: 30 seconds
  - Intensity: 20% to 40%
  - Training frequency: two to three times per week
  - Training volume: four to five exercises
  - Specific exercises used in the training:
    - Single leg squats
    - Step ups/downs
    - Calf raises
    - Hamstring curls/straight leg deadlifts
  - Core (include a variety of these exercises; some examples are listed in the following):
    - Front/side planks
    - Back extension
    - Prone alternate arm and leg extension

The preceding recommendations are not considered comprehensive training programs, but rather suggestions to supplement rehabilitation and strength and conditioning programs. Well-rounded programs should consider the following variables: developmental age, training age, gender, and specific mesocycle within the training year.

Sports Performance Testing

General Information

- It is imperative to determine all risk factors associated with tibial stress fracture and develop a systematic rehabilitation approach based on the findings.
- Subjective evaluation should include a thorough history:
  - Previous injury history
  - Volume and intensity of training
  - Type of shoe worn
  - Screen for female athlete triad

Specific Tests

- Closed chain lower limb control during a single leg sit to stand using the following criteria:
  - Balance on one leg and squat back toward an apparatus that is approximately mid-thigh height.
  - *Tap* the apparatus with the buttocks and come back up to starting position in a slow and controlled manner.
  - The athlete needs to be able to avoid the following for 30 consecutive repetitions per limb:
    - Hips Trendelenburg
    - Hip adduction

  - Hip internal rotation
  - Tibial internal rotation
  - Foot pronation
- Video running assessment viewed in slow motion or frame by frame (when high impact activity is appropriate).
  - One minute cadence count while running at a preferred speed (when high impact is appropriate).
    - No biomechanical abnormalities recognized.

Specific Criteria for Progression to the Next Stage to Determine Readiness for Running

- Six to eight weeks is necessary for bone healing.
- High impact activities (plyometrics and running) should be symptom free.

Specific Criteria for Release to Unsupervised Complete Participation in Running

- Pain free running and plyometrics
- No biomechanical abnormalities recognized in follow up video gait assessment viewed frame by frame
- Good lower limb control with all closed chain exercises
- 5/5 Strength of gluteus medius and gluteus maximus
- Solid understanding of gradual changes to running program (distance, speed, topography of training surface)

Recommended Ongoing Exercises

- Hip strengthening and lower limb control exercises listed in Phase I
- Core stabilization exercises
- Cadence work and corrections to biomechanical running style

Evidence

Barrios JA, Crossley KM, Davis IS: Gait retraining to reduce the knee adduction moment through real-time visual feedback of dynamic knee alignment. *J Biomech* 43:2208–2213, 2010.

In this laboratory study, eight healthy, varus-aligned subjects underwent a gait modification protocol. Real-time, visual feedback of dynamic knee alignment was provided with use of a computer monitor over eight training sessions. Over the course of the eight training sessions, feedback was lessened to encourage learning. Natural and modified gait were re-assessed post-training and at 1 month follo up. Comparisons were made within subjects to pretraining gait. The knee adduction moment, as well as hip adduction, hip internal rotation, and knee adduction angles were evaluated. (Level III evidence)

Bennell KL, Malcolm SA, Thomas SA, et al: The incidence and distribution of stress fractures in competitive track and field athletes. A twelve-month prospective study. *Am J Sports Med* 24:211–217, 1996.

Bennell et al. recruited 108 track and field athletes via letters to competitive track and field clubs' coaches and athletes. Subjects were followed for 12 months while they performed their normal training and competition regimen. After 12 months, subjects were questioned by one examiner about injuries sustained and training performed in the 12-month period. The diagnosis of a stress fracture was determined via bone scan or CT scan, using a blinded protocol. Stress fracture per 1000 hours of exposure was calculated for women, men, and all athletes combined. Incidence of stress fracture was also calculated by event. (Level IIb evidence)

Buist I, Bredeweg SW, Lemmink KA, et al: Predictors of running-related injuries in novice runners enrolled in a systematic training program: a prospective cohort study. *Am J Sports Med* 38:273–280, 2010.

The 532 participants from the original GRONORUN study were assessed by a physician and completed a baseline questionnaire before starting the study. Information from these participants was analyzed to determine gender-specific predictors of running-related injury in novice runners training for a 4-mile fun run in this individual cohort study. The authors found different predictors for injuries in male and female novice runners. The authors discussed a couple of limitations of their study. First, the predictors assessed were not inclusive of all potential risk factors to running related injury. Second, exposure to running and running-related injury were self-reported. (Level IIb evidence)

Crowell HP, Davis IS: Gait retraining to reduce lower extremity loading in runners. *Clin Biomech* 26:78–83, 2011.

Crowell et al. hypothesized that peak positive acceleration, vertical force loading rates, and vertical force impact peak would be reduced after a gait training program and that these changes would continue at 1 month follow-up. They performed an a priori power analysis and determined they needed 10 subjects. They chose 10 subjects with high ground reaction forces because high ground reaction forces have been shown to correlate with increased risk of tibial stress fracture. The authors measured tibial acceleration and ground reaction forces of 10 subjects while running overground at a set pace with a standardized running shoe. The subjects underwent a training program that consisted of eight sessions over a 2-week period. At each session real-time visual feedback was used to provide tibial acceleration via accelerometer taped to their anterior shin. Subjects were asked to run softer, make their footfalls quieter, and keep the acceleration peaks below a line placed at 50% of the mean peak positive acceleration. Visual feedback was progressively removed over the last four sessions. Post training data collection was performed immediately following the eighth session and again 1 month later. Significant reductions in the variables were maintained at 1 month follow-up. (Level IIIb evidence)

Distefano LJ, Blackburn JT, Marshall SW, et al: Gluteal muscle activation during common therapeutic exercises. *J Orthop Sports Phys Ther* 39(7):532–540, 2009.

Distefano et al. conducted an experimental laboratory study to determine the electromyographic (EMG) activity of the gluteus maximus and gluteus minimus for 12 commonly used exercises on 21 healthy, physically active subjects who volunteered to participate. Their objective was to quantify and compare EMG amplitude during exercises of varying difficulty to identify which exercises recruit the muscles best. The authors used surface electrodes placed on the gluteus maximus and gluteus minimus. The choice of surface electrodes may be viewed as a flaw because portions of the gluteus medius is deep to the gluteus maximus, gluteal aponeurosis, and iliotibial band. They normalized data collected to a maximal voluntary isometric contraction (MVIC) for hip extension and hip abduction. The method used to measure to

supposedly measure the MVIC of the gluteus medius was to test hip abduction strength in 25° of hip abduction in a side lying position. The standard way to test gluteus medius strength is in an abducted and extended position with slight external rotation. This could skew the results. The exercises tested were well chosen to represent those commonly used in the clinic. They performed a reliability analysis of data collected across the four repetitions of each exercise. $ICC_{3,1}$ values ranged from 0.93 to 0.98 for all exercises except the three versions of a hop. The exercises that produced the greatest gluteus medius EMG signal were side-lying hip abduction (81% MVIC), single limb squat (64% MVIC), and lateral band walk (61% MVIC). For the single limb squat exercise, they encouraged participants to reach for the floor with the contralateral hand to be certain they were squatting deeply enough. However, I believe the form used encourages hip Trendelenburg, which we are trying to avoid. Therefore I do not use this exact style of exercise. The clam exercises with 30° hip flexion and 60° hip flexion scored at the bottom of the list with 40% and 38% MVIC, respectively. However, authors tested this exercise without external resistance. In the clinic it is commonly used with Thera-Band around both legs just above the knees. I believe if the clam exercise were analyzed with resistance, the outcome may be different. Therefore despite the study results, I choose to use this exercise. (Level IIIb evidence)

Heiderscheit BC, Chumanov ES, Michalski MP, et al: Effects of step rate manipulation on joint mechanics during running. *Med Sci Sports Exerc* 43(2):296–302, 2011.

The authors conducted a three-dimensional kinematic and kinetic analysis of the hip, knee, and ankle joints of 45 healthy runners (averaging 29 km/week) volunteering to participate in this experimental laboratory study. Based on a power analysis with minimum power of 80%, 38 subjects were needed to detect a 20% change in joint biomechanics. They recorded data at the subjects preferred step rate, ± 5% and ± 10% of the preferred step rate. Their goal was to characterize lower limb biomechanics at varying step rates, but constant speed during running. The study was well conducted. Further results are discussed in the Final Case. (Level IIIb evidence)

Hreljac A: Impact and overuse injuries in runners. *Med Sci Sports Exerc* 36:845–849, 2004.

Hreljac conducted a review of available evidence to summarize the etiology of running related injuries. (Level V evidence)

Kaeding CC, Yu JR, Wright R, et al: Management and return to play of stress fractures. *Clin J Sport Med* 15(6):442–446, 2005.

Authors performed a Medline search for peer reviewed publications regarding the etiology, classification, treatment, and natural history of stress fractures. They developed an algorithm for treatment of stress fractures based on retrospective case series, evidence-based papers, and the clinical experience of their sports medicine team. (Level IIIa evidence)

Milner CE, Ferber R, Pollard CD, et al: Biomechanical factors associated with tibial stress fracture in the female runner. *Med Sci Sports Exerc* 38:232–328, 2006.

In this retrospective, cross-sectional study, Milner et al. sought to determine the differences in structure and biomechanics between trained female distance runners with a history of tibial stress fracture compared with those without a history of stress fracture. Subjects were recruited by direct contact and fliers posted. Twenty rearfoot strikers with a history of tibial stress fracture were matched for age and mileage to 20 controls without history of stress fracture. A priori power calculations were performed to determine the minimal sample size needed: between 9 and 20 subjects were needed. Subject wore a standard neutral running shoe and ran overground at a standardized speed for 23 meters. (Level IIIb evidence)

Milner CE, Hamill J, Davis IS: Distinct hip and rearfoot kinematics in female runners with a history of tibial stress fracture. *J Orthop Sports Phys Ther* 40(2):59–66, 2010.

In this cross-sectional controlled laboratory study, authors investigated the kinematics of the hip, knee and rearfoot in the frontal and transverse planes of female long distance runners with a history of tibial stress fracture. Subjects ran over ground while data was collected from a force platform. (Level: IIIb evidence)

Niemuth PE, Johnson RJ, Myers MJ, et al: Hip muscle weakness and overuse injuries in recreational runners. *Clin J Sport Med* 15(1):14–21, 2005.

The authors studied hip muscle strength in 30 injured runners compared with 30 uninjured controls in this individual case-control study. Injured subjects were chosen as a convenience sample from an injury clinic. Control subjects were chosen randomly from a pool of volunteers from a distance running club. Injured subjects and controls were matched for gender, weight, and leg dominance. All subjects were considered recreational runners, who were averaging a minimum of 10 miles per week over the last 3 months and not running at a competitive level. Hip muscle strength was recorded using hand-held dynamometry for the hip flexors, extensors abductors, adductors, internal rotators, and external rotators. Measurements were made by a single measurer and normalized to body mass. Results indicated that injured hip abductors and hip flexors were significantly weaker than their uninjured side. The uninjured side's muscles strength was comparable to the controls' muscle strength. The results suggest that unilateral hip muscle weakness exists in injured runners that does not exist in uninjured runners. Given the study design, one cannot conclude a cause-effect relationship. (Level IIIb evidence)

Van Gent RN, Siem D, Van Middelkoop M, et al: Incidence and determinants of lower extremity running injuries in long distance runners: A systematic review. *Br J Sports Med* 41:469–480, 2007.

Van Gent et al. conducted a systematic review with the primary purpose of presenting an overview of the incidence and potential risk factors associated with lower limb injuries in distance runners. They consulted PubMed for published articles up to January 2006. They defined distance runner as an individual running at least 5 kilometers per training or race, but not belonging to an elite group. Authors clearly defined their inclusion and exclusion criteria. They examined 1113 titles and abstracts and narrowed their final selection to 17 articles. The final selection included 13 prospective cohort studies and four retrospective cohort studies. Pooling of the results was not possible. Therefore the authors presented a "synthesis" of the results. Incidence of injury reported varied from 19.4% to 79.3%. Injuries to the hip and pelvis ranged from 3.3% to 11.5%. Females are more likely to be injured. There was conflicting evidence for an association between an increase in training or inexperience in running and running-related injuries. Training volume greater than 64 kilometers per week was a risk factor for running related injury. A history of previous running injury was a significant risk factor for injuries. (Level IIa evidence)

Varner K, Younas S, Lintner D, et al: Chronic anterior midtibial stress fractures in athletes treated with reamed intramedullary nailing. *Am J Sports Med* 33:1071–1076, 2005.

Case series of 7 collegiate-level athletes with 11 chronic anterior midtibial stress fractures followed for a mean duration of 17 months. Each underwent intramedullary nailing. Average return to sport was 4 months. (Level IV evidence)

Zadpoor AA, Nikooyan AA: The relationship between lower-extremity stress fractures and ground reaction force: A systematic review. *Clin Biomech* 26:23–28, 2011.

A systematic review of the literature on the relationship between history of tibial and metatarsal stress fractures and ground reaction forces and loading rate was conducted. A meta-analysis result showed no significant difference in the ground reaction forces between groups. However, the loading rate was significantly different between groups. (Level IIa evidence)

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Multiple Choice Questions

QUESTION 1. Research has shown that a manipulation of cadence to what rate has been shown to significantly reduce lower limb forces and risk of stress fracture?

A. Cadence of 180 steps per minute
B. Increase of 15% of runner's preferred cadence
C. Increase of 10% of runner's preferred cadence
D. Cadence of 175 steps per minute

QUESTION 2. High risk stress fractures typically return to sport in:

A. 6 months
B. 4 months
C. 12 weeks
D. 6 to 8 weeks

QUESTION 3. The most common site of stress fracture in a runner is the:

A. Femur
B. Sacrum
C. Fifth metatarsal
D. Tibia

QUESTION 4. Tibia stress fracture is often caused by:

A. Training errors
B. Abnormal biomechanics
C. Strength deficits
D. All of the above

QUESTION 5. True or False

It is thought that poor neuromuscular control and strength of the hip may contribute to running-related injuries.

Answer Key

QUESTION 1. Correct answer: **C** (see Phase II)

QUESTION 2. Correct answer: **B** (see Introduction)

QUESTION 3. Correct answer: **D** (Introduction/ Incidence)

QUESTION 4. Correct answer: **D** (Incidence)

QUESTION 5. Correct answer: **True**

Chapter 37



Tibial Shaft Fractures

INTRODUCTION

Lance E. LeClere, MD, LCDR, MC, USN, and Robert M. Lucas, MD

Epidemiology

- Tibial shaft fractures are the most common long bone fracture treated by orthopedic surgeons.[1]
- Tibial shaft fractures occur at a rate of 26 per 100,000 persons per year.[1]
- The average age of patients that sustain a tibial shaft fracture is approximately 37 years.[2]
- In general, there is a bimodal age distribution for tibial shaft fractures. Most commonly, tibial shaft fractures occur in adolescents and are the result of high energy trauma.[1] A second peak in incidence may occur later in life owing to osteoporosis.[2]
- Tibial shaft fractures are more common in men, at a ratio of approximately 2:1.[3]
- In general, tibial shaft fractures are rarely the result of a sports injury. Most tibial shaft fractures are the result of high-energy mechanisms. High-impact sports and collision sports such as football, rugby, and martial arts are just a few examples. However, some low-energy sports injuries can also cause tibial shaft fractures. This is usually owing to torque and rotational forces on the leg, such as in downhill skiing or gymnastics.
- Tibial shaft fractures can occur via compression, tension, or rotational forces, direct impact, or combination of these forces. In general, tibial shaft fractures sustained during sport are from high-energy, direct impact mechanisms or from low-energy injuries that occur via rotational forces to the leg while the foot is planted on the ground. In the case of downhill skiing, often bindings do not release and a rotational force about the leg results in a spiral tibial fracture (Figure 37-1). Soccer players commonly sustain tibial shaft fractures from direct impact and account for up to 80% of sports-related tibial shaft fractures.[2] These fractures are usually transverse or short oblique in nature (Figure 37-2).

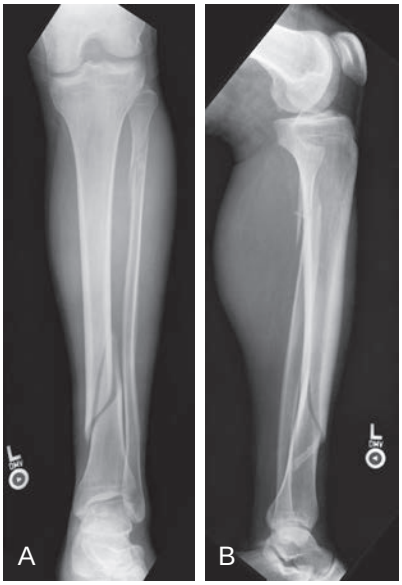

FIGURE 37-1. An anteroposterior (**A**) and lateral (**B**) radiograph of a spiral tibial shaft fracture. These types of fractures are most typically seen as the result of a low-energy, rotational mechanism. One example is a skiing injury.

Pathophysiology

Intrinsic Factors

- There are no specific anatomical, developmental, or neuromuscular factors that specifically predispose an athlete to tibial shaft fractures.
- Metabolic and pathological conditions of the bone such as osteopenia, osteoporosis, infection, and neoplasms may impair bone quality and predispose athletes to tibial shaft fractures.

The views and opinions expressed in this chapter are the those of the authors and are not necessarily representative of the official policy or views of the Department of the Navy, the Department of Defense, nor the U.S. Government.



FIGURE 37-2. An anteroposterior (**A**) and lateral (**B**) radiograph of a transverse tibial shaft fracture. This transverse pattern is often seen in a low-energy direct-impact type of injury, such as in soccer.

Extrinsic Factors

- Extrinsic factors that may predispose athletes to tibial shaft fractures are footwear or equipment that prevents the foot from pivoting or rotating with the leg. For example, skiers who sustained tibial shaft fractures have been found to have binding release values that are higher than noninjured skiers,[4,5] and improvements in the design of ski bindings that allow for release of skis more readily have decreased the incidence of ski-related tibial shaft fractures.[3]
- Failure to wear proper equipment may leave the athlete more prone to fracture from direct impact. Lack of proper protective shin guards in soccer may predispose players to tibial shaft fractures.[6]

Traumatic Factors

- High-energy trauma is the leading cause of tibial shaft fractures. Usually this is a result of direct impact, such as a tackle in football or getting kicked in soccer.
- Fractures that result from low-energy trauma are usually the result of rotational injuries, such as skiing.

Classic Pathological Findings

- Classic findings include pain, soft tissue swelling, gross deformity of the leg on visual inspection, palpable fracture, or even an open fracture.
- Plain radiographs of the tibia and fibula and anteroposterior and lateral planes will confirm diagnosis and allow for fracture classification.

Clinical Presentation

History

- Typically the patient will feel and/or hear a "pop" or "crack" and have the immediate onset of severe pain and inability to bear weight.
- It is important to establish the mechanism of injury because higher-energy injuries may lead to more significant soft tissue damage, swelling, and higher risk of developing compartment syndrome.
- Low-energy injuries or the presence of preceding pain may be related to underlying intrinsic disorders of the bone such as osteoporosis, osteopenia, infection or benign or malignant neoplasms.

Physical Examination

Abnormal Findings

- Tenderness to palpation at fracture site
- Gross deformity on visual inspection
- Significant soft tissue swelling
- Overlying skin or soft tissue damage may be present, such as blistering of the skin or open wounds
- Higher incidence of open fractures caused by limited soft tissue coverage
- Suspicion for possible compartment syndrome should arise when there is pain out of proportion to examination, firm swollen soft tissues, pain with passive stretch of ankle or toes and paresthesias, especially in the deep and superficial peroneal nerve distributions. Pallor, pulselessness, paralysis, and a cool extremity or late signs and concern for significant soft tissue necrosis.

Pertinent Normal Findings

- Nontender along tibial shaft
- No gross deformity of the leg
- No crepitus or motion over the area of maximal tenderness

Imaging

- Anteroposterior and lateral plain radiographs will confirm diagnosis and assist in fracture classification. It is important to include imaging of the knee and ankle.
- The quality of the bone should be taken into account when evaluating plain film x-rays to assess for metabolic, pathological, or infectious conditions and evidence of any previous fractures, which may indicate an underlying disorder.
- Rarely computed tomography (CT) or magnetic resonance imaging (MRI) is required for diagnosis. CT may be helpful in determining whether fracture lines extend into articular surfaces. Heightened concern for intra-articular fractures should arise with spiral fractures in the proximal and distal third of the tibia.[7]
- MRI may be useful in further evaluation in bone and soft tissues if a pathological fracture is suspected.

Differential Diagnosis

- Contusion: No gross deformity will be present. Radiographs will be normal. The patient may or may not be able to bear weight on the affected extremity, although if the patient is able to bear weight the presence of a fracture is significantly less likely.

Treatment

Nonoperative Management

- Cast immobilization (Figure 37-3) with long leg casting or patellar tendon bearing casting.
- Early cast immobilization with transition to Sarmiento functional bracing (Figure 37-4)

Guidelines for Choosing Among Nonoperative Treatments

- Acceptable alignment for nonoperative treatment generally include[1]:
  - Less than 1 cm shortening
  - 5° valgus, 0° varus
  - 10° procurvatum or recurvatum
  - 10° external rotation, 0° internal rotation
- Patellar tendon bearing casts and Sarmiento functional bracing are chosen based primarily on patient and treating physician preference. Large series of functional bracing show excellent healing rates and alignment in properly selected patients.[8]
- Patients who are in poor general health, have significant co-morbidities, or a low preinjury motility status.



FIGURE 37-3. A, An example of a long leg cast used for treatment of a tibial shaft fracture. **B,** An example of a patellar tendon-bearing cast. Often a long leg cast is transitioned to a patellar tendon-bearing cast after initial healing. A patellar tendon cast allows for weight bearing by the patient.

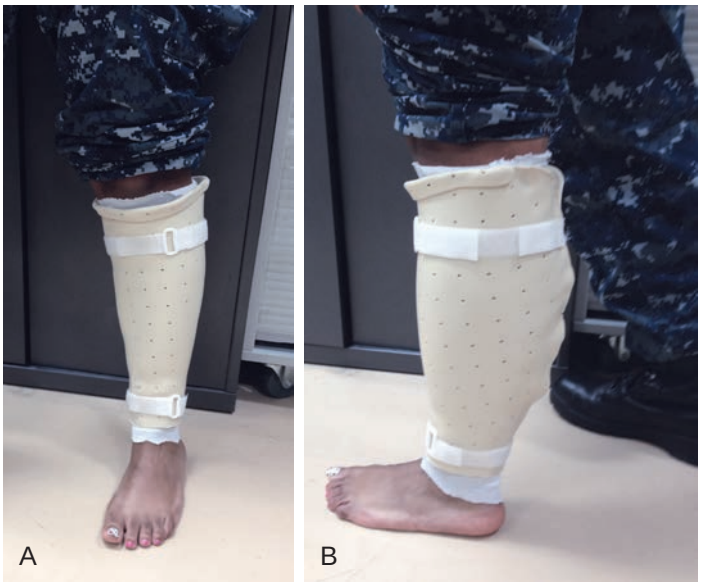

FIGURE 37-4. A,B, A Sarmiento functional brace used for nonoperative treatment of a tibial shaft fracture.

Surgical Indications

- Open fractures (strong relative)
- Neurovascular injury (strong relative)
- Failure to achieve acceptable alignment in cast/brace (relative)
- Patient preference (relative)
- Tibial fracture with intact fibula (relative)
- Extensive bone loss (relative)
- Failure to achieve acceptable closed reduction—see preceding criteria (strong relative)
- Polytrauma (relative)
- Desire for early weight bearing (relative)

Aspects of History, Demographics, or Exam Findings That Affect Choice of Treatment

- Patients who cannot tolerate prolonged cast immobilization or will be poorly compliant with bracing are more suitable candidates for surgical treatment.
- Patients with open fractures or neurovascular damage tend to be treated surgically, although open fracture is not necessarily an absolute indication.
- Surgical treatment has shown lower rates of nonunion, delayed union, and faster time to union.[9,10]
- In general, patients can begin weight bearing earlier with surgical treatment if intramedullary nails are used. Therefore patients who wish to return to full weight bearing or prefer not to be casted are more suitable candidates for surgery.
- Surgeons in North America are more likely to used reamed intramedullary nails for both open and closed tibia shaft fractures.[11]

Aspects of Clinical Decision Making When Surgery Is Indicated

- Most midshaft tibia fractures are treated with intramedullary nailing (Figure 37-5). More proximal or distal fractures or those with severe comminution may be treated with open reduction and internal fixation with plates and screws.[12]
- For intramedullary nailing, a transpatellar or peripatellar tendon approach should be considered. Although the incidence of anterior knee pain is high after intramedullary nailing (67%), there appears to be no advantage of one approach over the other in its prevention.[13]
- Open fractures may be initially treated with external fixation, followed by conversion to intramedullary nailing within 2 weeks; however, they may also be initially treated with either reamed or undreamed intramedullary nailing.[14]
- Patients who develop compartment syndrome require emergent fasciotomies.

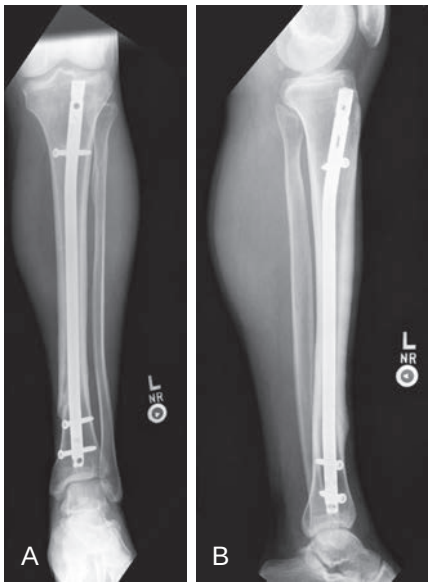

FIGURE 37-5. An anteroposterior (**A**) and lateral (**B**) radiograph of a tibial shaft fracture treated with an intramedullary nail.

Evidence

Bhandari M, Guyatt HG, Swiontkowski MF: Treatment of open fractures of the shaft of the tibia; a systematic review and meta-analysis. *JBJS Br* 83(1):62–68, 2001.

The authors performed a systematic review and meta-analysis of current literature evaluating the effects of various methods of treatment of open tibial shaft fractures. They were able to conclude that unreamed nails reduce the incidence of reoperations, superficial infections, and malunions when compared with external fixators. They were unable to determine whether reamed or unreamed intramedullary nailing was a better treatment option. (Level IV evidence)

Karladani AH, Granhed H, Edshage B: Displaced tibia shaft fractures: A prospective randomized study of closed intramedullary nailing versus cast treatment in 53 patients. *Acta Orthop Sand* 71:160–167, 2000.

The authors randomized patients with closed and grade 1 open tibial shaft fractures to intramedullary nailing versus treatment by closed casting. They found a lower time-to-union, lower delayed union rate, and higher subjective outcome scores with intramedullary nailing. Based off of their results they recommended intramedullary nailing as the preferred treatment. (Level I evidence)

Toivanen JA, Vaisto O, Kannus P, et al: Anterior knee pain after intramedullary nailing of fractures of the tibial shaft. A prospective, randomized study comparing two different nail-insertion techniques. *J Bone Joint Surg Am* 84-A:580–585, 2002.

The authors randomized patients with tibia shaft fractures undergoing intramedullary nailig to treatment with paratendinous or transtendinous nail insertion. They found no significant differences in regard to the rate of anterior knee pain, patient-specific outcome scores, strength, or functional testing between the two groups. (Level I evidence)

Vallier HA, Cureton BA, Patterson BM: Randomized, prospective comparison of plate versus intramedullary nail fixation for distal tibia shaft fractures. *J Orthop Trauma* 25(12):736–741, 2011.

The authors randomized patients with distal tibia shaft fractures to treatment with plate fixation versus intramedullary nailing. They found equal incidience of infection, nonunion, and secondary procedures, with a higher incidence of malalignment in the intramedullary nailing group. (Level I evidence)

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Multiple Choice Questions

QUESTION 1. Tibial fractures are most commonly seen in which age group?

A. 5 to 10 years old
B. 14 to 20 years old
C. 30 to 40 years old
D. Over 80 years old

QUESTION 2. The appropriate treatment for tibial shaft fractures is:

A. Casting
B. Bracing
C. Intramedullary nails
D. All of the above

QUESTION 3. Which of the following tibial fracture patterns is most commonly seen in a downhill skier?

A. Transverse
B. Spiral
C. Comminuted
D. Open

Answer Key

QUESTION 1. Correct answer: **B** (see Epidemiology)

QUESTION 2. Correct answer: **D** (see Treatment)

QUESTION 3. Correct answer: **B** (see Epidemiology)

NONOPERATIVE REHABILITATION OF TIBIAL SHAFT FRACTURES

LT Katelyn H. McCormick, DPT, LT, MSC, USN, and Lance E. LeClere, MD

GUIDING PRINCIPLES OF NONOPERATIVE REHABILITATION

- Period of non/partial weight bearing for bone callus formation
- Restore full ankle/knee range of motion
- Once full range of motion is established progress to strength training (open kinetic chain)
- Progress weight bearing status, closed kinetic chain strengthening, balance training
- Plyometric training and sport-specific training

Phase I (weeks 1 to 4)

Protection

- If nonsurgical options are selected, the patient will be immobilized with the use of a cast or brace (American Academy of Orthopedic Surgeons guidelines), with possible use of crutches during this time of non–weight-bearing status.

Management of Pain and Swelling

- Nonsteroidal antiinflammatory drugs (NSAIDs)
- Ice
- Compression

Techniques for Progressive Increase in Range of Motion

- Patient will be most likely in a hard cast for approximately 4 to 6 weeks for healing and hard callus bone formation.
- X-rays should be ordered every 1 to 2 weeks for first 4 weeks to ensure there is no displacement of fracture per AAOS guidelines.

Manual Therapy Techniques

- None at this time because the involved area is immobilized and to promote bone healing

Stretching and Flexibility Techniques for the Musculotendinous Unit

- If the patient has a below-knee cast or brace, hamstring stretching is important to facilitate normal gait once cast/brace is discharged/removed.

Other Therapeutic Exercises

- During the acute phase while the patient is immobilized, concentrate on upper extremity and hip strengthening while maintaining non–weight-bearing status, using core strength/stability training.

Activation of Primary Muscles Involved

- Activation of gastrocnemius, soleus, fibularis, and tibialis musculature may be limited due to immobilization during initial phase.
- Depending on the type of casting or bracing, during the initial phase gentle isometrics may be the only way to activate the musculature mentioned in the preceding.

Techniques to Increase Muscle Strength, Power, and Endurance

- While the patient is immobilized in either a cast or brace, lower extremity therapeutic exercises should focus on other lower extremity strengthening to include:
  - Hip abduction
  - Gluteal strengthening
  - Straight leg raises
  - Quadriceps and hamstring strengthening
- The patient will most likely have to perform open kinetic chain exercises at this time secondary to the patient's non–weight-bearing status.

Milestones for Progression to the Next Phase

- Radiographic confirmation of healed fracture site before removal of cast
- Decreased pain

Phase II (weeks 4 to 12)

Clinical Pearl

According to Wolff's law, increased weight-bearing activities can help to determine the formation of bone.[1]

Protection

- If the patient demonstrates an antalgic gait, patient may be issued a CAM walking boot or crutches may be used to decrease forces through the injured area.

Management of Pain and Swelling

- Ice
- Interferential current using electrical stimulation to decrease any pain or swelling following treatment

TIMELINE 37-1: **Nonoperative Rehabilitation of Tibial Fractures**

PHASE I (weeks 1 to 4)	PHASE II (weeks 4 to 12)	PHASE III (weeks 12 to 36)
• Period of immobilization in long- leg cast, patellar tendon bearing cast, or Sarmiento functional bracing • Ice	• AROM/ AAROM/ PROM for full ankle/ knee ROM • Manual talocrural joint mobilizations: Grades I/II → III/IV • Ankle isometrics • Non–weight-bearing ankle strengthening (OKC with Thera-Band resistance) • Stationary bike • OKC strengthening for hip and knee • Lower extremity stretching • Progression of weight bearing status: D/C walking boot/crutches if used • Gait training • Aquatic therapy • Body weight squats, lunges • Leg press/shuttle • Single leg stance/balance activities • Step ups/downs • Elliptical • Initiating walk-jog progression	• Progression of walk-jog progression • Plyometrics • Running/sprints • Agility and sport-specific drills • Return to sport

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Manual techniques will be determined following an assessment of the individual's foot and ankle to include talocrural, subtalar, and first metatarsophalangeal joint mobility.
- Specific techniques will include anteroposterior, posteroanterior, and distraction mobilizations for improving ROM and mobility deficits.
- Mobilizations will start with Grade 1 to 2 and advance to Grades 3 to 4 as the patient tolerates.

Soft Tissue Techniques

- Soft tissue mobilization or massage to the gastrocnemius and soleus complex for increasing flexibility and ankle dorsiflexion range of motion, following a period of immobilization.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Patient should be instructed in how to stretch the gastrocnemius and soleus muscle groups if he or she has limitations in dorsiflexion range of motion.
- Stretching should be continued until normal and symmetrical dorsiflexion ROM is achieved bilaterally. Low-load, long-duration stretching is stretching that takes place multiple times per day (two to three times), for longer hold periods (30 to 60 seconds), and increased repetitions per set (5 to 10 repetitions).
- Active stretching is to be continued once normal ROM is achieved (20- to 30-second hold, two to three sets, one to two times per day).

Other Therapeutic Exercises

- Total lower extremity strengthening should be included as a part of the patient's program to include hip abduction, gluteals, quadriceps, and hamstring musculature.
- Core stability/strengthening exercises such as front and side planks should be incorporated into the strengthening program.
- Total lower extremity strengthening should include lower extremity strengthening to include the hip and thigh musculatures.
- Aquatic therapy/pool based exercise is a beneficial way for progressing weight bearing while performing gross lower extremity ROM and strengthening.
- Initially following removal of cast or brace, instruct the patient in AROM of the ankle to include ankle pumps for improving active dorsiflexion and plantarflexion ROM and pumping out swelling from the distal joints. The patient should also be instructed in ankle circles (clockwise and counterclockwise) for gross ankle range of motion and decreasing swelling of the distal joint segments.
- Ankle isometrics in all directions if initial AROM of the ankle is painful.

Activation of Primary Muscles Involved

- With a tibial shaft fracture and following a period of immobilization, strengthening to all compartments of the distal lower extremity will need to include:
  - Anterior compartment: ankle dorsiflexors (tibialis anterior, extensor digitorum longus, extensor hallucis longus and fibularis tertius)
  - Lateral compartment: ankle everters (fibularis longus, fibularis brevis)
  - Posterior compartment: gastrocnemius and soleus, plantaris, popliteus, flexor hallucis longus, flexor digitorum longus, and tibialis posterior

Open and Closed Kinetic Chain Exercises

- Open kinetic chain exercises: Intrinsic foot muscle strengthening exercises (towel/toe curls exercises and marble pickups) and ankle strengthening exercises (four-way resisted Thera-Band exercises [inversion, eversion, dorsiflexion, and plantarflexion])
- Closed kinetic chain exercises: Progression of weight bearing activities without an increase of pain to include: double leg bridging (Figure 37-6), progressing to single leg bridging; squatting activities with multiple foot positions and bases of support, multi-directional lunges, deadlifts, progression of weight for both double and single leg shuttle/leg press

Sensorimotor Exercises

- Single-leg balance activities progressing from a firm surface to soft/unsteady surface (Figure 37-7)

Functional Exercises

- Beginning of functional exercises as increased weight bearing is tolerated such as squats, lunges (anterior/posterior/lateral), step ups/downs (Figure 37-8)

Milestones for Progression to the Next Phase

- Decreased pain with weight-bearing activities
- Symmetrical lower extremity ROM to include ankle dorsiflexion and knee flexion/extension as measured in open and closed kinetic chain positions

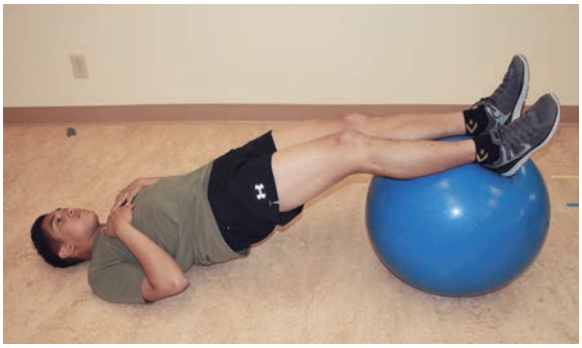

FIGURE 37-6. Double-leg bridging.

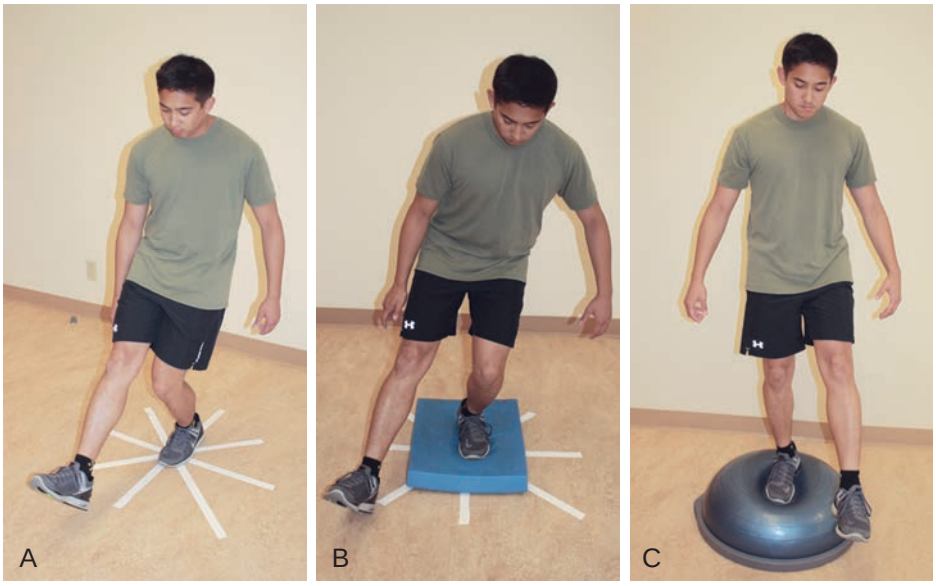

FIGURE 37-7. Single-leg balance activities progressing from a firm surface to soft/unsteady surface. **A,** Ground, steady surface. **B,** Foam, uneven surface. **C,** BOSU balance trainer, uneven surface.

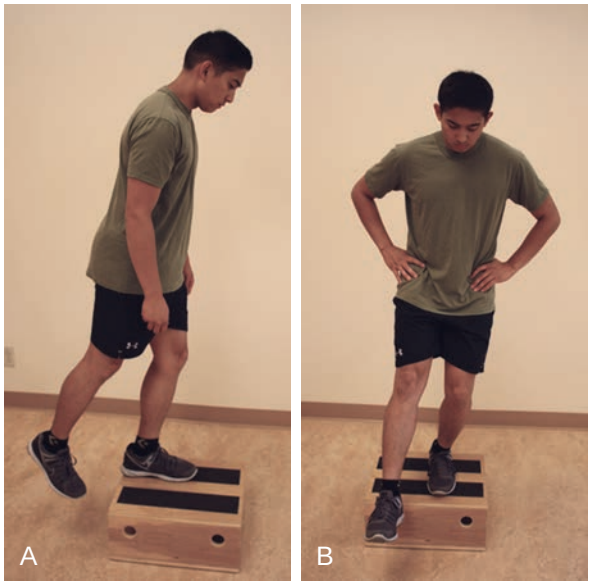

FIGURE 37-8. A, Step up. **B,** Step down.

- Lower extremity strength 5/5
- Normal pain free gait

Phase III (weeks 12 to 36)

Management of Pain and Swelling

- As for Phase II

Techniques for Progressive Increase in Range of Motion

Soft Tissue Techniques

- As for Phase II

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Active stretching to the gastroc/soleus muscle complex along with the hamstring musculature as part of warmup activities before the advancement to higher demand exercises (20- to 30-second hold, two to three repetitions)

Activation of Primary Muscles Involved

- As for Phase III, gross lower extremity and core strengthening for return to athletics is continued

Sensorimotor Exercises

- Progression of single leg balance activities by adding dynamic upper extremity movements or opposite lower extremity movements (Figure 37-9).
- Advance these exercises by increasing the amount of movement, speed of the movement, and the number of repetitions.

Techniques to Increase Muscle Strength, Power, and Endurance

- Progression of closed kinetic chain exercises for dynamic strengthening and endurance for return to sport-related activity

Plyometrics

- Progression to plyometrics begins with partial weight-bearing hops and jumps, starting on Shuttle Systems or in a pool.
- Once partial weight-bearing plyometrics are tolerated, the athlete can progress to full weight bearing activities, including double leg hops moving toward single leg hops and box jumps.

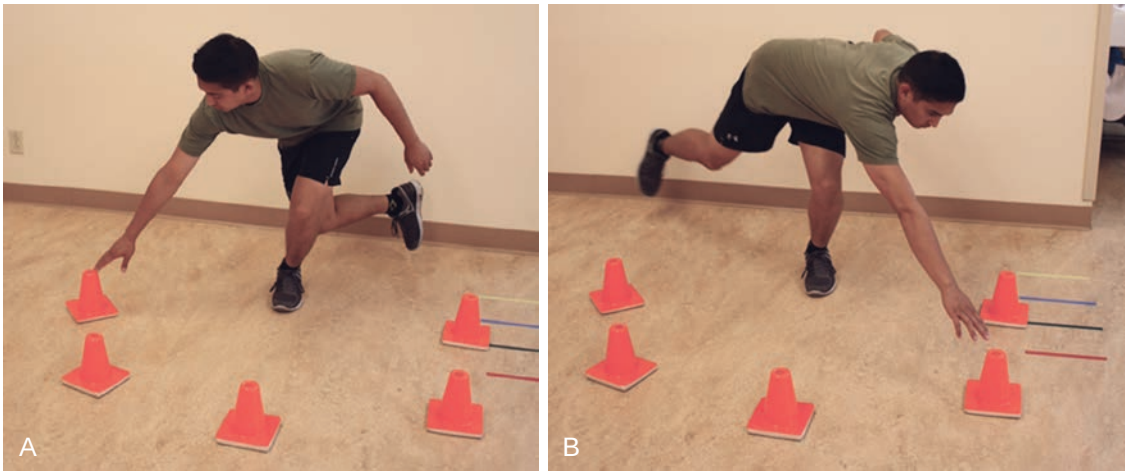

FIGURE 37-9. A,B, Progression of single-leg balance activities by adding dynamic upper extremity movements or opposite lower extremity movements



FIGURE 37-10. Multidirectional movements on unstable surfaces: squats on BOSU balance trainer.

- Box jumps and bounding exercises may be performed to control impact and landing for proper shock absorption and explosive moments.

Sport-Specific/Functional Exercises

- Multidirectional movements to both stable and unstable surfaces such as lunges, squats (on BOSU [Figure 37-10], foam rolls, stability ball)
- Multidirectional plyometric drills to include forward-backward and side-to-side hopping (both with and without outside resistance)
- Walk-jog progression
- Resisted forward and backward running activities

Milestones for Progression to Advanced Sport-Specific Training and Conditioning

- Running without symptoms
- Jumping and multidirectional movements without symptoms
- No functional limitations

Criteria for Abandoning Nonoperative Treatment and Proceeding to Surgery or More Intensive Intervention

- Non-healing fracture with increased pain with weight-bearing activities

Performance Enhancement and Beyond Rehabilitation: Training/Trainer and Optimization of Athletic Performance

- Maintaining proper flexibility and strength of the lower extremities for symmetrical gait and performance of functional activities
- Integration of sport-specific training/activities into training program to move from the rehabilitation stage to returning to sport performance level[2]
- Rehabilitation should also include practice/training on multiple surfaces most similar to the athlete's specific practice and competition environment. For example, to return to athletic competition in a sport such as skiing, one should begin with training on flat to moderate terrain and progress to more demanding environments.
- Training should not only focus on strict return to athletic activity, but should also include days of sport-specific drills and rest/work training practice cycles to build up to competition demands.

Specific Criteria for Return to Sports Participation: Tests and Measurements

- Full lower extremity strength and flexibility
- Symptom free during ambulation, running and functional activities

Evidence

Kokmeyer D, Wahoff M, Mymern M: Suggestions from the field for return-to-sport rehabilitation following anterior cruciate ligament reconstruction: Alpine skiing. *J Orthop Sports Phys Ther* 42(4):313–320, 2012.

This article while focusing on rehabilitation after ACL reconstruction, shows how the focus in functional rehabilitation is different when returning an individual to a sport such as skiing, compared with those who play a court or field sport. This article shows that rehabilitation focuses on closed kinetic chain training, eccentric loading, proprioception, and endurance training. (Level V evidence)

Macri F, et al: Validation of a standardized gait score to predict the healing of tibial fractures. *J Bone Joint Surg Br* 94-B:544–548, 2012.

This article showed a correlation of fracture healing when using patient subjective reports of pain with weight-bearing and gait analysis. This information can be beneficial for the understanding of fracture healing and the progression of weight bearing activities during the rehabilitation process. (Level II evidence)

Mueller MJ, Maluf KS: Tissue adaptation to physical stress: a proposed "Physical Stress Theory" to guide physical therapist practice, education, and research. *Phys Ther* 82:383–403, 2002.

This article offers an understanding of the "Physical Stress Theory" and how physical therapists can use this theory for the evaluation, examination, and treatment of patients to positively affect involved tissues and prevent further injuries in the future. The principles in this theory can assist physical therapists in the guided recovering of an individual during the rehab process, while assisting with prevention of future injuries. (Level V evidence)

Turner CH: Three rules for bone adaptation to mechanical stimuli. *Bone* 23(5):399–407, 1998.

This article creates a background of the fundamental principles that help to understand bone adaptation. By understanding how bone develops and adapts to certain stresses and stimuli, this could show possible benefits in early weight-bearing activities for stimulating bone development and healing. (Level IV evidence)

Turner CH, Robling AG: Designing exercise regimens to increase bone strength. *Exerc Sport Sci Rev* 31(1):45–50, 2003.

This article discusses how exercise and an effect on strengthening bones, which can show the benefit of an individual attending rehabilitation services following a fracture. (Level V evidence)

Turner CH, Robling AG: Exercise as an anabolic stimulus for bone. *Curr Pharmaceut Des* 10:2629–2641, 2004.

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Turner CH, Robling AG: Exercises for improving bone strength. *Br J Sport Med* 39:188–189, 2005.

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REFERENCES

1. Turner CH: Three rules for bone adaptation to mechanical stimuli. *Bone* 23(5):399–407, 1998.
2. Kokmeyer D, Wahoff M, Mymern M: Suggestions from the field for return-to-sport rehabilitation following anterior cruciate ligament reconstruction: Alpine skiing. *J Orthop Sports Phys Ther* 42(4):313–320, 2012.

Multiple Choice Questions

QUESTION 1. What type of strengthening should first be introduced following the period of immobilization?

A. Isotonic
B. Isometric
C. Isokinetic
D. Plyometric

QUESTION 2. What criteria should be met for the athlete to return to sports?

A. Full Lower extremity range of motion
B. Full strength
C. Normalized gait
D. All of the above

QUESTION 3. What are some of the benefits of performing AROM of the ankle following a period of immobilization?

A. Improving ankle range of motion
B. Strengthening ankle musculature
C. Decreasing swelling
D. A and C
E. All of the above

QUESTION 4. What is one way to determine healing status without the use of an x-ray?

A. Evaluation of one's gait pattern
B. Strength of involved musculature
C. Normal joint range of motion
D. None of the above

QUESTION 5. Ways to challenge one's proprioceptive control during single leg stance activities would include which of the following?

A. Adding uneven/unsteady surfaces
B. Increasing the number of repetitions and sets
C. Increasing amount of movement and speed of opposite upper and lower extremity resisted movements
D. Having the individual close their eyes
E. All of the above

Answer Key

QUESTION 1. Correct answer: **B** (see Phase I)

QUESTION 2. Correct answer: **D** (see Phase III)

QUESTION 3. Correct answer: **D** (see Phase II)

QUESTION 4. Correct answer: **A** (see Phase II)

QUESTION 5. Correct answer: **E** (see Phases II and III)

POSTOPERATIVE REHABILITATION AFTER TIBIAL SHAFT FRACTURE

Katelyn H. McCormick, DPT, LT, MSC, USN, Robert S. Eberly, MD, LCDR, MC, USN, and Lance E. LeClere, MD, LCDR, MC, USN

Indications for Surgical Treatment

- Open fractures
- Neurovascular injury
- Failure to achieve acceptable closed reduction or maintain alignment in cast/brace
- Patient preference
- Tibial fracture with intact fibula
- Extensive bone loss
- Polytrauma
- Desire for early weight bearing

Brief Summary of Surgical Treatment

The goal of surgical treatment is to re-establish acceptable length and alignment in the anteroposterior and lateral planes. Surgical treatment offers the benefit of lower incidence of malalignment, lower nonunion rate, and earlier weight bearing.[1] That being said, surgical management is not free from potential complications. Timing of surgical intervention, a well thought out surgical plan, and respect for the soft tissues all play a role in successful surgical management. It is often said that all fractures are soft tissue injuries with an underlying fracture. Nowhere is this truer than in the leg, where the soft tissue overlying the tibia is minimal and subject to injury from the underlying bony fragments as well as the potential for thermal injury from reaming for intramedullary nailing.

Major Surgical Steps

- Placement of tourniquet as high on the leg as possible and sterile preparation of entire leg with operative leg draped free.
- Place guidewire over the skin and align with the anatomical axis and in-line with the lateral tibial spine. Mark this line to visualize axis throughout case without repeated fluoroscopy images.
- Cut the skin from the inferior pole of the patella to the tibial plateau. Dissect down to patellar tendon and incise and elevate the paratenon off of the tendon medially and laterally to define the borders of the tendon.
- Incise patellar tendon full thickness in-line with the fibers. Bluntly dissect fat pad with your finger down to the tibial plateau.
- Maximally flex the knee and align the guidewire with the anatomical axis. Check your anteroposterior alignment with fluoroscopy. With guidewire in place check your start point on a lateral image of the knee. Ideal start point is parallel with the anterior tibial cortex and on the superior aspect of the flat spot of the articular margin. Angle your hand so that the trajectory of the guidewire will not contact the posterior cortex with a steep angle for an intramedullary trajectory.
- Advance the guidewire 8 to 10 cm into the metaphysis. Confirm position and trajectory on anteroposterior and lateral images. The guidewire should be parallel with the anterior cortex and just medial to the lateral tibial spine. Avoid a posteriorly directed vector.
- Introduce starting reamer with a tissue sleeve to protect the patellar tendon. When reaming your starting hole, if the knee is not hyperflexed your hole will be enlarged anteriorly and will violate the anterior cortical bone. Attention must be paid to keep the knee hyperflexed and to apply a posteriorly directed force to the tissue sleeve.
- Throughout the case reamers will be introduced and removed and it is imperative to retract the skin and not run the reamer in the soft tissue to limit soft tissue injury.
- Bend the guidewire about 15° about 2 cm proximal to the ball tip. If the bend if the guidewire is lined up with

the axis of the t-handle chuck during loading, this can act as a reference for directing the ball tip past the fracture site and directing the wire in the distal tibia. This will allow precise adjustments in trajectory and decrease the number of fluoroscopic images required for determining trajectory.
- Once the starting point has been opened, placement of the knee on a triangle large enough to elevate the foot off the table will extend the knee and assist with reduction.
- Reduce the fracture with manual traction and gross manipulation. Alternately, placement of a universal distractor medially can assist with reduction if there is limited assistance. If using a universal distractor, carefully plan out placement of pins so that they do not interfere with nail placement. Additionally the pins can serve a secondary role as blocking screws if well thought out.
- Additionally pointed reduction forceps, introduced through stab incision at the level of the fracture, can be used for reduction of short oblique fractures.
- Once the reduction is obtained and confirmed with fluoroscopy the guidewire can be passed across the fracture site. Confirm that the wire is intramedullary on anteroposterior and lateral images and advance to the distal tibial physeal scar. The tip of the guidewire should be centrally localized and impacted into subchondral bone to prevent a change in wire trajectory during sequential reaming.
- Measure nail length off of the guidewire. If nail length falls between available sizes use the shorter length to avoid nail prominence.
- Never ream with the fracture unreduced or malreduced. If reamed in a poorly reduced position the nail will only hold the fracture in the nonreduced position in which it was reamed.
- Before reaming estimate the narrowest canal diameter using both anteroposterior and lateral radiographs. Reaming is typically performed 1mm over the diameter of the isthmus to prevent nail incarceration.
- Begin reaming with an end-cutting reamer, usually an 8.5- or 9-mm reamer. Inspect reamer head to make sure threads are clear and sharp. This will reduce the amount of heat generated during reaming. When reaming, the head of the reamer should be past the cortical bone of the proximal tibia before turning on the reamer to avoid distortion of entrance hole.
- All reaming should be on full power, advanced slowly, and pistoned through areas of significant chatter to clear the cutting flutes.
- Care must be taken to not extract the guidewire when the reamer is removed. This is accomplished with back pressure from the wire pusher. Once the reamer has cleared the bone, a hemostat can be used to hold the guidewire in the canal.
- To reduce the thermal damage to bone, reaming should be stopped once reaming is 1 mm greater than the start of endosteal chatter.
- The nail size is selected based on diameter of reaming. Attach the insertion handle to the nail and check that the hole for the proximal interlocking screw is aligned with the handle.
- During insertion of the nail keep the handle aligned with the tibial crest. Keep the knee hyperflexed to prevent iatrogenic fracture of the posterior cortex.
- Once the nail is inserted, confirm depth with lateral fluoroscopy to ensure that nail is not proud in the joint
- In transverse fractures, the distal interlock screw can be inserted first and the nail back-slapped to improve inter-fragmentary compression and gap minimization. Distal interlock screws are placed from medial to lateral using the perfect circles technique. Using fluoroscopy, image the distal hole in the nail and rotate the c-arm and/or patient until the distal holes align and the radiolucent openings form a "perfect circle." Next localize the hole on the skin surface using the tip of a scalpel. When the scalpel tip is in the center of the perfect circle, incise the overlying skin. Bluntly spread down to bone. Next localize the tip of the drill to the center of the distal nail hole while contacting bone. Once the drill tip is in the center of the circle, raise the drill to a position that is collinear with the radiation beam and drill through cortex and nail. Confirm that the drill bit is in the center of the hole and bicortical with orthogonal imaging.
- Measure the depth of your screw with a depth gauge and insert the proper length of screw.
- Proximal interlocking screw can be inserted with the aid of the inserter handle and requires imaging only to confirm the appropriate length of the screw.
- Close peripatellar incision in layers with distinction between patellar tendon and paratenon. Close skin with staples or suture.

Factors That May Affect Rehabilitation

Anesthetic

- If using peripheral nerve block in conjunction with general anesthesia, close attention must be paid to postoperative exams to ensure a compartment syndrome does not go undiagnosed.
- If femoral nerve block is used postoperatively protect patient during weight bearing with a knee immobilizer to prevent falls secondary to quadriceps weakness.

Surgical

- Meticulous surgical dissection with clear delineation of the paratenon from the patellar tendon with separate closures of both layers will help reduce postoperative adhesions.
- Surgical approach (parapatellar vs. tendon splitting) to the starting point does not appear to affect the incidence of anterior knee pain which has been found to be as high as 67% in some studies.[2]

Other Surgical Techniques and Options

- Proximal and distal tibia fractures may be better treated with open reduction and internal fixation with plates and screws.

- Use of proximal dynamic interlock screws to allow for interfragmentary compression with weight-bearing in simple transverse fracture. Do not use in length unstable fractures.

GUIDING PRINCIPLES OF POSTOPERATIVE REHABILITATION

- Early weight bearing as tolerated by patient and dictated by fracture characteristics
- Emphasis on knee range of motion to prevent stiffness and limit scar tissue formation
- Ankle flexion and extension to preserve range of motion and increase venous return

Phase I (days 0 to 14):[1] Immediate Postoperative Period

Clinical Pearl

Early weight bearing as tolerated is recommended following surgical intervention of tibia shaft fractures to assist with bone healing per Wolff's law.[3]

Goals

- Decrease pain and inflammation
- Initiate early range of motion of the ankle and knee
- Initiate early weight bearing

Protection

- Crutches used initially following after surgery, but progressed to weight bearing as tolerated without crutches within 2 to 3 weeks.

Management of Pain and Swelling

- Oral pain medications
- Cryotherapy to reduce pain and inflammation.

[1]Prehabilitation, if appropriate, is described in the Nonoperative Rehabilitation section of this chapter.



FIGURE 37-11. Mobilization.

- Therapeutic modalities such as TENS and IFC e-stim
- Elevation of surgical limb
- Cryotherapy to reduce swelling

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Grades I, II, and III talocrural, subtalar, distal tibiofibular, mid-foot joint, and patellar mobilizations (Figure 37-11)

Soft Tissue Techniques

- Soft tissue mobilization or massage to the gastroc/soleus complex for increasing flexibility and ankle dorsiflexion range of motion

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Ankle circles (ABCs), ankle pumps, heel slides, long sitting gastroc/soleus stretching (Figure 37-12) and hamstring stretching

Other Therapeutic Exercises

- Total leg strength: Total lower extremity strengthening should be included as a part of the patient's program to include hip abduction, gluteus, quad and hamstring musculature.
  - Four-way straight leg raises, bridges, hamstring curls, and so on
- Core stability: Front and side planks

TIMELINE 37-2: **Postoperative Rehabilitation After Repair of Tibial Fracture**

PHASE I (postoperative weeks 0 to 2)	PHASE II (postoperative weeks 2 to 8)
• AROM/ AAROM/ PROM for full ankle/knee ROM • Manual talocrural joint mobilizations: Grade I/II → III/IV • Ankle isometrics • Early weight bearing: weight shifting • Gait with crutches: progressing to without • Ice	• AROM/ AAROM/ PROM for full ankle/knee ROM • Manual talocrural joint mobilizations: Grade I/II → III/IV • Ankle isometrics • Non–weight-bearing ankle strengthening (OKC with Thera-Band resistance) • Stationary bike • OKC strengthening for hip and knee • Lower extremity stretching • Gait training • Aquatic therapy (once surgical incision is healed) • Body weight squats, lunges • Leg press/shuttle • Single-leg stance/balance activities • Step ups/downs • Elliptical/StairClimber



FIGURE 37-12. Long-sitting gastroc/soleus stretching. **A,** Non–weight-bearing gastroc stretch (knee extended). **B,** Non–weight-bearing soleus stretch (knee flexed).

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Four-way ankle isometrics: dorsiflexion, plantarflexion, inversion, and eversion

Sensorimotor Exercises

- Front to back and side to side weight shifting to progress tolerance to weight bearing and for proper gait mechanics

Milestones for Progression to the Next Phase

- Able to perform Phase I exercises without pain or increase in swelling
- WBAT (weight bearing as tolerated) without increased swelling to the involved area

Phase II (postoperative weeks 2 to 8)

Goals

- Protection of repaired structures
- Decrease pain and inflammation
- Restore full ROM of the ankle and knee
- Discontinue use of crutches
- Full weight-bearing status
- Restore lower extremity strength

Protection

- Patient to continue use of crutches or straight cane if demonstrates an antalgic gait pattern

Management of Pain and Swelling

- As for Phase I

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Grades I, II, III, and progression to IV as tolerated by patient to the talocrural, subtalar, distal tibiofibular, mid-foot joint, and patellar mobilizations

Soft Tissue Techniques

- Soft tissue mobilization to the gastroc/soleus and hamstring musculature
- Scar mobilizations to surgical incision

TIMELINE 37-2 Postoperative Rehabilitation After Repair of Tibial Fracture (Continued)

PHASE III (postoperative weeks 8 to 16)	Postoperative weeks 16+
• Progression of walk-jog progression • Plyometrics • Running/sprints • Agility and sport-specific drills (week 10)	• Continue with functional lower extremity strengthening and progression to specific sport-related activities • Return to sport

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Patient should be introduced to stretching to the gastrocnemius and soleus muscle groups if patient has limitations in dorsiflexion range of motion. Stretching should be continued until normal and symmetric dorsiflexion ROM is achieved bilaterally. Low load long duration stretching includes stretching that takes place multiple times per day (two to three times), for longer hold periods (30 to 60 seconds), and increased repetitions per set (5 to 10 repetitions). Active Stretching is to be continued once normal ROM is achieved (20- to 30-second hold, two to three sets, one to two times per day).
- Stretching can be progressed from long sitting to standing as tolerated

Other Therapeutic Exercises

- Stationary bike for ankle/knee ROM and low impact cardio
- TLS and core stability strengthening same as Phase I with progression to aquatic-based cardio and strengthening once surgical incisions have healed
- Elliptical and StairClimber for cardio

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Resistance band exercises: DF, PF, INV, and EV (Figure 37-13)
- Four-way ankle isometrics
- Progression of seated heel raises to double leg standing heel raises, then single leg

Open and Closed Kinetic Chain Exercises

- Open kinetic chain exercises: To include: intrinsic foot muscle strengthening exercises: towel/toe curls (Figure 37-14) exercises and marble pickups (Figure 37-15). Four-way resisted Thera-Band exercises (inversion, eversion, dorsiflexion, and plantarflexion).
- Closed kinetic chain exercises: Progression of weight-bearing activities without an increase of pain to include: double leg bridging, progressing to single leg bridging; squatting activities with multiple foot positions and bases of support, multi directional lunges, deadlifts, progression of weight for both double and single leg shuttle/leg press.

Neuromuscular Dynamic Stability Exercises

- Seated BAPS board, progress to standing (Figure 37-16)
- Single leg balance activities progression from a firm surface to soft/uneven surfaces

Functional Exercises

- Beginning of functional exercises as increased weight bearing is tolerated such as squats, lunges (anterior/posterior/lateral), step ups/downs



FIGURE 37-13. Resistance band exercises. **A,** Resisted plantarflexion. **B,** Resisted dorsiflexion. **C,** Resisted inversion. **D,** Resisted eversion.



FIGURE 37-14. A,B, Towel/toe curls.



FIGURE 37-15. Marble pickups.



FIGURE 37-16. Seated BAPS board.

Milestones for Progression to the Next Phase

- Phase II exercises performed without pain or swelling
- Ambulates without assistance device
- Symmetrical lower extremity ROM: to include ankle DF, knee flexion/extension, measured in open and closed kinetic chain
- Lower extremity strength 5/5 (symmetrical bilaterally)
- Normal and pain free gait
- Imaging shows good bone healing

Phase III (postoperative weeks 8 to 16)

Goals

- Continue to improve functional strength
- Progression back to functional activities

Management of Pain and Swelling

- Pain management as for Phase I
- Cryotherapy as needed for swelling

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Grades 2 to 4 to the talocrural, subtalar, distal tibiofibular, mid-foot joint, and patellar mobilizations as needed

Soft Tissue Techniques

- Soft tissue mobilization to the gastroc/soleus and hamstring musculature
- Scar mobilizations to surgical incision as needed

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Patient should be introduced to stretching to the gastrocnemius and soleus muscle groups if patient has limitations in dorsiflexion range of motion. Stretching should be continued until normal and symmetrical dorsiflexion ROM is achieved bilaterally. Low load long duration stretching includes stretching that takes place multiple times per day (two to three times), for longer hold periods (30 to 60 seconds), and increased repetitions per set (5 to 10 repetitions). Active stretching is to be continued once normal ROM is achieved (20 to 30 second hold, two to three sets, one to two times per day).
- Stretching progressed standing as tolerated

Other Therapeutic Exercises

- TLS and core stability strengthening same as Phase II
- Aquatic based therapy: swimming, water jogging
- Elliptical and StairClimber for cardio training

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Resistance band exercises: DF, PF, INV, and EV
- Four-way ankle isometrics
- Progression of seated heel raises to double leg standing heel raises, then single leg (Figure 37-17)

Open and Closed Kinetic Chain Exercises

- Open kinetic chain exercises: To include: intrinsic foot muscle strengthening exercises: towel/toe curls exercises and marble pickups. Four-way resisted Thera-Band exercises (inversion, eversion, dorsiflexion, plantarflexion).
- Closed kinetic chain exercises: Progression of weight-bearing activities without an increase of pain to include: double leg bridging, progressing to single leg bridging; squatting activities with multiple foot positions and bases of support, multi-directional lunges, deadlifts, progression of weight for both double and single leg shuttle/leg press.

Neuromuscular Dynamic Stability Exercises

- Single leg balance activities progression from a firm surface to soft/uneven surfaces, BOSU ball balance, and weight shifting, ball toss with SL balance, star drill
- Resisted side/posterior/anterior stepping (flat foot and on toes)

Plyometrics

- Progression of plyometrics beginning with partial weight-bearing hops and jumping, starting on Shuttle Systems or in a pool. Once partial weight-bearing plyometrics, the athlete can progress to full weight-bearing activities to include double leg hops moving toward single leg hops, and box jumps. Box jumps and bounding exercise may be performed to train for control impact and landing for proper shock absorption and explosive moments.

Sport-Specific and Functional Exercises

- Multidirectional movements to both stable and unstable surfaces: lunges, squats (on BOSU, foam rolls, stability ball)
- Multidirectional plyometric drills to include forward-backward, side-to-side hopping (both with and without outside resistance)
- Ladder drills



FIGURE 37-17. A, Standing double-leg heel raises. **B,** Standing single-leg heel raises.

- Walk-jog progression
- Resisted forward and backward running activities

Milestones for Progression to the Next Phase

- Phase III exercises performed without pain or swelling
- Symmetrical lower extremity ROM: to include ankle, knee flexion/extension, measured in open and closed kinetic chain
- Lower extremity strength 5/5 (symmetrical bilaterally)
- Symmetrical unilateral stance
- Repeat imaging continues to show good bone healing

Outcome Measure

- Foot and ankle disability index (FADI)
- Foot and ankle disability index sport,
- Lower extremity functional scale (LEFS)

Milestones/Criterion-Based Rehabilitation Guidelines for Progression to Discharge

- Performance of Phase III activities without pain or swelling
- Performance of agility and sport specific drills without pain or movement asymmetry
- Hop testing: Involved limb within 85% the distance of the noninvolved limb
- Running gait without asymmetry

Criteria for Return to Sport

- Athletes should be pain free and demonstrate symmetrical ROM and strength
- Symmetry of gait with running, cutting, and pivoting movements
- Symmetry of LE jumping (unloading) and landing (loading)
- Hop tests:
  - Single hop for distance
  - Crossover
  - Triple hop for distance
  - Vertical jump

Evidence

Bone LB, et al: Displaced isolated fractures of the tibial shaft treated with either cast or intramedullary nailing. *JBJS* 79-A(9):1336–1341, 1997.

This article evaluates the functional results of cast treatment in comparison with intramedullary nailing in closed tibial shaft fractures. This study showed that patients managed operatively with nails had better functional outcomes to include preserved alignment and length with a decrease in non-unions. (Level IV evidence)

Kokmeyer D, Wahoff M, Mymern M: Suggesting from the field for return-to-sport rehabilitation following anterior cruciate ligament reconstruction: Alpine skiing. *J Orthop Sports Phys Ther* 42(4):313–320, 2012.

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This article shows a correlation of fracture healing when using patient subjective reports of pain with weight-bearing and gait analysis. This information can be beneficial for the understanding of fracture healing and the progression of weight-bearing activities during the rehabilitation process. (Level II evidence)

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This article offers an understanding of the "Physical Stress Theory" and how physical therapists can use this theory for the evaluation, examination, and treatment of patients to positively affect involved tissues and prevent further injuries in the future. The principles in this theory can assist physical therapists in the guided recovery of an individual during the rehabilitation process, while assisting with prevention of future injuries. (Level V evidence)

Toivanen JA, Vaisto O, Kannus P, et al: Anterior knee pain after intramedullary nailing of fractures of the tibial shaft. A prospective, randomized study comparing two different nail-insertion techniques. *J Bone Joint Surg Am* 84-A:580–585, 2002.

The authors randomized patients with tibia shaft fractures undergoing intramedullary nailing to treatment with paratendinous or transtendinous nail insertion. They found no significant differences in regard to the rate of anterior knee pain, patient-specific outcome scores, strength, or functional testing between the two groups. (Level I evidence)

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2. Toivanen JA, Vaisto O, Kannus P, et al: Anterior knee pain after intramedullary nailing of fractures of the tibial shaft. A prospective, randomized study comparing two different nail-insertion techniques. *J Bone Joint Surg Am* 84-A:580–585, 2002.
3. Turner CH: Three rules for boned adaptation to mechanical stimuli. *Bone* 23(5):399–407, 1998.

Multiple Choice Questions

QUESTION 1. Reaming of the tibia should continue until:

A. First evidence of endosteal chatter
B. 1 mm beyond first evidence of chatter
C. 2 mm beyond first evidence of chatter
D. You can get the largest nail available down the canal

QUESTION 2. Which factors will influence the success of surgical management?

A. Surgical timing with consideration of overlying soft tissue injury
B. Adequacy of reduction before reaming
C. Limiting soft tissue injury at start point
D. All of the above

QUESTION 3. Which of the following is *not* an acceptable technique for reduction?

A. Pointed reduction clamps through stab incisions at fracture site
B. Manual traction and manipulation
C. Reaming through fracture and using the nail to attain reduction
D. Universal distractor with proximal and distal pins

QUESTION 4. Anterior knee pain is associated with which surgical approach?

A. Infrapatellar split
B. Superior transpatellar
C. Lateral peripatellar approach
D. All surgical approaches

QUESTION 5. When is WBAT allowed after surgical intervention?

A. Immediately
B. Week 2
C. Week 4
D. Week 6

QUESTION 6. Which of the following would be used to improve range of motion limitations?

A. Stretching (seated or standing)
B. Joint mobilizations
C. Soft tissue/scar tissue mobilizations
D. All of the above

QUESTION 7. Which of the following is a component of active stretching?

A. Performed until normal and symmetrical DF range of motion is achieved
B. Continued even once normal range of motion is achieved
C. Hold periods are longer (30 to 60 seconds)
D. Increased repetitions per set (5 to 10 repetitions)

QUESTION 8. Which of the following is an example of beginning to initiate plyometrics into an individual's treatment program?

A. Partial weight bearing on shuttle system
B. Partial weight bearing in pool
C. Starting with double leg activities
D. All of the above
E. None of the above

QUESTION 9. When is agility and sport-specific training begun?

A. Week 8
B. Week 10
C. Week 12
D. Week 14

Answer Key

QUESTION 1. Correct answer: **B** (see Surgical Steps)

QUESTION 2. Correct answer: **D** (see Surgical Steps)

QUESTION 3. Correct answer: **C** (see Surgical Steps)

QUESTION 4. Correct answer: **D** (see Surgical Steps)

QUESTION 5. Correct answer: **A** (see Phase I)

QUESTION 6. Correct answer: **D** (see Phase II)

QUESTION 7. Correct answer: **B** (see Phase II)

QUESTION 8. Correct answer: **D** (see Phase III)

QUESTION 9. Correct answer: **B** (see Phase III)

BEYOND BASIC REHABILITATION: RETURN TO SKIING AFTER TREATMENT OF TIBIAL SHAFT FRACTURE

Katelyn McCormick, DPT, LT, MSC, USN

Introduction

ASPECTS OF SKIING THAT REQUIRE SPECIAL ATTENTION IN REHABILITATION

- Eccentric-loading
- Closed chain
- Acceleration/deceleration movements

- Tibial shaft fractures are a risk with downhill skiing; however, more common injuries include knee sprains and upper extremity injuries.[1]
- Based on past studies, the likelihood of tibial fractures is greater in individuals wearing binding-release valves.[2]
- Factors in tibial fractures include rotational forces, direct collision, and the binding of the ski boot not opening properly.[3]
- For athletes to return to the sport of downhill skiing following a tibial shaft fracture, extensive rehabilitation is recommended to improve full range of motion, flexibility, muscle strength, dynamic stability, and eccentric control.[4]

Literature

- There is limited research discussing the return to skiing following tibial fractures. However, advanced rehabilitation for sport-specific training can begin approximately 8 to 12 weeks post surgery or once the individual is pain free with weight-bearing activities, normal gait, full ankle and knee range of motion, and strength 85% of the opposite lower extremity. Strength testing can be measured through manual muscle testing and/or the use of a hand-held dynamometer.

Phase I: Advanced Strength and Conditioning Programs

Periodization

- Mesocycle: weeks 1 to 4

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- Training continuum
- Flexibility/joint mobility for joint stability
- Cardiorespiratory training
- Training for optimum muscle functional strength

Training Principles Used in the Design of the Program

- Principle of progression
- Principle of overload

Application of Acute Training Variables

- During Phase I and early in Phase II of rehabilitation, the main focus is on regaining full range of motion and mobility and strength of the involved joints/segments.
- The acute training variables include choosing certain exercises to progress ROM and strength and determining the order of their effectiveness, the amount of resistance or load, number of repetitions and sets, speed of the exercise and rest breaks.
- There will also be a progression from individual-segment range of motion and strengthening (isometrics, isotonic, concentric and eccentric) exercises to multisegment activities.
- Exercises used in the training include:
  - Four-way hip exercises, straight leg raises beginning weeks 1 to 3 (during initial period of non– or partial weight bearing)
  - Ankle isometrics: seated ankle dorsiflexion and plantarflexion, foot intrinsic strengthening (beginning immediately)
  - Resisted ankle strengthening (beginning weeks 2 to 3)
  - Stationary bike (beginning week 2)
  - Pool therapy:
    - Walking beginning weeks 2 to 3 or once closure and healing of surgical incision is noted
    - Double-leg (DL) heel raises, progressing to single-leg (SL) heel raises starting initially in chest-deep water
    - Pain-free weight shifting/gait training initially with crutches and/or boot approximately weeks 3 to 4
- Specifics:
  - Repetitions: 10 to 15
  - Sets: 2 to 4
  - Intensity: low
  - Training frequency: 2 to 4 days per week, allowing at least 24 hours recovery time between training sessions
  - Training duration: 30 to 60 minutes

Application of Chronic Training Variables

- Chronic training variables include aerobic capacity, anaerobic capacity, flexibility, strength, power, and speed.
- During Phase I in the period of restricted weightbearing, the individual can maintain some cardiovascular

training with the use of the upper body ergometer as early as week 1 and can begin aquatic-based suspended walking and jogging as soon as the surgical incisions are healed.

Phase II: Performance Enhancement Training Techniques

Periodization

- Mesocycle: Weeks 4 to 12

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- Training continuum
- Flexibility/joint mobility for joint stability
- Sensorimotor and balance training
- Multi-planar training activities
- Training for optimum muscle functional strength and power

Training Principles Used in the Design of the Program

- Progression
- Overload
- Variation
- Principles of specificity

Application of Acute Training Variables

- In Phase II closed chain exercise and functional strengthening are progressed as weight bearing is increasingly tolerated.
- Focus continues to be on achieving full/normalized mobility of involved segments and increasing strength, but also increasing intensity of activities.
- Progression of the number of repetitions and work : rest ratio should also be increased.
- Specific exercises used in training:
  - Continuation of activities from Phase I
  - Aquatic-based therapy for full progression of weight bearing and initial strengthening with less loading
  - Progressive weight-bearing strengthening to begin with double leg/single leg shuttle/leg press
  - Progression of closed chain strengthening to include double leg/single leg heel raises, body weight squats, static and then to multidirectional lunges (Figure 37-18*A*-C). (Progression of these activities can include varying depths of increased knee flexion.)
  - Initiating single leg balance activities: Progression from static to dynamic balance activities (SL on foam surface [Figure 37-19], to ½ foam roll, to more dynamic activities with upper extremity and opposite lower extremity movements).
- Specifics:
  - Repetitions: 8 to 12 repetitions per set
  - Sets: 3 to 5
  - Rest interval: At least 1 minute between sets
  - Intensity: Moderate, working to 85% of full strength by end of phase II
  - Training frequency: Three to four times per week (with at least 24 hours between training sessions)
  - Training duration: 30 to 60 minutes

Application of Chronic Training Variables

- Variables to be considered for chronic training include aerobic and anaerobic capacity/training, strength, speed, flexibility, power, and agility.
- The strength and flexibility of both the involved and uninvolved joint segments should be continually addressed while progressing with speed, power, and agility over time.
- Cardiorespiratory training also needs to continually be addressed, although the individual may not be at his or her normal level of physical training.
- Cardiorespiratory training
  - Aquatic-based exercise to include walking and jogging in variable water depths
  - Stationary cycling: Varying duration and resistance
  - Elliptical trainer
  - Rowing machine
  - Gait training: Using treadmill walking with progression from flat to inclined surfaces

TIMELINE 37-3: **Return to Skiing After Treatment of Tibial Shaft Fracture**

PHASE I (weeks 1 to 3)*	PHASE II (weeks 4 to 8)
• A/AA/PROM of the ankle/knee • Grade 1 and 2 TC joint mobilizations progressing to Grade 3 to 4 • Ankle isometrics • Lower extremity stretching (gastroc/soleus/hamstrings) • OKC hip/knee strengthening • Stationary bike • Progressive ankle resisted strengthening with Thera-Band • Progressive weight bearing • Gait training	• AROM/ AAROM/ PROM for full ankle/knee ROM • Manual talocrural joint mobilizations: Grade I/II → III/IV • Ankle isometrics • Non–weight-bearing ankle strengthening (OKC with Thera-Band resistance) • Stationary bike • OKC strengthening for hip and knee • Lower extremity stretching • Gait training • Aquatic therapy (once surgical incision is healed if treated operatively) • Body weight strengthening: squats, lunges • Leg press/shuttle • Single leg stance/balance activities • Step ups/downs • Elliptical/StairClimber

*Mild variation in treatment timeline depending on surgical fixation versus nonoperatively managed.

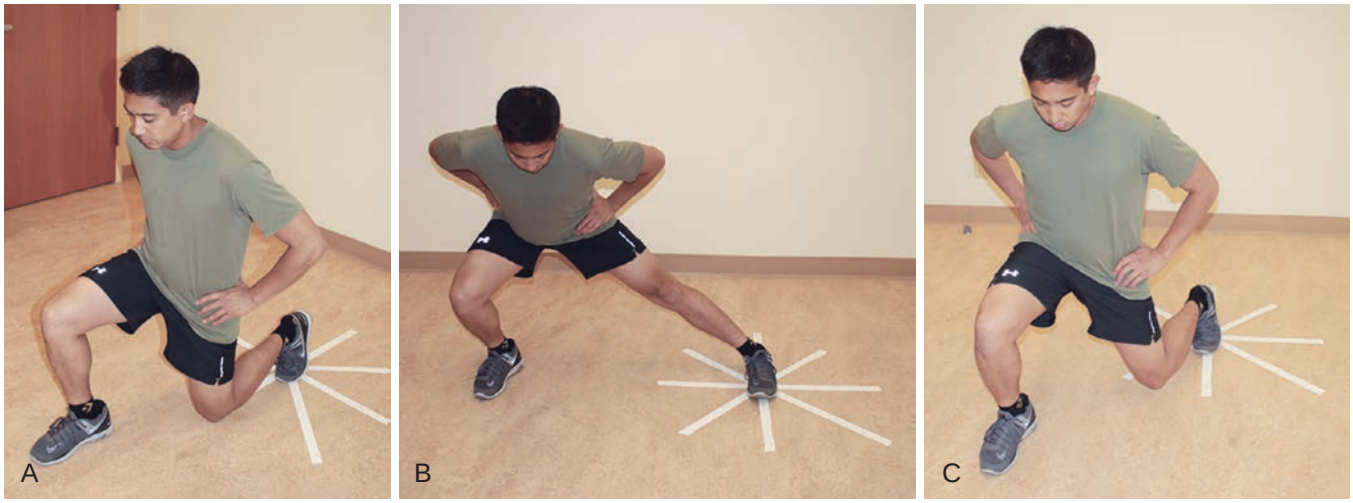

FIGURE 37-18. Multidirectional lunges. **A,** Anterior lunge. **B,** Lateral lunge. **C,** Diagonal lunge.



FIGURE 37-19. Single-leg balancing on a foam surface.

Phase III: Sport-Specific Training

Periodization

- Mesocycles: Weeks 12 to 36

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- Training continuum
- Multiplanar training activities
- Training for increasing functional strength and power
- Neuromuscular dynamic stability exercises
- Plyometric training
- Functional training

TIMELINE 37.3 **Return to Skiing After Treatment of Tibial Shaft Fracture** (Continued)

PHASE III (weeks 8 to 12)	PHASE IV (weeks 12 to 36)
• Continued closed kinetic chain lower extremity strengthening and single leg proprioceptive training • Progression of walk-jog program • Plyometrics: starting with partial weight bearing such as in pool or on shuttle system and progressing to full weight bearing • Functional testing	• Multi-planar training activities • Progression of plyometric training • Neuromuscular dynamic stability exercises • Eccentric CKC training • Sport-specific drills • Outcome testing and assessment

Training Principles Used in the Design of the Program

- Principle of progression
- Principle of overload
- Principle of variation
- Principle of individualization
- Principle of specificity: Specific adaptation to imposed demands (SAID)

Application of Acute Training Variables

- During this phase of rehabilitation, much of the focus is on dynamic functional activities that are symmetrical bilaterally.
- There should be an increase in the number of repetitions, sets, speed, range of movement, different types of contraction, and decreasing rest periods.
- There will also be a progression of plyometric activities. Progression of plyometrics include type of activity, intensity, and specifics to sport-related training (such as eccentric phase of plyometric exercises).[4] Plyometric activities should not exceed three times per week, allowing for approximately 48 hours rest between training sessions.
- Specifics:
  - Repetitions: Plyometrics 30 to 140 contacts per session
  - Sets: 3 to 5
  - Rest interval: work-to-rest ratio of 1:5 to 1:10 for plyometrics
  - Intensity: Moderate to high
  - Training frequency: One to three times per week (no consecutive days)
  - Training duration: 30 to 90 minutes
  - Strengthening: Front squats, lunges, step ups, jump squats, eccentric training
- Neuromuscular stabilization and plyometrics: focus on single and double leg eccentric loading: DL/SL squat holds, then progressing to uneven surfaces such as half foam rolls/BOSU (Figure 37-20*A,B*) and adding sport cord resistance and outside source perturbations
  - Phase I Plyometrics: Two-foot ankle hops, double-leg squat jumps, double-leg jumps over obstacle (forward and lateral)
  - Phase II Plyometrics: Single-leg hops (vertical, forward and backward, side to side)
  - Phase III Plyometrics: Box or BOSU jumps (Figure 37-21*A*-*C*) (double- and single-leg): jump up, progress to jump down, forward/lateral jumps, increasing heights
- Specific exercises used in training:[5]
  - Progression of skiing initially on flat groomed surfaces, progressing to more challenging terrain

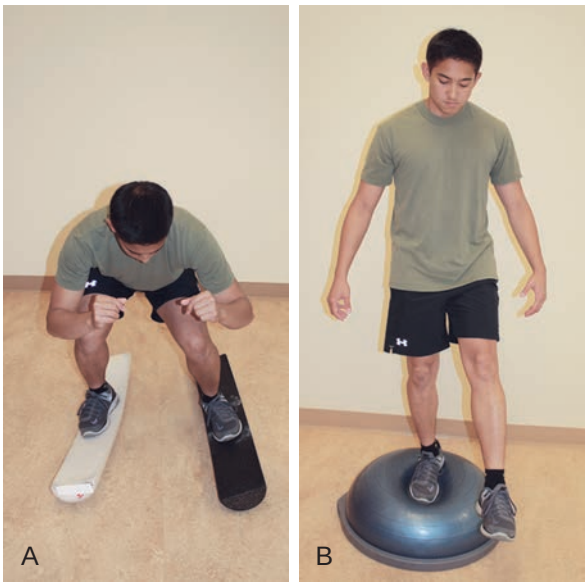

FIGURE 37-20. Single- and double-leg eccentric loading on uneven surfaces such as (**A**) half foam rolls and (**B**) BOSU ball.

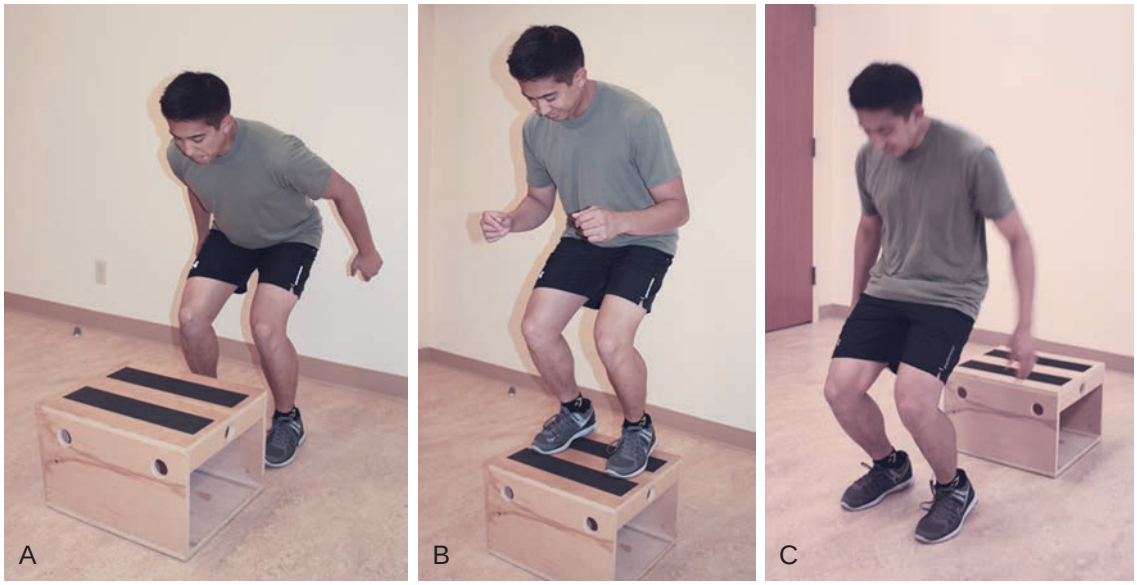

FIGURE 37-21. A-C, Box jumps (double and single leg). Jump up, progress to jump down, forward/lateral jumps, increasing heights.

- Side slipping: smooth and distinctive stops
- Progression of turns: neutral stance, squat position, single leg, turns with hops

Application of Chronic Training Variables

- Chronic training variables are focused throughout the final training phase by making sure there is a normalization of strength, endurance, speed flexibility, power, and agility when comparing the involved with the uninvolved side.
- The focus is on making sure movement patterns are being performed in correct form, without compensatory mechanisms, which could lead to other injuries and lack of full recovery.
- Specific training focused on an individual component should be performed on alternating days, but training sessions should include periods of utilizing multiple chronic training variables for full return to specific sport.

Sports Performance Testing

General Information

- General history: Training background, future occupational and sport demands/goals
- Medical history: General health, other health conditions, medications, systemic diseases, previous injuries (sport or non–sport related)
- Surgical History: Lower extremities, spine, and so on.
- Outcome surveys: Lower Extremity Functional Scale, Foot and Ankle Outcome Scale and Foot and Ankle Ability Measure (FAAM; depending on location of tibia fracture)
- Sports injury history: Current injury history to include other injuries to the lower extremity or spine, mechanism of injury, when it occurred

Specific Criteria for Progression to the Next Stage to Determine Readiness for Skiing

- Progression from one phase to the next is determined by one's performance, including adequate range of motion, strength, and functional activity assessment such as gait mechanics, not on time alone.
  - Functional testing can be assessed by evaluating activities such as double/single squatting, hop testing, and gait and running mechanics.
- For example, progression to Phase II begins when the individual is full weight bearing and full range of motion of the ankle.
- Progression to Phase III occurs with no pain with weight-bearing activities, full ankle ROM in both closed and open kinetic chain positions, full and symmetrical strength, and normal and pain-free gait.
- Objective tests
  - Dynamic muscle performance testing
    - Double and single leg squat holds assessing the hold time for endurance while maintaining proper knee varus and valgus alignment starting at 2 to 3 months.
  - Movement performance testing:
    - Ankle ROM to include closed kinetic chain assessment of DF beginning at 2 to 3 months
    - Functional movement screening: First assessment at approximately 2 to 3 months. Waiting to perform this screen allows time for regaining full ankle range of motion and restoring lower extremity strength, to limit the number of factors that would be contributing to the deficits in their results.
  - Sport-specific testing (balance and stabilization testing) starting at 3 months. The individual should have full range of motion and 5/5 strength, along with a minimum of 85% side to side symmetry for returning to full participation in sports.
    - Static stand
    - Single leg squat
    - Single leg hop for distance
    - Single leg hop down from 12-inch step
    - 6-meter timed hop for distance
    - Triple hop for distance
  - The difference between an athlete returning to skiing rather than a sport such as basketball is the need for closed kinetic chain control.
- Other tests
  - Isokinetic testing of ankle DF/PF and INV/EV if available
    - Involved limb should show a minimum of 85% side to side symmetry when compared with the uninvolved limb.

Specific Criteria for Release to Unsupervised Complete Participation in Skiing

- Before being released to participation in their specific sport, the individual should have normal and pain-free walking and running gait.
- The individual should also have at least 85% strength, which can be measured by manual muscle testing and/or use of a hand held dynamometer and functional assessment of the involved lower extremity compared with the noninvolved side. Strength testing would be an example of quantitative measure, along with results from functional testing such as distance achieved on single leg hop tests. However, the quality of the movement will also need to be evaluated and determined for the individual to return to his or her desired sport. The individual's movement pattern, point of fatigue, and substitutions are all qualitative ways at evaluating his or her movement pattern.
- The individual should show a minimum of 85% side to side symmetry on all testing before full return to sports.

Recommended Ongoing Exercises

- Even after the athlete has returned to the sport of skiing, neuromuscular stabilization training should continue, focusing on eccentric control with closed kinetic chain activities, multi-planar dynamic squats and lunges, along with sport specific training and drills.

Evidence

Berg HE, Eiken O: Muscle control in elite alpine skiing. *Med Sci Sports Exerc* 31:1065–1067, 1999.

This article was used to gain an understanding of the muscle control needed with different skiing events. Using this information allows for an understanding of the different stresses and activities an individual would need to perform to return to a specific skiing activity and assist with guiding the rehabilitation process. (Level IV evidence)

Burkner A, Simmen HP: Fractures of the lower extremity in skiing: The influence of ski boots and injury pattern. *Sportverletz Sportschaden* 22(4):207–212, 2008.

This article looked at what were some of the major causes of tibial fractures when participating in downhill skiing activities. (Level IV evidence)

Deibert MC, Aronsson DD, Johnson RJ, et al: Skiing injuries in children, adolescents and adults. *J Bone Joint Surg Am* 80:25–32, 1998.

This was a prospective study that was performed to gather information on skiing injuries, to include the age group that had the most injuries, the most common injuries, and what some of the causes of injury. (Level IV evidence)

Koehle MS, Lloyd-Smith R, Taunton JE: Alpine ski injuries and their prevention. *Sports Med* 32:785–793, 2002.

This article looks at some of the possible causes of lower limb injuries during skiing. By having a better understanding of how individuals get injured, it could allow for future prevention. (Level V evidence)

Kokmeyer D, Wahoff M, Mymern M: Suggestions from the field for return-to-sport rehabilitation following anterior cruciate ligament reconstruction: alpine skiing. *J Orthop Sports Phys Ther* 42:313–325, 2012.

This article while focusing on rehabilitation following ACL reconstruction, shows how the focus in functional rehabilitation is different when returning an individual to a sport such as skiing, compared with those who play a court or field sport. This article shows that rehabilitation focuses on closed kinetic chain training, eccentric loading, proprioception, and endurance training. (Level V evidence)

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1. Koehle MS, Lloyd-Smith R, Taunton JE: Alpine ski injuries and their prevention. *Sports Med* 32:785–793, 2002.
2. Deibert MC, Aronsson DD, Johnson RJ, et al: Skiing injuries in children, adolescents and adults. *J Bone Joint Surg Am* 80:25–32, 1998.
3. Burkner A, Simmen HP: Fractures of the lower extremity in skiing: The influence of ski boots and injury pattern. *Sportverletz Sportschaden* 22(4):207–212, 2008.
4. Berg HE, Eiken O: Muscle control in elite alpine skiing. *Med Sci Sports Exerc* 31:1065–1067, 1999.
5. Kokmeyer D, Wahoff M, Mymern M: Suggestions from the field for return-to-sport rehabilitation following anterior cruciate ligament reconstruction: Alpine skiing. *J Orthop Sports Phys Ther* 42:313–325, 2012.

Multiple Choice Questions

QUESTION 1. Which of the following is not required to begin advanced rehabilitation for sport-specific training?

A. Full AROM
B. Full strength
C. Pain-free weight-bearing activities
D. Normal gait mechanics

QUESTION 2. Which of the following is not a common cause of tibial fractures while skiing?

A. Rotational forces
B. Direct collisions
C. Traction of the joint
D. Type of binding of the ski boots

QUESTION 3. What is the benefit of an aquatic-based program in the initial phases of rehabilitation?

A. Initiate early protected weight bearing
B. Continue cardiovascular conditioning
C. Gait training
D. All of the above

QUESTION 4. During sport-specific training, what factors are important to consider during the progression of plyometrics?

A. Specific sport
B. Type of activity
C. Intensity
D. Rest periods
E. All of the above

QUESTION 5. Which sport-specific functional testing would be the most beneficial for a skier to return to sport?

A. Single leg squat
B. Single leg hop for distance
C. Triple hop for distance
D. 6-meter hop for distance

Answer Key

QUESTION 1. Correct answer: **B** (see Introduction)

QUESTION 2. Correct answer: **C** (see Introduction)

QUESTION 3. Correct answer: **D** (see Phase 1)

QUESTION 4. Correct answer: **E** (see Sport-Specific Training)

QUESTION 5. Correct answer: **A** (see Specific Criteria for Progression to the Next Stage to Determine Readiness for Skiing)

Chapter 38



Achilles Tendinopathy and Rupture

INTRODUCTION

James H. Flint, MD, LCDR, MC USN Michael D. Rosenthal, PT, DSc, SCS, ECS, ATC, CSCS, and John-Paul H. Rue, MD, CDR, MC USN

Epidemiology

- Rising incidence of Achilles tendinopathy and rupture caused by increasing participation in recreational and competitive sports
- Most commonly an overuse injury from repetitive strain, as opposed to traumatic etiology
- Age: typically middle age (mean 40 years old)
- Sex: Men greater than women (although incidence in women increasing as participation in sports increases)
- Sport: mid- to long-distance running and jumping sports; basketball very common for acute rupture in recreational athletes
- Sports position: None specific; any position that involves repetitive excess load on the Achilles tendon

Pathophysiology

Intrinsic Factors

- Advancing age
- Gender
- Abnormal dorsiflexion range of motion
- Abnormal subtalar range of motion
- Decreased plantar flexion strength
- Forefoot varus
- Cavus foot
- Improper conditioning/training
- History of intratendinous or peritendinous corticosteroid injection
- Recent history of fluoroquinolone use
- Genetic predisposition possible
- Co-morbidity: obesity, hypertension, diabetes, high cholesterol

Extrinsic Factors

- Repetitive forceful loading or sudden extreme loading of the Achilles tendon (e.g., strong eccentric loading as when landing from a jump shot)
- Training errors[1]
  - Excessive mileage (volume)
  - Increase in training intensity
  - Uneven training surfaces (i.e., hills, excessively crowned roads)
- Environmental factors
  - Slippery and/or uneven roads/courts
- Inadequate equipment
  - Improper footwear (nonathletic shoes, unevenly worn/warped shoes)
- Previous injury

Traumatic Factors

- Direct trauma or penetrating injury to the Achilles tendon
- Repetitive microtrauma within the tendon from excessive or frequent activity with inadequate rest periods

Classic Pathological Findings

- Paratenonitis: thickened paratenon, adherent to underlying tendon. Inflammatory infiltration of the paratenon seen microscopically.
- Paratenonitis with tendinosis: combination of paratenonitis and tendinosis

The opinions herein are those of the authors and not the official policy or position of the United States Government, Department of Defense, or Department of the Navy.

- Tendinosis: Noninflammatory degeneration of tendon fibers. Tendon may appear discolored and thickened or nodular. Microscopically: lack of inflammatory cells, scattered neovascularization, possible necrosis and/or calcification. Typically appears 2 to 6 cm proximal to the calcaneal insertion.
- Rupture (partial or complete): frank disruption and separation of tendon fibers. Evidence of tendinosis typically present.

Clinical Pearl

The majority of Achilles tendon problems are in the category of tendinosis.[2] In addition to a lack of inflammatory cells, ultrastructural findings include altered cellular (collagen) alignment and increased vascularity. This altered tendon structure has been shown to improve with eccentric loading.

Clinical Presentation

History

- Middle-aged recreational athlete or "weekend warrior"
- For elite athletes, inquire about changes/increases in training intensity and/or duration
- For paratenonitis: focal pain and tenderness after activity; progresses to symptoms at beginning of activity or with less intense/routine activities
- For tendinosis: typically nonpainful, patient may complain of swelling or nodularity of the tendon
- For acute rupture (partial or complete): patient may describe feeling of being kicked in the back of the leg, a severe cramping sensation, or feeling a "pop"
- Inquire about previous history of treatment, to include corticosteroid injection(s) or recent use of fluoroquinolone antibiotics.

Physical Examination

- Warmth, thickening, swelling, and/or crepitus
- Tenderness to palpation, typically 2 to 6 cm above the calcaneal insertion
- Tendon nodularity (painful when paratenonitis present, painless if pure tendinosis)
- Positive "painful arc sign": pain originating within the tendon will move with ankle movement, whereas pain caused by paratenonitis will remain fixed
- Calf atrophy
- Decreased/painful ankle dorsiflexion
- Specific to partial or complete rupture
- Palpable defect in the tendon (Figure 38-1)
- Hematoma/ecchymosis
- Inability to perform single heel rise or decreased plantar flexion strength
- Positive Thompson test: lack of foot plantar flexion with compression of superficial calf (Figure 38-2)

Clinical Pearl

When performing the Thompson test, position the patient in the prone position. The knee may be flexed or extended (have the foot hang off the end of the exam table). Ensure that you isolate the superficial posterior compartment of the calf (gastro-soleus complex). Compressing the entire calf will stretch the deep posterior compartment (FHL, FDL, tibialis posterior), which can result in false plantar-flexion of the foot. Comparison with the contralateral side is recommended to assess for asymmetry of the magnitude of plantarflexion.



FIGURE 38-1. A palpable gap is characteristic of a complete tendon rupture.

- O'Brien needle test: a sterile needle placed perpendicularly in the tendon, proximal to the injury, will move in the opposite direction of foot plantarflexion or dorsiflexion if the tendon is intact distally
- Hyper-dorsiflexion sign: with the patient prone and knees bent 90°, maximal passive dorsiflexion of the feet will show asymmetry. Increased dorsiflexion (DF) on the injured side indicates a loss of DF restraint provided by the Achilles tendon.



FIGURE 38-2. The Thompson test. Intraoperative exam bilaterally showing no plantarflexion of the right foot when the superficial compartment is compressed.



FIGURE 38-3. Plain radiograph in a patient with posterior ankle pain. Note the presence of an os trigonum.

Imaging

- Plain radiography: not particularly helpful for Achilles tendinopathy, but may help rule out other diagnoses (i.e., symptomatic Os trigonum, Haglund deformity). Soft tissue swelling typically present with partial or complete rupture (Figure 38-3).
- Ultrasound: fast and inexpensive. May reveal peritendinous fluid or adhesions (as with tendinopathy), or partial/complete rupture on dynamic exam. Color Doppler may show abnormally increased blood flow. Potential utilization of US in determination of operative or conservative management of Achilles ruptures.[3]
- Magnetic resonance imaging (MRI): usually second-line after ultrasound because of cost. Extremely helpful in classifying tendinopathy and for diagnosing partial and complete tendon tears (Figures 38-4 and 38-5).

Differential Diagnosis

- Acute rupture
- Partial rupture
- Achilles tendinopathy
- Retrocalcaneal bursitis—often associated with Haglund deformity. Pain localized to insertion site of Achilles tendon, however, will be anterior to the actual tendon on exam.
- Insertional tendinosis—often associated with Haglund deformity. History may include aggressive hill running. Pain is localized to Achilles tendon insertion.
- Symptomatic Os trigonum—pain with foot plantar flexion, as when going downstairs. Plain x-ray will reveal the symptomatic ossicle.
- Posterior ankle impingement
- Posteromedial tendon tendinopathy (tibialis posterior, flexor hallucis longus)[2]
- Subluxation/dislocating peroneal tendons—pain/discomfort at distal aspect of lateral malleolus, typically with feeling of popping or clicking. If severe enough, will be reproducible on physical exam. MRI helpful in making definitive diagnosis when exam is equivocal.
- Sever's disease
- Sural neuritis
- Systemic disease

Treatment

Nonoperative Management

Nonsurgical treatment options for Achilles tendinopathy include[1]:

- Ankle/foot orthosis (AFO) to correct mechanical misalignment(s)
- Nonsteroidal antiinflammatory drugs (NSAIDs)
- Modification of training programs or sports activities (relative rest)
- Physical therapy

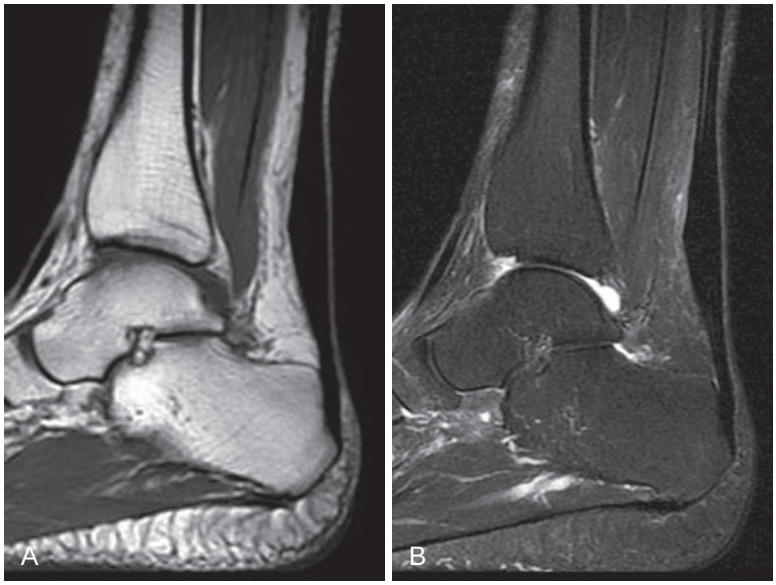

FIGURE 38-4. Typical T1-weighted (**A**) and T2-weighted (**B**) MRI findings in a patient with Achilles tendinosis. Note the thickened tendon without significant inflammatory findings on T_2-weighted images.

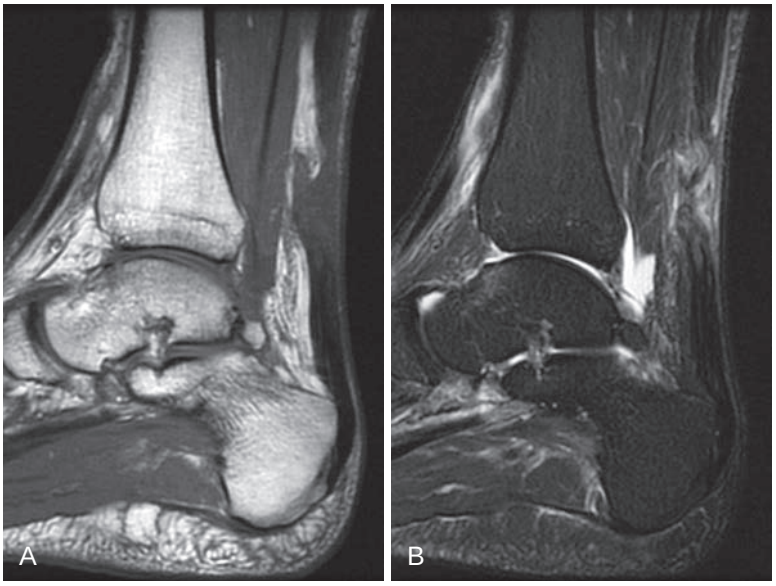

FIGURE 38-5. MRI of a patient with an Achilles tendon rupture. T1-weighted (**A**) and T2-weighted (**B**) images show frank disruption of the tendon fibers.

- Eccentric training exercises
- Brisement (injection of anesthetic or saline into paratenon sheath to break adhesions; for paratenonitis only)
- Extracorporeal shock wave therapy
- Corticosteroid injection—generally contraindicated because of risk of tendon disruption; however peritendinous injection has been beneficial in some cases of paratenonitis.
- Sclerosing agent injections (i.e., Polidocanol)
- Prolotherapy
- Air Heel brace[4]
- Night splints
- Low-level laser therapy
- Iontophoresis
- Stretching exercises
- Soft tissue and joint mobilizations (manual therapy)
- Taping
- Heel lifts
- Night splints

Nonsurgical treatment options for Achilles rupture include:

- Casting/bracing
- Accelerated functional rehabilitation[5]

Guidelines for Choosing Among Nonoperative Treatments

- For older individuals who are less athletic/active, treatment will initially consist of immobilization (along with rest and ice) of the lower leg with subsequent integration of conservative rehabilitation methods to restore mobility, strength, and functional capability.
- For younger, more active patients, or athletes, relative rest with modification of training regimens is important. The same conservative measures also apply.
- For tendinopathy, eccentric training exercises have been shown to be beneficial[4,6–10]
- If initial conservative measures fail, additional nonsurgical treatment options may be pursued depending on patient desire and willingness

Surgical Indications

Surgical treatment options for Achilles tendinopathy include:

- Percutaneous tenotomy
- Open paratenon and/or tendon debridement/excision (with tendon repair/reconstruction as indicated)

Surgical treatment options for Achilles rupture include:

- Open repair
- Percutaneous repair
- Open repair with lengthening, augmentation, or reconstruction (for chronic ruptures)

Surgical indications for Achilles tendinopathy:

- Absolute indications: none
- Relative indications: Achilles tendinosis (or paratenonitis with tendinosis) that is resistant to conservative measures

Surgical indications for Achilles rupture (acute or chronic):

- Absolute indications: open wound requiring irrigation/debridement
- Relative indications: failure of nonoperative measures, elite athletes who desire faster return to activity
- Choice of operative treatment should ultimately fall on the patient after appropriate discussion of the risks, benefits, and alternatives to surgery.

Aspects of History, Demographics, or Exam Findings That Affect Choice of Treatment

- Age
- Participation in competitive sports
- Severity/persistence of symptoms
- Adherence to prior interventions
- Response to prior treatments

Aspects of Clinical Decision Making When Surgery Is Indicated

- Patient characteristics (i.e., age, athlete or nonathlete)
- Underlying medical conditions (i.e., diabetes, peripheral vascular disease, skin condition)
- Patient preference

- Among athletes, desire to begin earlier, more aggressive rehabilitation with possible earlier return to activity
- Occupational/sports demands

Evidence

Alfredson H, Cook J: A treatment algorithm for managing Achilles tendinopathy: New treatment options. *Br J Sports Med* 41:211–216, 2007.

A review article discussing Achilles tendinopathy treatment.

Maffulli N, Kader D: Tendinopathy of tendo achillis. *J Bone Joint Surg Br* 84:1–8, 2002.

A review article discussing Achilles tendinopathy treatment.

Maffulli N, Longo UG, Denaro V: Novel approaches for the management of tendinopathy. *J Bone Joint Surg Am* 92:2604–2613, 2010.

Current Concepts Review of management options for Achilles tendinopathy.

Petersen W, Welp R, Rosenbaum D: Chronic Achilles tendinopathy: A prospective randomized study comparing the therapeutic effect of eccentric training, the AirHeel brace, and a combination of both. *Am J Sports Med* 35:1659–1667, 2007.

This prospective, randomized study of 100 patients compared eccentric training with the AirHeel brace in patients with chronic Achilles tendinopathy. At 6, 12, and 54 weeks, both groups showed improvement. Pain, function, and tendon thickness were not statistically different between groups; no synergistic effect was found. (Level I evidence)

Reddy SS, Pedowitz DI, Parekh SG, et al: Surgical treatment for chronic disease and disorders of the achilles tendon. *J Am Acad Orthop Surg* 17:3–14, 2009.

A general overview of Achilles tendinopathy and rupture.

Saltzman CL, Tearse DS: Achilles tendon injuries. *J Am Acad Orthop Surg* 6:316–325, 1998.

A general overview of Achilles tendinopathy and rupture.

Willits K, Amendola A, Bryant D, et al: Operative versus nonoperative treatment of acute Achilles tendon ruptures: A multicenter randomized trial using accelerated functional rehabilitation. *J Bone Joint Surg Am* 92:2767–2775, 2010.

This multicenter, prospective, randomized study of 144 patients compared operative and nonoperative treatment of acute Achilles ruptures, using accelerated functional rehabilitation in both groups. At 2 years, there was no statistical different in outcome measures for all variables. The authors supported accelerated functional rehabilitation and nonoperative treatment. (Level I evidence)

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10. Saltzman CL, Tearse DS: Achilles tendon injuries. *J Am Acad Orthop Surg* 6:316–325, 1998.

Multiple Choice Questions

QUESTION 1. Extrinsic factors associated with Achilles tendinopathy and ruptures include all of the following except

A. change in intensity of training program.
B. forefoot varus.
C. improper footwear.
D. running or jumping on hard or uneven surfaces.

QUESTION 2. Classic pathological findings of Achilles tendinosis include

A. inflammatory cell infiltrate.
B. thickened paratenon.
C. scattered neovascularization.
D. All of the above

QUESTION 3. A 40-year-old man feels a sudden, sharp pain in the back of his ankle while playing basketball. He reports a feeling of being kicked in the back of the leg and cannot walk off the court. What findings are likely to be present on exam?

A. Palpable defect in the Achilles tendon
B. Positive Thompson test
C. Inability to perform a single heel rise on the affected side
D. All of the above

QUESTION 4. The preceding patient elects nonoperative management. Which of the following are appropriate treatment options?

A. Peritendinous steroid injection
B. Brisement
C. Short-term casting with accelerated functional rehabilitation
D. Pain control with NSAIDs, and custom orthotics to allow immediate weight bearing and therapy

Answer Key

QUESTION 1. Correct answer: **B** (see Pathophysiology)

QUESTION 2. Correct answer: **C** (see Pathophysiology)

QUESTION 3. Correct answer: **D** (see Clinical Presentation)

QUESTION 4. Correct answer: **C** (see Treatment)

NONOPERATIVE REHABILITATION OF ACHILLES TENDINOPATHY

Leslie C. Hair, PT, DSc, OCS, FAAOMPT, Michael D. Rosenthal, PT, DSc, SCS, ATC, James H. Flint, MD, LCDR, MC USN, and John-Paul H. Rue, MD, CDR, MC USN

GUIDING PRINCIPLES OF NONOPERATIVE REHABILITATION

- Restoration of normal joint mobility
- Progressive increase in neuromuscular demands (strength, endurance, and power)
- Evaluation and management of impairments throughout the kinetic chain likely to contribute to Achilles tendinopathy
- The goal of rehabilitation of Achilles tendinopathy is a safe and complete return to preinjury level of activity.
- In order to achieve this goal, a multimodal treatment approach is used. This approach focuses on restoration of mobility and muscular performance, not just isolated to the lower leg, but including the kinetic chain from the thoracolumbar region distally.
- Initiation of formal rehabilitation will vary depending upon the severity of tendinopathy at the time the athlete initiates care.
- However the milestones for management are the same whether care begins in the early acute, subacute, chronic, or acute on chronic stage.
- Milestones include normalization of talocrural and subtalar mobility, ability to perform single leg heel raises and eccentric gastroc-soleus exercises without pain, and progressive return to activities requiring rapid stretch-shortening cycles (i.e., running and jumping).
- Progression from phase to phase is based on improvements in functional performance and reduction in pain, not a rigid timeline.

Phase I (weeks 2 to 4)

Protection

- If the athlete displays an antalgic or altered gait, a CAM walking boot or crutches may be used to offload forces through the injured area.

Management of Pain and Swelling

- Ice[1]
- Pulsed ultrasound[2]
- Low level laser therapy[3]
- Iontophoresis[3]
- Foot orthosis for correction of excessive pronation
- Heel lift to reduce strain on the Achilles tendon

Techniques for Progressive Increase in Range of Motion

- Initial treatment should include awareness of the athlete's fitness level and consideration of what cardiorespiratory training may be used to mitigate deconditioning.
- Popular conditioning exercises in this early stage of rehabilitation include swimming, non–weight-bearing pool jogging (if pain free), and the upper body ergo meter. Exercises for the sound leg, core musculature, and upper body should be incorporated along with cardiorespiratory training treatment to optimize the athlete's readiness for return to sport upon resolution of the Achilles tendinopathy.
- Restoration of range of motion (ROM) follows a thorough evaluation of talocrural and subtalar mobility.
- Additional ROM assessment of proximal (i.e., hip) or distal joints (i.e., first metatarsophalangeal joint) should also be included, particularly in patients with prior injury to these regions.

TIMELINE 38-1: **Nonoperative Rehabilitation of Achilles Tendinopathy**

PHASE I (weeks 2 to 4)	PHASE II (weeks 3 to 12)

• Manual therapy
• Soft tissue techniques
• Stretching
  • Static stretching and active stretching
• Static single leg balance
• Four-way ankle isometrics
  • Low intensity eccentric loading
• Strengthening—legs and core
	• Manual therapy
	• Soft tissue techniques
	• Stretching
	  • Static stretching and active stretching
	• Sensorimotor exercises
	  • Dynamic single leg balance exercises
	• Eccentric loading
	• Strengthening—legs and core
	• Open kinetic chain and closed kinetic chain exercises
	• Plyometrics—low intensity and volume
	• Functional exercise
	• Sport-specific exercise

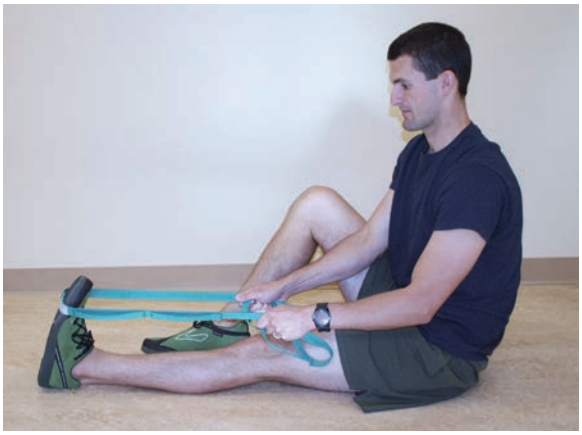

FIGURE 38-6. Strap assisted static stretch.



FIGURE 38-7. Active stretch performed with knee straight and knee slightly bent. The uninvolved side is "reaching" into the sagittal plane in a rhythmic manner.

- Muscular performance assessment will vary based upon the severity and irritability of the patient's condition.

Manual Therapy Techniques

- Identify mobility impairments through a manual exam of the foot and ankle. May use various techniques, including anteroposterior, posteroanterior, distraction, and translatory mobilization or manipulation to improve movement restrictions.

Soft Tissue Techniques

- The use of soft tissue mobilization (i.e., transverse friction massage, instrumented soft tissue mobilization) may be used to reduce pain and improve mobility. Utilization of these techniques in acute tendinopathy and paratendinitis is not recommended.[4]

Stretching/Flexibility Techniques for the Musculotendinous Unit

- Stretching exercises, to include the gastrocnemius and soleus muscle groups, may improve function in patients with dorsiflexion restrictions. Stretching should be performed with both static stretching (Figure 38-6) to restore normal musculotendinous extensibility (recommend comparison with the uninvolved limb), and by way of active and dynamic stretching (Figure 38-7).
- Static stretching performed two to three times daily with each set containing 5 to 10 repetitions and holding the stretch for 20 to 30 seconds. This type of stretching is incorporated into all phases of tendinopathy rehabilitation until symmetrical and pain free ROM about the ankle has been achieved.
- Active stretching performed for periods of 20 to 30 seconds, repeated for two to three sets, and repeated one to two times daily. Active stretching techniques will be implemented in all rehabilitation phases with the exception of the acute tendinopathy phase. Active stretching techniques will continue to be used once symmetry of ROM has been achieved and should be incorporated into the warmup portion of the rehabilitation and return to function phases.

TIMELINE 38-1 Nonoperative Rehabilitation of Achilles Tendinopathy (Continued)

PHASE III (weeks 12 to 36)	PHASE IV (weeks 16 to 52)

• Manual therapy
• Soft tissue techniques
• Stretching
  • Static, active, and dynamic stretching
• Total body strengthening
  • Olympic lifts
• Eccentric loading
• Strengthening—legs and core
• Sensorimotor exercises
• Open kinetic chain and closed kinetic chain exercises
• Plyometrics
• Functional exercise with reaction drills
• Sport-specific exercise with multiplanar and transitional movements
	• Manual therapy
	• Soft tissue techniques
	• Flexibility—calf and lower extremity
	  • Static, active, and dynamic stretching
	• Eccentric loading
	• Functional exercise
	• Sport-specific exercise
	• Transition to performance training
	• Sport-specific testing



FIGURE 38-8. Resistance band eccentric loading.

Other Therapeutic Exercises

- Eccentric loading
  - Two protocols are most frequently cited in the literature. Curwin and Stanish reported a program consisting of three sets of 10 repetitions and titrated by pain. This protocol included both concentric and eccentric muscle action. Increasing speed of the exercise was performed as part of the progression along with addition of light weight.[5] This program is recommended in Phase I for patients with acute tendinopathy. Initial loading may be induced by use of a resistance strap or band (Figure 38-8).
  - For those with chronic tendinopathy, the eccentric training program advocated by Alfredson is recommended.[6,7] Alfredson's protocol involves slow speed eccentric loading, exercising to the level of the athlete's pain, and includes the addition of greater loads as part of the exercise progression. The unaffected contralateral lower extremity returns the affected ankle to the starting position.
- Total leg strengthening to include the hip and thigh musculature
- Core strengthening exercises (i.e., side and front planks, pushups)
- Total lower extremity stretching to include the thigh, hip, and lumbosacral region

Activation of Primary Muscles Involved

- The posterior leg muscles, in particular the gastrocnemius and soleus, which join to form the Achilles tendon are the muscles targeted with the eccentric loading.

Sensorimotor Exercises

- Single leg balance exercises are introduced in this early phase of rehabilitation. Balance proprioception exercises progress from a firm to soft or unsteady surface.

Open and Closed Kinetic Chain Exercises

- Limited OKC exercises are incorporated. They include intrinsic foot muscle exercises to include towel/toe curls exercises and marble pickups. If the athlete is unable to tolerate weight bearing, OKC four-way (inversion, eversion, dorsiflexion, and plantarflexion) isometric or resistance band exercises may be utilized. CKC exercises include bridging with double leg support progress to single leg support.

Techniques to Increase Muscle Strength, Power, and Endurance

- Begin total lower extremity therapeutic exercise to include hip stabilization exercises; for example, hip abduction, gluteal strengthening, straight leg raises, and hamstring strengthening. This will include primarily CKC exercises of squatting (with varying base of support) (Figure 38-9*A,B*), dead lifts (double leg progressing to single leg), and lunges in the frontal plane in Phase I. Power and endurance components will be addressed by changes in the speed and/or duration of movement.



FIGURE 38-9. A,B, Squatting with differing bases of support imparts varying stress on the Achilles tendon and can help in transition to higher level, functional, and sport-specific activities.

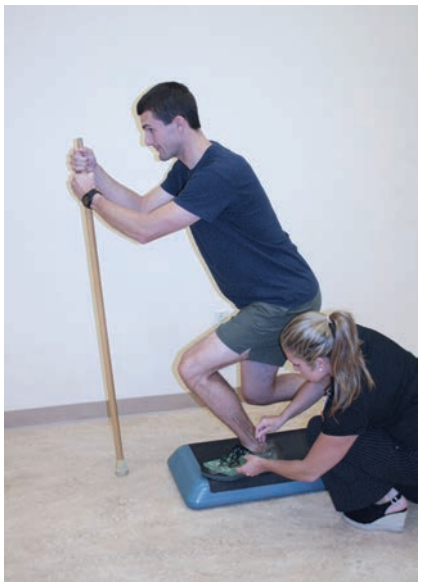

FIGURE 38-10. Closed kinetic chain assessment of dorsiflexion.

Milestones for Progression to the Next Phase

- Decreased pain
- Symmetry in lower extremity ROM: dorsiflexion measured in both the open and closed kinetic chain position (Figure 38-10)
- Normal gait

Phase II (weeks 3 to 12)

Clinical Pearl

Phase II involves a significant systematic increase in the dynamic stresses applied to the Achilles tendon. Ice application is not recommended prior to exercising because it increases tendon stiffness and the pain inhibition produced by icing may mask awareness of excessive exercise intensity.[5]

Management of Pain and Swelling

- Same as in Phase I.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Same as in Phase I.

Soft Tissue Techniques

- Same as in Phase I.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Static stretching will now be performed following cardiorespiratory and other rehabilitation exercises. The active stretching exercises will be a key focus of the warmup exercises before beginning higher level strengthening exercises.
- Static stretching performed one to two times daily with each set containing three to five repetitions and holding the stretch for 20 to 30 seconds.
- Active stretching techniques performed for periods of 20 to 30 seconds, repeated for two to three sets, and performed before higher level speed or resistance exercises to prepare the Achilles tendon for the increased loads.

Other Therapeutic Exercises

- Eccentric loading protocol (either the Curwin and Stanish or Alfredson protocol). Both protocols have been demonstrated to improve strength and function while decreasing pain in patients with midportion Achilles tendinopathy. Neither protocol has been proved superior.[8]
- Total leg strengthening exercises will now progress to include split squat exercises, double leg and single leg deadlifting, and sagittal plane lunges.
- Total spine and lower body stretching will continue throughout all phases of rehabilitation.

Sensorimotor Exercises

- Balance and proprioception exercises will incorporate sport- or activity-specific surfaces (i.e., basketball court, track surface, or gymnastics pad) and multiple planes of movement. Examples of exercises include the star excursion exercise or wall reach (Figure 38-11), which can include multiple angles/planes of movement. Exercise progression and promotion of tissue adaptation is accomplished by increasing the amplitude of movement (ROM), speed of movement (intensity), and volume of the activity (repetitions or duration of the exercise).



FIGURE 38-11. Wall reach. Reaching may be performed in the sagittal, frontal or transverse planes.

Open and Closed Kinetic Chain Exercises

- OKC exercises may include the use of isokinetic resistance exercises for dorsiflexion, plantarflexion, inversion and eversion. Although the focus is on progression of the more functional CKC exercises, such as squats and lunges mentioned previously in this phase, OKC exercises promote strength and local muscular endurance gains.

Plyometrics

- Gravity or weight bearing reduced plyometric exercises may be initiated during this phase. Examples include jumping or hopping in a pool, or using a gravity-reduced device (i.e., Total Gym or Shuttle Systems equipment). Plyometric volume should initially be very low and measured by foot contacts. Initial plyometric volume in the injured athlete should not exceed 30 foot contacts per workout with two to three workouts per week.

Functional Exercises

- Incorporate functional exercises such as squats, lunges, side lunges, and stepups into the total lower extremity strengthening routine.

Sport-Specific Exercises

- Form walking exercises (i.e., high knees with heel raise; Figure 38-12). Initiate sport-specific exercise into the routine for athletes. Start with low speed and low impact activities.

Milestones for Progression to the Next Phase

- Attainment of 5/5 strength of lower extremity muscles found to be weak during the evaluation and subsequent rehabilitation
- Symmetrical single leg squat and lunge



FIGURE 38-12. High knee walking with heel raise.

- Pain free heel raise × 15
- Pain free single leg hop × 5

Phase III (weeks 12 to 36)

Management of Pain and Swelling

- Same is in Phase I.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- See Phase II.

Soft Tissue Techniques

- See Phase II.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Static stretching should be performed one to two times daily with each set containing three to five repetitions and holding the stretch for 20 to 30 seconds.
- Active and dynamic stretching techniques should be performed for periods of 15 to 30 seconds, repeated for two to three sets.

Other Therapeutic Exercises

- Total body strengthening exercises during this phase include deadlifts, hang cleans or power cleans, and push-presses.

Activation of Primary Muscles Involved

- Although the gastrocnemius and soleus are the primary muscles involved, effective return to athletics requires the synergistic activation of trunk and lower extremity muscles.

Sensorimotor Exercises

- Further progression of exercises from Phase II with increasing amplitude of movement (ROM), speed of movement (intensity), and volume of activity (repetitions or duration of the exercise).

Techniques to Increase Muscle Strength, Power, and Endurance

- Closed kinetic chain exercises are primarily used for increasing muscular strength, power, and endurance in the final phase. Exercise selection progresses from basic exercises (i.e., squats to squat jumps to weighted squat jumps) to sport specific exercises (i.e., static single leg hops to high skipping to bounding).

Plyometrics

- Final stage plyometrics include progression to full weight bearing plyometrics and a gradual increase in

training volume and intensity. Progression involves counter movement jumps (double leg advancing to single leg) and box jumps (progressing in box height). Plyometric volume gradually increases to 40 to 80 repetitions. Athletes whose sport includes high volume and high intensity demands may approach 120 to 200 foot contacts no more than twice weekly.[9]

Functional Exercises

- Multidirectional and transitional movement (i.e., anterolateral to posteromedial lunging)
- Reaction drills (i.e., change of direction movements; forward, lateral, jump).
- Walk-jog progression

Sport-Specific Exercises

- Selection is based upon demand/needs analysis of the athlete's sport or functional impairment.
  - Progressive increase from jogging to sprinting
  - Agility drills (e.g., figure-eight runs, T-drills)
  - Run and jump repeats
  - Line drills

Milestones for Progression to the Next Phase

- Countermovement jumping without symptoms
- Run without symptoms

Criteria for Abandoning Nonoperative Treatment and Proceeding to Surgery or More Intensive Intervention (weeks 16 to 52)

- Inability to regain strength
- Inability to regain function
- Debilitating pain
- Patient preference

Milestones/Criterion-Based Rehabilitation Guidelines to Progress to Advance Sport-Specific Training and Conditioning

- Greater than 75% symmetry in hop testing
  - May include SL hop for distance, SL vertical jump, SL triple hop, and box jumps
- Symmetry with single leg heel raise endurance test (maximum repetitions)

Tips and Guidelines for Transitioning to Performance Enhancement

- The transition to performance enhancement involves the inclusion of both sport-specific activities as well as continued variety of training stimulus (modes of training) and application of training variables (amplitude of movement, speed of movement, duration of activity/volume, and frequency of training stimulus).
- Although this program involves a progression of each component of athleticism (e.g., mobility, strength, power, endurance), the transition to performance enhancement and return to sport should involve a careful manipulation of variables and incorporate an undulating periodization model.
- This model enables effective upregulation of certain training variables while down-regulating other training components.

Performance Enhancement and Beyond Rehabilitation: Training/Trainer and Optimization of Athletic Performance

- Integration of training/sport-specific variables is required in the training "bridge" from rehabilitation to performance enhancement.
- This analysis should include all variables of the athlete's chosen sport. For example, the sport surface (i.e., court, field), frequency of training and competition, and rest-work cycles during practice and competition.
- Additionally, if the athlete's onset of symptoms was nontraumatic, a comprehensive kinetic chain assessment should be included in the later phase of rehabilitation in hopes of identifying possible strength and/or mobility asymmetries that could be the underlying cause of the condition and increase the likelihood of injury recurrence.

Specific Criteria for Return to Sports Participation: Tests and Measurements

- Greater than 85% symmetry in hop testing

Evidence

Alfredson H, et al: Heavy-load eccentric calf muscle training for the treatment of chronic Achilles tendinosis. *Am J Sports Med* 26:360–366, 1998.

This research article provides an overview of the treatment protocols for Achilles tendinosis. The article discusses treatment and its variables associated with proper rehabilitation progression. (Level II evidence)

Carcia CR, et al: Achilles pain, stiffness, and muscle power deficits: Achilles tendinitis. *J Orthop Sports Phys Ther* 40:A1–26, 2010.

This comprehensive review article provides a synopsis of the evidence basis for numerous components of the management of Achilles tendinopathy. The overview includes review of examination and intervention components and provides the level of evidence associated with each aspect. (Level II evidence)

Cook JL, et al: Achilles tendinopathy. *Man Ther* 7:121–130, 2002.

This review article provides a comprehensive review of the manual therapy management of Achilles tendinopathy. The overview includes a review of the intervention components. (Level V evidence)

Cook JL, Purdam CR: Rehabilitation of lower limb tendinopathies. *Clin Sports Med* 22:777–789, 2003.

This review article provides a comprehensive review of the lower extremity tendinopathies. The overview provides a concise review the myriad of treatment options and some of the research that has assessed efficacy of the interventions. (Level V evidence)

Khan K, Cook J: The painful nonrupture tendon: clinical aspects. *Clin Sports Med* 22:711–725, 2003.

This review article covers the spectrum of evaluation and treatment of tendon injuries to include lower and upper extremity conditions. (Level V evidence)

Mafi N, et al: Superior short-term results with eccentric calf muscle training compared to concentric training in a randomized prospective multicenter study on patients with chronic Achilles tendinosis. *Knee Surg Sports Traumatol Arthrosc* 9:42–47, 2001.

This study randomized patients with chronic noninsertional Achilles tendinosis to either eccentric or concentric calf muscle training groups. A significant increase in patient reported improvement was noted in the eccentric training group. (Level I evidence)

Mayer F, et al: Effects of short-term treatment strategies over 4 weeks in Achilles tendinopathy. *Br J Sports Med* 41:228–236, 2007.

This study randomized men with Achilles tendinopathy to one of three treatment groups (Control, orthoses, or physiotherapy). Following 4 weeks of therapy, both treatment groups were improved with comparable improvements between groups. (Level II evidence)

Wasielewski NJ, Kotsko KM: Does eccentric exercise reduce pain and improve strength in physical active adults with symptomatic lower extremity tendinosis? A systematic review. *J Ath Trng* 42:409–421, 2007.

This article reviewed 27 studies that were randomized controlled trials involving the treatment of Achilles or patellar tendinosis in adults that utilized eccentric exercise as one of the treatment components. (Level I evidence)

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Multiple Choice Questions

QUESTION 1. The following training variable(s) are included in the eccentric training protocol described by Curwin and Stanish.

A. Only eccentric movement of the injured Achilles
B. Slow speed of eccentric movement
C. Performance with the knee bent and knee straight
D. Titration of training volume based upon pain

QUESTION 2. The following training variable(s) are included in the eccentric training protocol described by Alfredson.

A. Concentric movement on the side of the injured Achilles
B. High speed of eccentric movement
C. Gradually increasing training volume
D. Gradual increase in training resistance

QUESTION 3. The following modalities are appropriate for use with Achilles tendinopathy

A. Ultrasound
B. Low level laser therapy
C. Ice
D. There is limited evidence for use of modalities with Achilles tendinopathy and rehab should focus on restoring mobility and strength

QUESTION 4. Functional exercise and sport-specific exercise should begin in phase?

A. Phase 1 (weeks 1 to 2)
B. Phase 2 (weeks 3 to 12)
C. Phase 3 (weeks 12 to 36)
D. Phase 4 (weeks 16 to 52)

QUESTION 5. What criteria indicate a need for referral to the orthopedic surgeon and consideration of operative intervention?

A. Inability to regain strength
B. Inability to gain function
C. Debilitating pain
D. All of the above

Answer Key

QUESTION 1. Correct answer: **D** (see Phase I)

QUESTION 2. Correct answer: **D** (see Phase II)

QUESTION 3. Correct answer: **D** (see Phase I)

QUESTION 4. Correct answer: **B** (see Phase III)

QUESTION 5. Correct answer: **D** (see Criteria for Abandoning Nonoperative Treatment and Proceeding to Surgery or More Intensive Intervention)

POSTOPERATIVE REHABILITATION OF ACHILLES TENDINOPATHY

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Indications for Surgical Treatment

- Failure of nonoperative measures, typically after at least 3 to 6 months[1–3]
- Patient preference

Brief Summary of Surgical Treatment

Major Surgical Steps

- Achilles paratenonitis
  - Choice of anesthesia, patient in prone position on well-padded table
  - Place tourniquet on affected extremity before rolling for ease of application
  - Posteromedial incision to avoid small saphenous vein and sural nerve
  - Full thickness incision through skin down to paratenon
  - Identify any thickened or fibrotic areas of the paratenon and excise. Lyse any adhesions to the underlying tendon. Avoid excising anteriorly to preserve the blood supply to the tendon.[3,4]
  - Close the incision and dress the wound.
  - Postoperative splint or boot for edema control and soft tissue rest/wound healing
  - Rehabilitation should start as soon as the wound is sufficiently healed.
- Achilles tendinosis
  - For solitary, well-defined nodules less than 2.5 cm, percutaneous longitudinal tenotomies can be performed.
- May be performed in outpatient setting without use of tourniquet in some cases.[1,2]
- Rehabilitation can start (or continue) as soon as the stab incision(s) is sufficiently healed.

Clinical Pearl

When performing percutaneous tenotomy, ultrasound guidance should be used to ensure precise placement of the scalpel within the affected portion of the tendon.[1,2]

- For larger, or multiple, nodules, or in cases of tendinosis with associated paratenonitis, an open procedure is performed.
  - The same operative setup and surgical approach is used as described in the preceding.
  - Paratenonitis is addressed as in the preceding, and attention is then turned to the tendon proper.
  - Intratendinous incisions are made as indicated over the nodular areas. Nodular tissue (degenerated tendon) is excised and the tendon is repaired side-to-side with a buried, absorbable suture.[1,2,4,5]
  - Close the remaining paratenon and skin in layers.
  - Dress the wound and place the patient in a short-leg splint or removable boot.
  - The patient may bear weight fully and perform gentle range of motion, but formal rehabilitation should be postponed until the wound is sufficiently healed.

Factors That May Affect Rehabilitation

Anesthetic

- As indicated, patients may benefit from short-term narcotic analgesia. Be aware of the patient's pain medication needs and tailor accordingly.

Surgical

- Degree of tendinosis and/or paratenonitis
  - More advanced cases, which involve open procedures, need more time to recover and heal postoperatively when compared with simpler cases that may be addressed with percutaneous procedures.
- Size of exposure
  - More extensive debridement may require more extensive surgical incisions. Rehabilitation should not impede sufficient wound healing. Soft tissue healing takes precedence over initiation of aggressive rehabilitation.
- Quality of the tendon
  - For patients with severe tendinosis, with or without paratenonitis, consider allowing more time for soft tissue healing before starting aggressive rehabilitation.

Other Surgical Techniques and Options

- Endoscopic debridement[2]
- Advanced options (for patients with greater than 50% to 75% tendon degeneration)
  - Tendon transfers[3]
- For example, FDL, FHL
  - Allograft tendon reconstruction[3]

Before Surgery: Overview of Goals, Milestones, and Guidelines[1]

Guiding Principles of Postoperative Rehabilitation

- Understanding the stages of soft tissue healing and anatomic structures involved.

[1]*Prehabilitation, if appropriate, is described in the Nonoperative Rehabilitation section of this chapter.*

- Application of appropriate levels of physical stress to the healing soft tissue to promote optimal recovery.
- Development of a systematic approach to soft tissue overload with the long-range goal in mind.
- Effective patient education on the comprehensive rehabilitation program.

Phase I (days 0 to 14): Immediate Postoperative Period

Clinical Pearl

Gentle non–weight-bearing motion should commence immediately. Active ROM and passive dorsiflexion with resistance band or stretch strap should be performed throughout the day. Active plantarflexion is allowed immediately.

Goals

- Protection of repaired structures
- Decrease pain and inflammation
- Prevent effects of immobilization

Protection

- Padded splint with the ankle in neutral dorsiflexion (DF).
- Crutch-assisted ambulation for the first 10 to 14 days.

Management of Pain and Swelling

Treatment for Pain/Analgesia

- Oral pain medications
- Cryotherapy to reduce pain and inflammation.
- Therapeutic modalities such as TENS and IFC e-stim.

Decrease Swelling

- Cryotherapy to reduce swelling
- Elevation of surgical limb

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Talocrural, subtalar, and mid-foot joint mobilizations

Soft Tissue Techniques

- Achilles tendon soft tissue mobilizations
- Scar mobilization to region of incision once closed
- Stretching/flexibility techniques for the musculotendinous unit
- Towel gastroc-soleus stretch (pain free)
- Ankle AROM (ABCs)

Other Therapeutic Exercises

- Straight leg raises
- May perform upper body and core exercises not requiring support of the involved lower extremity.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Resistance band exercises—dorsiflexion (DF), plantarflexion (PF), inversion (INV), and eversion (EV)
- Four-way ankle isometrics
- Seated heel (PF) and toe (DF) raises

Sensorimotor Exercises

- BAPS board (seated)

Milestones for Progression to the Next Phase

Performs all Phase I rehabilitation exercises without pain or increase in swelling

Phase II (weeks 2 to 6)

Clinical Pearl

Removable walking boot with adjustable heel is used for weeks 2 to 4. At week 2, weight bearing without crutches is allowed in the walking boot. Stationary bike is allowed when the patient tolerates full weight bearing. Discontinue walking boot at weeks 4 to 6.

Goals

- Protection of repaired structures
- Decrease in pain and inflammation

TIMELINE 38-2: **Postoperative Rehabilitation of Achilles Tendinopathy**

PHASE I (weeks 0 to 2)	PHASE II (weeks 3 to 6)	PHASE III (weeks 6 to 10)
• Splint (first 24 h) • Walking boot with crutches • DC crutches at week 2 • PROM for DF, PF, Inv, Ev • AROM ankle exercises (no active PF) • Joint mobilizations • Seated BAPS	• Walking boot • Aqua jogging • Stationary bike • AROM for all ankle motions • Seated heel/toe raises • Joint mobilizations • Scar mobilization	• D/C walking boot by week 6 • PREs for all ankle motions • Body weight squats and lunges • Standing eccentric gastroc-soleus • Gait training • Walking/jogging on trampoline • Mobilizations/flexibility as needed • Standing proprioceptive exercises • Begin walk/run progression at Week 8

- Discontinued use of crutches and walking boot
- Full weight-bearing status
- Normal ROM

Protection

- Use a walking boot for ambulation without crutches

Management of Pain and Swelling

- Same as Phase I

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Talocrural, subtalar, and mid-foot joint mobilizations

Soft Tissue Techniques

- Achilles tendon soft tissue mobilizations
- Scar mobilization to incision

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Towel calf stretch
- Ankle circles (ABCs)
- Ensure normal ROM in hip and knee and address any restrictions during this period.

Other Therapeutic Exercises

- Stationary bike
- Swimming and aqua jogging (wound healing must be complete)
- Straight leg raises
- Leg press, body weight squats

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Muscle activation of the gastroc-soleus complex during this second phase of rehabilitation begins with isometric plantar flexion and light resisted plantar flexion using a towel or resistance bands.

Techniques to Increase Muscle Strength, Power, and Endurance

- Lower body strengthening, including bodyweight squats, lunges, and wall sits; progressing to include leg press, step-up and step downs in the sagittal and frontal planes.

Functional Exercises

- Gait training from 3 to 6 weeks

Milestones for Progression to the Next Phase

- Full AROM
- Ambulates without assistance device

Phase III (weeks 6 to 10)

Goals

- Restore normal gait mechanics.
- 5/5 lower extremity strength
- Begin a walk-jog program.

Protection

- Walking boot discontinued

Management of Pain and Swelling

Treatment for Pain/Analgesia

- Cryotherapy
- Therapeutic modalities such as laser therapy and electrical stimulation as needed

Decrease Swelling

- Cryotherapy

Techniques for Progressive Increase in Range of Motion

- Same as in Phase II plus
  - Standing gastroc-soleus stretch (straight and bent knee)
  - Gastroc-soleus stretching using a slant board

Other Therapeutic Exercises

- Elliptical trainer
- Stairmaster

TIMELINE 38-2 **Postoperative Rehabilitation of Achilles Tendinopathy** (Continued)

PHASE IV (weeks 10 to 14)	PHASE V (weeks 14 to 24)	PHASE VI (weeks 24 to 52)
• Strength training • Single leg eccentric loading exercises • Olympic/power lifting • Running program progression • Begin agility and sport specific drills in controlled environment at week 12	• Running/sprint drills • Plyometrics • Agility and sport-specific drills (skipping → hopping → jumping) • Return to sport	• Individual strength and flexibility program based on impairments • Running/sprint drills • Plyometrics • Agility and sport-specific drills (skipping → hopping → jumping) • Return to sport

- Standing hip abduction
- Standing hamstring curls

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Resistance band exercises—dorsiflexion, plantarflexion, inversion, and eversion
- Sitting heel raises progressing to bilateral standing heel raises with slow eccentric lowering into maximal DF

Sensorimotor Exercises

- In-line tandem walking and lunging
- Single limb stance (with and without Airex pad)
- Rebounder exercises including ball toss and catch
- Hurdle step
- Standing BAPS

Techniques to Increase Muscle Strength, Power, and Endurance

- Progress from bodyweight squats and lunges to include increasing levels of resistance.
- Multi-planar lunges

Functional Exercises

- Gait training
- Form walking: high knees, lateral stepping, hurdle step overs/unders
- Walk to jog progression
- Stair climbing

Milestones for Progression to the Next Phase

- Normal gait
- Able to perform bilateral heel raises and lunges
- Symmetry in unilateral stance

Phase IV (weeks 10 to 14)

Goals

- Jogging 5 to 10 minutes
- Begin agility and sport-specific training

Therapeutic Exercises

- Outdoor biking
- Stair machine

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Single leg calf raises
- Eccentric loading (Figure 38-13*A*,*B*) protocol with technique as described by Alfredson[6]
- Progression of eccentric loading
- Week 10: 1 × 15 daily (qd)
- Week 11: 2 × 15 qd
- Week 12: 3 × 15 qd
- Week 13: 3 × 15 twice daily (bid) for 3 days and qd for 3 days
- Week 14: 3 × 15 bid

Sensorimotor Exercises

- Progression of Phase III exercises to include single leg balance and reach exercises (Figure 38-14*A*,*B*)

Techniques to Increase Muscle Strength, Power, and Endurance

- Gravity-reduced plyometrics (Figure 38-15)
- Deadlifts
- Single leg progressive resistance exercises:



FIGURE 38-13. A, Eccentric gastroc-soleus exercise with the starting ("up") position performed by the uninvolved lower extremity. **B,** Eccentric gastroc-soleus exercise at the finishing ("down") position. The lowering (eccentric) phase is performed with the bodyweight entirely supported by the involved lower extremity.



FIGURE 38-14. A, Sagittal plane balance and reach. **B,** Frontal plane balance and reach.

- Open kinetic chain quad and hamstring exercises
- Single leg squats
- Lunges or stepup/downs with weights

Plyometrics

- Lower extremity plyometric drills beginning in gravity reduced
- Skipping
- Line hops in sagittal and frontal plane

Functional Exercises

- Running drills
- Lateral shuffle

Sport-Specific Exercises

- Preplanned in controlled environment, such as cutting, lateral shuffles, jumping, hopping, change of directions while jogging

Milestones for Progression to the Next Phase

- Jog 5 to 10 minutes without pain
- Able to perform agility and sport specific drills



FIGURE 38-15. Reduced load plyometrics.

Outcome Measure

- Incorporation of patient reported outcome measures may include use of the Foot and Ankle Disability Index (FADI), Foot and Ankle Disability Index Sport, or Lower Extremity Functional Scale (LEFS)

Phase V (weeks 14 to 24)

Clinical Pearl

> Thorough performance evaluation of the athlete is important to ensure a safe and effective return to preinjury activity levels. Patient reported outcome measures should be greater than 90% and performance testing should demonstrate a limb symmetry index of greater than 85%.

Goals

- Sprint without symptoms
- Jump without symptoms
- Greater than 90% symmetry on performance testing

Therapeutic Exercises

- Olympic lifting (i.e., clean and jerk, snatch)
- Hang cleans or power cleans

Techniques to Increase Muscle Strength, Power, and Endurance

- Ongoing progressive resistance exercises may include squats, lunges, leg press, and stepups/downs.

Plyometrics

- Jump rope
- Box jumps

- Hopping and jumping in the sagittal, frontal, and transverse planes
- Bounding
- Tuck jumps

Functional Exercises

- Sprinting
- Change of direction drills
- Ladder drills

Sport-Specific Exercises

- Reactionary drills (i.e., change of direction in running in response to whistle, transition from running to jumping upon random signal).
- Sport specificity drills should include progression toward total work requirements of sport (duration, volume, and intensity of exercises).

Milestones for Progression to the Next Phase

- Performance of agility and sport specific drills without pain or movement asymmetry
- Limb symmetry index (LSI) of greater than 85% for hop testing
- LSI = Involved limb distance/uninvolved limb distance × 100

Phase VI (weeks 24 to 56)

Criteria for Return to Sport

General

- Athletes should be pain free and demonstrate symmetrical ROM and strength.
- Symmetry of gait with running, cutting, and pivoting movements
- Symmetry of LE jumping (unloading) and landing (loading)
- Hop tests may include any combination of the following and may be selected based upon specificity related to the athlete's sport. Single hop for distance, crossover triple hop for distance, triple hop for distance, and vertical jump should be at least 90% of the distance or height performed on the unaffected limb.

Sport-Specific

- For the athlete with demands for jumping observation of symmetry during jumping and landing should be conducted before sport, intermittently during the event, and then at the end of a simulated game/sport performance to assess for potential degradation of limb symmetry owing to fatigue.
- Needs analysis must be performed for any given sport. The rehab specialist should be able to determine the demands of the sport in question and determine optimal tests and exercises to ensure readiness for return to sport.

After Return to Sport

Continuing Fitness or Rehabilitation Exercises

- Total body strengthening exercises, including lower extremity and core stability
- Plyometrics

Exercises and Other Techniques for Prevention of Recurrent Injury

- Maintenance of strength, mobility, and neuromuscular control/stability.
- Continuing sport specific training.
- Incorporation of effective training principles and caution with consecutive training days of increased training volume.

Evidence

Alfredson H, et al: Heavy-load eccentric calf muscle training for the treatment of chronic Achilles tendinosis. *Am J Sports Med* 26:360–366, 1998.

This prospective study applied a heavy-load eccentric training program versus conventional treatment to 15 recreational athletes (in each group) with chronic Achilles tendinosis. Following the 12-week program all patients in the eccentric training group had returned to preinjury levels of activity. None of the patients in the conventional treatment group returned to preinjury activity levels. (Level II evidence)

Bohu Y, Lefevre N, Bauer T, et al: Surgical treatment of Achilles tendinopathies in athletes. Multicenter retrospective series of open surgery and endoscopic techniques. *Orthop Traumatol Surg Res* 95:S72–S77, 2009.

A retrospective review of the literature with the aim of describing and analyzing surgical treatment of Achilles tendinopathy. (Level IV evidence)

Maffulli N, Kader D: Tendinopathy of tendo achillis. *J Bone Joint Surg Br* 84:1–8, 2002.

A review article discussing Achilles tendinopathy treatment focused on the body of the Achilles and not insertional region conditions. The article reviews tendon pathology, as well as conservative and operative management options with an extensive review of the available literature. (Level IV evidence)

Maffulli N, Longo UG, Denaro V: Novel approaches for the management of tendinopathy. *J Bone Joint Surg Am* 92:2604–2613, 2010.

Current concepts review of management options for Achilles tendinopathy. The article includes a discussion of the pathology along with operative and nonoperative management. The aim of operative treatment is discussed along with new operative procedures. Further research is advocated to evaluate best treatment options for optimal outcomes. (Level V evidence)

Reddy SS, Pedowitz DI, Parekh SG, et al: Surgical treatment for chronic disease and disorders of the achilles tendon. *J Am Acad Orthop Surg* 17:3–14, 2009.

A general overview of Achilles tendinopathy and rupture to include discussion of imaging options and spectrum of disease. A myriad of surgical options are presented with nonsurgical therapy recommended as the primary treatment for most patients. Long-term outcome studies were advocated to further guide treatment decisions. (Level V evidence)

Saltzman CL, Tearse DS: Achilles tendon injuries. *J Am Acad Orthop Surg* 6:316–325, 1998.

A general overview of Achilles tendinopathy and rupture. (Level V evidence)

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1. Maffulli N, Kader D: Tendinopathy of tendo achillis. *J Bone Joint Surg Br* 84:1–8, 2002.
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4. Saltzman CL, Tearse DS: Achilles tendon injuries. *J Am Acad Orthop Surg* 6:316–325, 1998.
5. Bohu Y, Lefevre N, Bauer T, et al: Surgical treatment of Achilles tendinopathies in athletes. Multicenter retrospective series of open surgery and endoscopic techniques. *Orthop Traumatol Surg Res* 95:S72–S77, 2009.
6. Alfredson H et al: Heavy-load eccentric calf muscle training for the treatment of chronic Achilles tendinosis. *Am J Sports Med* 26:360–366, 1998.

Multiple Choice Questions

QUESTION 1. When is running allowed during the rehabilitation protocol?

A. Week 4 to 6
B. Week 6 to 8
C. Week 8 to 10
D. Week 10 to 12

QUESTION 2. When are agility and sport-specific training begun?

A. Week 8
B. Week 10
C. Week 12
D. Week 14

QUESTION 3. When is the walking boot discontinued?

A. Week 2 to 4
B. Week 4 to 6
C. Week 6 to 8
D. Week 8 to 10

QUESTION 4. In what ROM position is the ankle placed for the postoperative splint?

A. 20° of plantarflexion
B. 10° of plantarflexion
C. Neutral ankle position
D. 10° of dorsiflexion

QUESTION 5. How much tendon degeneration is typically involved before a surgeon would strongly consider advanced surgical techniques such as tendon transfer?

A. 0% to 15%
B. 15% to 25%
C. 25% to 50%
D. 50% to 75%

Answer Key

QUESTION 1. Correct answer: **B** (see Week 6 to 8)

QUESTION 2. Correct answer: **C** (see Week 10 to 14)

QUESTION 3. Correct answer: **A** (see Week 2 to 6)

QUESTION 4. Correct answer: **C** (see First 14 Days)

QUESTION 5. Correct answer: **D** (see Surgical Technique)

NONOPERATIVE REHABILITATION OF ACHILLES TENDON RUPTURE

Bradley Wells, PT, DPT, Michael D. Rosenthal, PT, DSc, SCS, ECS, ATC, CSCS, James H. Flint, MD, LCDR, MC USN, and John-Paul H. Rue, MD, CDR, MC USN

GUIDING PRINCIPLES OF NONOPERATIVE REHABILITATION[3]

- Initial immobilization into 20° PF to promote approximation of ruptured tendon
- Patient casted in 20° PF for initial 10 days and is NWB using crutches
- Early mobilization with AROM DF to neutral and PROM PF
- No DF beyond neutral until week 4.
- Rehabilitation of Achilles tendon rupture is directed toward a safe and complete return to preinjury levels of activity.
- Attainment of these goals necessitates soft tissue approximation along with restoration of mobility and strength.
- Recent reviews of operative and nonoperative management have suggested that operative treatment results in better functional outcomes and reduced incidence of rerupture.[1,2]
- However more recent publications have reported comparable functional outcomes between operative and nonoperative treatment groups when early and functional rehabilitation is implemented.[3–6]

Phase I (days 10 to weeks 4)

Protection

- Plantar flexion (PF) cast is discontinued between 10 and 14 days
- Patient placed in removable orthosis with 20° PF
- Non–weight bearing (NWB) using bilateral crutches

Techniques for Progressive Increase in Range of Motion

- Early mobilization performed once every hour with emphasis being on no dorsiflexion (DF) past neutral
- AROM: DF to neutral
- PROM: PF as tolerated

Milestones for Progression to the Next Phase

- Maintenance of soft tissue approximation
- DF to, but not exceeding, neutral

Phase II (weeks 4 to 6)

Protection

- Removable orthosis brought to neutral
- Continued NWB ambulation with use of bilateral crutches

Management of Pain and Swelling

- Rest, ice, compression, elevation, and pain medication as indicated

Techniques for Progressive Increase in Range of Motion

Soft Tissue Techniques

- Gentle soft tissue/cross-friction massage to affected area of tendon
- ROM
  - Mobilization performed once every 2 to 4 hours with emphasis on:
    - AROM: DF not to exceed neutral
    - PROM: PF as tolerated

Other Therapeutic Exercises

- Strengthening of the proximal lower extremity muscles
  - Straight leg raises, open kinetic chain knee extension and flexion
- Strengthening exercises for unaffected lower extremity (LE) can be performed as long as affected LE remains NWB

Activation of Primary Muscles Involved

- Submaximal isometric muscle contraction of the posterior lower leg musculature and affected Achilles tendon is permissible in the PF cast and orthosis. Muscles involved include the gastrocnemius and soleus.

Clinical Pearl

The rehabilitation specialist must closely monitor restoration of DF mobility to prevent overzealous return of mobility. The possibility of excessive DF and unwarranted lengthening of the healing Achilles results in poor muscular function in the later stages of rehabilitation and suboptimal outcome.[7] Essential to this surveillance is effective education of the athlete regarding this topic.

Phase III (weeks 6 to 8)

Protection

- Weight-bearing as tolerated (WBAT) in orthosis with heel lift of 2 to 3 cm.

Management of Pain and Swelling

- Rest, ice, compression, elevation, pain medication as indicated
- Electrical stimulation

TIMELINE 38-3: **Nonoperative Rehabilitation for Acute Achilles Tendon Rupture**

Phase I (weeks 0 to 4)		PHASE II (weeks 4 to 6)	PHASE III (weeks 6 to 8)
Day 0–10	Day 10-Week 4		
• Cast in 20° PF • NWB using crutches	• D/C PF cast Apply removable orthosis set to 20° PF • Every hour-AROM DF not to exceed neutral and PROM PF	• Removable orthosis brought to neutral • Gentle soft tissue mobilization • Gentle gastroc/soleus isometrics • SLRs, OKC knee extensions and flexion • Well leg exercises	• WBAT in orthosis with 2- to 3-cm heel lift • Gait training on level surface in orthosis • Joint mobilizations • Balance and proprioceptive training in orthosis • DF AROM not to exceed 10° • Begin pool therapy: Walk → run in full emersion • Stationary bike in orthosis • CKC exercises in orthosis: squats, leg press with DF to neutral

Techniques for Progressive Increase in Range of Motion

Range of Motion

- Mobilization performed once every 3 to 4 hours with emphasis on:
  - AROM: DF not to exceed 10°
  - PROM: PF as tolerated

Manual Therapy Techniques

- Posterior and anterior ankle mobilizations of the talus on tibia.
- Medial and lateral subtalar joint mobilizations

Soft Tissue Techniques

- Soft tissue massage may include instrumented soft tissue mobilization techniques and cross friction massage to affected Achilles tendon.

Stretching/Flexibility Techniques for the Musculotendinous Unit

- Begin gentle DF stretching not to exceed 10°. Stretching should begin in the open kinetic chain mode and progress to include closed kinetic chain stretching.
- AAROM and AROM exercises are initiated for plantar flexion, inversion, and eversion.

Other Therapeutic Exercises

- Total leg strength exercises: static lunge with involved leg forward, wall squats or leg press with control of CKC DF to neutral
- Core stability exercises: front plank with pain-free stress on the involved LE and side planks
- Initiation of isolated strengthening of the gastroc-soleus complex with gentle resistance band plantarflexion exercise

Sensorimotor Exercises

- While in the orthosis the athlete may begin weight shift exercises progressing toward single leg balance as long as there is no Achilles pain.

Open and Closed Kinetic Chain Exercises

- OKC exercises to include straight-leg raises (SLRs), knee extension, and knee flexion.



FIGURE 38-16. Gravity reduced, dorsiflexion limited, squats.

- CKC exercises may include gravity reduced squats (Figure 38-16) progressing to wall squats and leg press. DF should not exceed neutral during performance of these exercises

Milestones for Progression to Advanced Sport-Specific Training and Conditioning

- AROM: DF 10°, PF, eversion, inversion normal
- Pain free full weight-bearing

Phase II (weeks 8 to 12)

Protection

- Discontinue orthosis
- Patient permitted full weight bearing
- Patient is permitted to wear normal shoes with heel lift of 1 cm if needed.

Management of Pain and Swelling

- Same as Phase III

TIMELINE 38-3 Nonoperative Rehabilitation for Acute Achilles Tendon Rupture (Continued)

PHASE IV (weeks 8 to 12)	PHASE V (weeks 12 to 16)	PHASE VI (weeks 16 to 24)
• Remove Orthosis, 1 cm heel lift as needed • Seated heel/toe raises • OKC PF with resistance bands • CKC exercises: step ups → step downs • Proprioceptive training: double leg → single leg balance drills • Gait training on treadmill level surface → gentle incline • Stationary bike • Pool therapy: Double leg toe raise → single leg	• Squats, lunges, leg press, lunges, leg press • Pool therapy: gentle jogging and hopping-start in chest deep water → waist deep	• Olympic/power lifting • Plyometrics • Walk-jog progression • Screening for return to sports and implementation/progression of sport-specific exercises

Techniques for Progressive Increase in Range of Motion

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Gradual progression of DF stretching in both OKC and CKC. DF ROM should gradually improve and not exceed the uninvolved LE.

Other Therapeutic Exercises

- Total leg strength exercises: deadlift, straight leg deadlifts

Activation of Primary Muscles Involved

- Seated heel and toe raises (Figure 38-17*A,B*)
- Bilateral heel raises starting with the majority of weight on the uninvolved leg and progressing to increase work performed by the involved LE.
- Low level eccentric muscle strengthening of the gastrocsoleus complex may be initiated in an OKC manner. Patient to perform active PF with minimal resistance, apply eccentric force with belt or strap and allow gradual movement into available end range of DF.

Sensorimotor Exercises

- Frontal and sagittal plane weight shifting from double leg stance to single leg stance. Progression of sensorimotor training will include changing the support surface (i.e., foam, wobble board), altering visual input (i.e., eyes open, eyes closed), and adding movement of the UE or uninvolved LE in the sagittal, frontal, or transverse planes.

Open and Closed Kinetic Chain Exercises

- Progression of Phase III exercises by increasing the amount of resistance and amplitude (ROM) of movement with DF beyond neutral.
- Additional CKC exercises: step ups, step downs, progression of heel rise to single leg toward the end of Phase IV

Criteria for Abandoning Nonoperative Treatment and Proceeding to Surgery or More Intensive Intervention

- Failure of tendon ends at rupture site to approximate within 10 mm with ankle in neutral position.[7]
- Failure of tendon ends to completely approximate in 20° of ankle PF.[7]
- Surgical intervention may be suggested if rerupture occurs after nonoperative management.

Milestones for Progression to Advanced Sport-Specific Training and Conditioning

- Full ankle ROM in OKC and CKC
- Patient able to perform single leg heel rise
- 5/5 strength of proximal LE muscle
- Normal gait

Phase II (weeks 12 to 16)

Management of Pain and Swelling

- Same as Phase III

Therapeutic Exercises

- Total leg strength exercises: squats, lunges, leg press
- Core exercises: wood chopper, diagonal chop and lift pattern (Figure 38-18*A,B*)
- Pool therapy: form walking (high knees with heel rise), jogging, and jumping progressing to hopping (chest deep water progressing to waist deep water)



FIGURE 38-17. A, Seated heel raise. **B,** Seated toe raise.



FIGURE 38-18. A, Diagonal chop. **B,** Diagonal lift.

Plyometrics

- At week 12 jogging and hopping exercises are initiated in the pool. At week 16 a ground based return to running program and gravity reduced plyometrics (Figure 38-19) may be initiated if the patient is able to perform 10 to 15 single leg heel rises without pain.

Phase VI (weeks 16 to 24)

Management of Pain and Swelling

- Same as Phase III

Therapeutic Exercises

- Total leg strength exercises: front squats and multi-directional lunges
- Total body strengthening: deadlifts, hang cleans, power cleans



FIGURE 38-19. Gravity reduced plyometrics.

Plyometrics

- Begin dry land jumping and observe for symmetry of loading/unloading and monitor the athlete's response. Plyometric volume will begin at 20 to 30 foot contacts twice weekly from weeks 16 to 20. Foot contacts may increase from 20 to 50 foot contacts per workout with two to four sessions per week during weeks 20 to 24.[8,9]
- Jumping drills should include sagittal, frontal, and transverse plane movements.

Running Progression

- Walk-jog progression for weeks 16 to 20 with emphasis on increasing duration or volume of running, 2 to 3 days per week.
- Weeks 21 to 24: Begin to focus on increasing the speed of running. Continue with running 2 to 3 days per week.

Tips and Guidelines for Transitioning to Performance Enhancement

- Transition to performance enhancement begins when the athlete is able to demonstrate normal running gait, pain free jumping/hopping capability, and expresses readiness and desire to advance.
- An athlete's fear of injury in returning to higher level activities should be questioned and addressed before initiation of sports specific and performance enhancement training. Initiation of performance enhancement training should include progressing level of intensity and frequency of training.
- Additional progression should involve transition from preplanned movements/activities to react and respond drills.

Performance Enhancement and Beyond Rehabilitation: Training/ Trainer and Optimization of Athletic Performance

- Performance optimization requires thorough demand analysis of the athlete's sport in preparation for safe and effective return to preinjury levels of competition.
- Training will progress along the spectrum of functional demands to include increasing intensity (speed, resistance) of movements, volume (duration and frequency) of training, and specificity (i.e., drills, directions of movement, rest patterns).
- Recovery and active rest are also strategic components in program planning for return to sport.

Specific Criteria for Return to Sports Participation: Tests and Measurements

- Single leg heel rise, symmetry of greater than 90% (number of repetitions to failure)
- Single leg hop for distance symmetry of greater than 90%
- Single leg vertical jump symmetry of greater than 90%
- Agility drills and hop tests performed without visual evidence of altered loading/unloading
- Athlete self-reported outcome measure of greater than 85%

Evidence

Hufner T, et al: Long-term results after functional nonoperative treatment of Achilles tendon rupture. *Foot Ankle Intl* 27:167–171, 2006.

This study reviewed the effectiveness of a treatment protocol for non-operative treatment of Achilles tendon rupture: 73.5% (N = 94) of patients were able to return to sport. The re-rupture rate was 6.4%. Strength was considered normal in 65.6% of patients. Nonoperative treatment achieved good results, but modifications to the treatment protocol were made at the conclusion of the study based on the results, including a repeat ultrasound 2 to 5 days after the first US to conclude nonoperative management is indicated, extending the use of 3-cm hindfoot elevation from 6 to 8 weeks, and then 1-cm hindfoot elevation in shoes for the following 3 months. (Level IV evidence)

Khan R, et al: Treatment of acute Achilles tendon ruptures: A meta-analysis of randomized, controlled trials. *J Bone Joint Surg* 87:2202–2210, 2005.

This meta-analysis included 12 trials involving 800 patients. Re-rupture occurred in 3.5% of patient treated operatively and 12.6% in patients treated nonoperatively. Complications besides re-rupture (infection, adhesions, decreased sensation) were found in 34.1% of operative patients versus 2.7% of nonoperative patients. It was also found that in those who suffered re-rupture, 2.4% were in a functional brace versus 12.2% who were casted. The authors concluded that operative management decreases the risk for re-rupture in Achilles tendon rupture repair patients but also raises the risk of other complications. (Level I evidence)

Nilsson-Helander K, et al: Acute Achilles tendon rupture: A randomized, controlled study comparing surgical and nonsurgical treatments using validated outcome measures. *Am J Sports Med* 38:2186–2193, 2010.

This study compared the 6- and 12-month outcomes in groups randomized to surgical versus conservative management. At 6 months the operative group performed superiorly on functional tests. At 12 months the surgical group was superior only in the heel rise work test. In both groups the functional performance on the injured limb was inferior to the uninjured limb at 12 months. (Level I evidence)

Twaddle B, et al: Early motion for Achilles tendon ruptures: Is surgery important? *Amer J Sports Med* 35:2033–2038, 2007.

This randomized prospective study placed 42 patients with acute Achilles tendon rupture in an operative or nonoperative group. Both groups received early motion in a removable orthosis and progressed to full weight-bearing in 8 weeks. Patients were followed over a 12-month period. There were no significant differences in plantarflexion, dorsiflexion, calf circumference, or MFAI scores. Early motion was deemed an acceptable form of rehabilitation for both surgically and nonsurgically treated patient who have suffered an acute Achilles tendon rupture. (Level I evidence)

Weber M, et al: Nonoperative treatment of acute rupture of the Achilles tendon: Results of a new protocol and comparison with operative treatment. *Amer J Sports Med* 31:685–691, 2003.

This retrospective cohort study compared 23 patients with acute Achilles tendon rupture treated nonoperatively with a equinus ankle cast and boot to 24 patients with the same injury who were treated operatively. Subsidence of pain, return to unaided walking, and return to work were faster for the nonoperative patients. Patient satisfaction, return to sports, and ultimate strength were found to be the same in both groups. The authors concluded that operative and nonoperative treatments for Achilles tendon rupture were equivalent. (Level II evidence)

Willits K, et al: Operative versus nonoperative treatment of acute Achilles tendon ruptures. *J Bone Joint Surg (Am)* 92:2767–2775, 2010.

This study randomized 144 patients and found better plantarflexion strength in the operative group at 1 year with other outcome measures demonstrating no significant differences. (Level I evidence)

Wong J, et al: Quantitative review of operative and nonoperative management of Achilles tendon ruptures. *Am J Sports Med* 30:565–575, 2002.

This review of 125 articles reported that re-rupture rates were greatest in the immobilized conservative management groups (10%) and skin healing complications highest in the open repair group and immobilization group (14.6%). It was noted that most articles had low quality of methodology and that a trend toward earlier mobilization was becoming apparent in the literature. Open repair and early mobilization was reported to provide the best outcomes. (Level I evidence)

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2. Khan R, et al: Treatment of acute Achilles tendon ruptures: A meta-analysis of randomized, controlled trials. *J Bone and Joint Surg (Am)* 87:2202–2210, 2005.
3. Twaddle B, et al: Early motion for Achilles tendon ruptures: Is surgery important? *Am J Sports Med* 35:2033–2038, 2007.
4. Weber M, et al: Nonoperative treatment of acute rupture of the Achilles tendon: Results of a new protocol and comparison with operative treatment. *Am J Sports Med* 31:685–691, 2003.
5. Willits K, et al: Operative versus nonoperative treatment of acute Achilles tendon ruptures. *J Bone Joint Surg (Am)* 92:2767–2775, 2010.
6. Nilsson-Helander K, et al: Acute Achilles tendon rupture: A randomized, controlled study comparing surgical and nonsurgical treatments using validated outcome measures. *Am J Sports Med* 38:2186–2193, 2010.
7. Hufner T, et al: Long-term results after functional nonoperative treatment of Achilles tendon rupture. *Foot Ankle Intl* 27:167–171, 2006.
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9. Chmielewski TL, Myer GD, Kauffman D, et al: Plyometric exercise in the rehabilitation of athletes: Physiological responses and clinical applications. *J Orthop Sports Phys Ther* 36:308–319, 2006.

Multiple Choice Questions

QUESTION 1. In the proposed treatment protocol for nonoperative management of acute Achilles tendon rupture, dorsiflexion beyond neutral should be avoided for _____ weeks.

A. 3
B. 4
C. 5
D. 6

QUESTION 2. During Phase I, the patient should remain in a removable orthosis set at _____ degrees of plantar flexion.

A. 10
B. 15
C. 20
D. 30

QUESTION 3. Gentle gastroc/soleus isometrics can be initiated during which phase of rehabilitation?

A. I
B. II
C. III
D. IV

QUESTION 4. During Phase III, which weight bearing status is recommended?

A. Full weight bearing (FWB)
B. Toe touch weight bearing (TTWB)
C. Non–weight bearing (NWB)
D. Weight bearing as tolerated (WBAT)

QUESTION 5. Return to running may begin during week _____ if the patient is symptom free.

A. 16
B. 12
C. 20
D. 23

Answer Key

QUESTION 1. Correct answer: **B** (see Box A: Guiding Principles of Rehabilitation)

QUESTION 2. Correct answer: **C** (see Phase I)

QUESTION 3. Correct answer: **B** (see Phase II)

QUESTION 4. Correct answer: **D** (see Phase III)

QUESTION 5. Correct answer: **A** (see Phase IV or Rehabilitation Timeline)

POSTOPERATIVE REHABILITATION OF ACHILLES TENDON RUPTURE

James H. Flint, MD, LCDR, MC USN, Michael D. Rosenthal, PT, DSc, SCS, ECS, ATC, CSCS, Charles E. Rainey, PT, DSc, DPT, OCS, SCS, CSCS, FAAOMPT, and John-Paul H. Rue, MD, CDR, MC USN

Indications for Surgical Treatment

- Failure of nonoperative measures, particularly in elite athletes who desire better functional performance and decreased rate of re-rupture[1–6]
- Patient preference

Brief Summary of Surgical Treatment

Major Surgical Steps

- Choice of anesthesia, patient in prone position on well-padded table
- Place tourniquet on affected extremity before rolling, consider bilateral prep to allow direct comparison of resting posture and tone presurgical and postsurgical repair
- Posteromedial incision to avoid small saphenous vein and sural nerve (Figure 38-20)
- Full-thickness incision through skin and paratenon directly down to tendon fibers
- Identify ragged edges proximal and distally ("mop ends") and judiciously trim back to more organized tissue (Figure 38-21).
- Suture the free ends using heavy, nonabsorbable suture; various techniques have been described and



FIGURE 38-20. A posteromedial incision is made to avoid the sural nerve and small saphenous vein. The length of incision will vary to allow optimal exposure and access to the tendon.



FIGURE 38-21. Exposed "mop-ends"; these will need to be trimmed judiciously to allow a cleaner, more organized, repair.

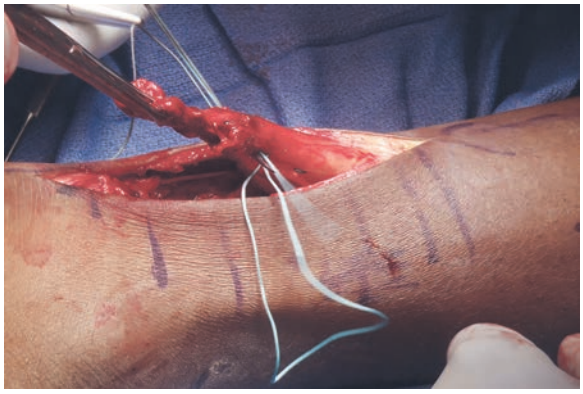

FIGURE 38-22. Various suture techniques are described. The Bunnell stitch was used in this case.

modifications exist (i.e., Bunnell, Kessler, Krackow)[5] (Figure 38-22).

- Once the tendon is repaired, ensure the foot does not fall into dorsiflexion.
- Close the paratenon and skin in layers (Figures 38-23 and 38-24).
- Dress the wound, place the patient in a short-leg splint in resting plantar-flexion (Figure 38-25).

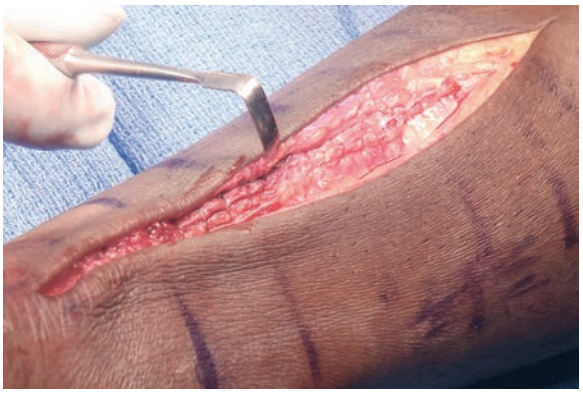

FIGURE 38-23. The paratenon is carefully preserved and reclosed with absorbable suture.

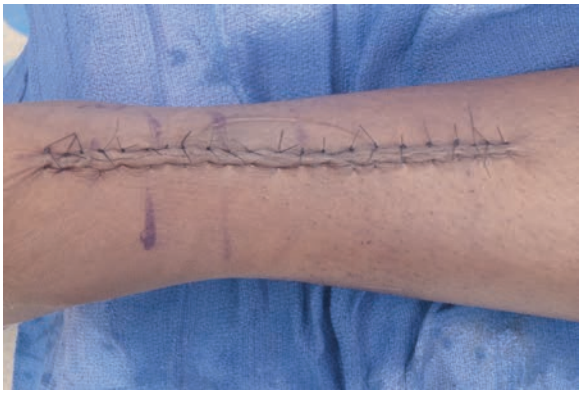

FIGURE 38-24. Various methods of skin-closure exist. Interrupted sutures allow equal tensioning of the skin, easy removal, and allows the surgeon to remove some sutures while leaving others in place (helpful when encountering skin healing issues)



FIGURE 38-25. A sterile dressing is applied and the ankle is secured in a plaster splint, with the ankle is resting plantar-flexion to protect the repair.

Factors That May Affect Rehabilitation

Anesthetic

- As indicated, patients may benefit from short-term narcotic analgesia. Be aware of the patient's pain medication needs and tailor accordingly.

Surgical

- Size of exposure
  - More extensive repairs require more extensive surgical incisions. Rehabilitation should not impede sufficient wound healing; stable soft tissue healing is necessary before aggressive rehabilitation.
- Amount of tendon retraction
  - If tendon edges were retracted and extensive plantarflexion, or advanced surgical techniques were required for repair (see the following), more time will need to be spent on recovering range of motion before aggressive rehabilitation.
- Quality of the tendon
  - For patients with underlying tendinosis or otherwise compromised tissue, consider allowing more time for the repair to heal before starting aggressive rehabilitation.

Other Surgical Techniques and Options

- Percutaneous repair
  - Alternative to simple open repair, with comparable outcomes[2,4,8]
  - Various techniques described, with varying number of stab incisions or small transverse incisions performed, and similar suture patterns to open repair[2,4,8]
- Advanced repair options (for chronic rupture or tendon retraction greater than 3 cm)[5,9]
  - Gastrocnemius turn-down
  - V-Y advancement
  - Tendon transfers/augmentation
    - That is FDL, FHL

Before Surgery: Overview of Goals, Milestones, and Guidelines[2]

GUIDING PRINCIPLES OF POSTOPERATIVE REHABILITATION

- Understanding the type of surgical procedure and quality of the repair.
- Understanding the stages of healing and the anatomic structures involved.
- Employing a systematic approach to soft tissue loading to optimize recovery.

[2]*Prehabilitation, if appropriate, is described in the Nonoperative Rehabilitation section of this chapter.*

Phase I (days 0 to 14): Immediate Postoperative Period

Clinical Pearl

Gentle non–weight-bearing motion may begin as early as postoperative day 1 in a motion restricted splint or brace. Passive and active ROM is limited to neutral dorsiflexion (DF), whereas there are no ROM limitations on gentle plantar flexion (PF), inversion (INV), or eversion (EV) during the first 6 weeks. Early return to DF ROM is likely to contribute to unwanted lengthening and tendon compliance, contributing to suboptimal outcomes.[10]

Goals

- Protect repaired Achilles tendon.
- Decrease pain and inflammation.
- Prevent effects of immobilization.

Protection

- Padded plantigrade splint is applied for first 24 to 96 hours (see Figure 38-25)
- Rigid walking boot with three heel wedges resulting in approximately 20° of equinus is applied after splint is discontinued.
- Weight bearing as tolerated on crutches with rigid walking boot.

Management of Pain and Swelling

Pain

- Oral pain medications
- Cryotherapy to reduce pain and inflammation.
- Therapeutic modalities such as TENS and IFC e-stim.

Swelling

- Cryotherapy to reduce swelling
- Elevation of surgical limb

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Grades I and II talocrural, subtalar, distal tibiofibular, and mid-foot joint mobilizations

Soft Tissue Techniques

- N/A until incision is healed.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Ankle circles (ABCs) with DF limited to neutral

Other Therapeutic Exercises

- Total leg strength: straight leg raises and side lying hip abduction

- Core stability: hook lying side planks, front planks on knees

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Three-way ankle isometrics: DF, inversion (INV), and eversion (EV)

Milestones for Progression to the Next Phase

- Able to perform Phase I exercises without pain or increase in swelling

Phase II (weeks 2 to 6)

Clinical Pearls

Rigid walking boot with heel lifts are used for 6 weeks. At week 2 to 4, ambulation occurs in full weight bearing using walking boot with two heel lifts without crutches. At week 4, remove one heel lift from walking boot. Discontinue crutches at week 2 to 4 and walking boot at week 6.

Goals

- Protection of repaired structures
- Decrease pain and inflammation
- Neutral DF ROM
- Discontinue use of crutches and walking boot
- Full weight-bearing status

Protection

- Use a walking boot for ambulation without crutches as tolerated

Management of Pain and Swelling

- Same as Phase I

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Grades I and II talocrural, subtalar, distal tibiofibular, and mid-foot joint mobilizations

Soft Tissue Techniques

- Achilles tendon soft tissue mobilizations
- Scar mobilizations to surgical incision

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Gentle towel calf stretch not to exceed neutral DF
- Ankle circles (ABCs)

Other Therapeutic Exercises

- Stationary bike with walking boot
- TLS as in Phase I. Add open kinetic chain (OKC) knee extension and flexion

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Resistance band exercises—DF, INV, and EV
- Four-way ankle isometrics
- Sitting calf (heel) raises beginning at week 5

Techniques to Increase Muscle Strength, Power, and Endurance

- Bodyweight squats and wall sits beginning at week 5 in walking boot

Neuromuscular Dynamic Stability Exercises

- Seated BAPS board

Milestones for Progression to the Next Phase

- Phase II exercises performed without pain or swelling
- Ambulates without assistance device

TIMELINE 38-4: **Postoperative Rehabilitation for Acute Achilles Tendon Rupture**

PHASE I (weeks 1 to 2)	PHASE II (weeks 3 to 6)	PHASE III (weeks 6 to 10)
• Splint (first 24 h) • Walking boot (three heel lifts) with crutches • PROM for DF not to exceed neutral • AROM ankle exercises (DF, EV, INV) • Joint mobilizations • Cryotherapy, e-stim	• Walking boot (two heel lifts) • DC crutches • Cryotherapy, E-stim • PROM for DF (not past neutral), PF, Inv, Ev • AROM for all ankle motions • Isometric and resistance band exercises • OKC PREs for knee and hip • Bodyweight squats, wall sits in boot • Stationary bike in boot • Joint mobilizations • Scar mobilization • Gait training with walking boot	• DC walking boot at week 6 • Wear shoes with one heel lift (D/C heel lift at week 8) • Resistance band exercises • Sitting heel raises • Stair climber • Aquatic therapy • Gait training • CKC Achilles stretch • Step ups • Bodyweight squat, lunges • Leg press • Single leg stance/balance exercises • Standing BAPS • Remove heel lift from shoes at week 8

Phase III (weeks 6 to 10)

Clinical Pearl

At week 6 the walking boot is discontinued. Ambulate in athletic shoes with one ¼- to ½-inch heel lift progressing to walking without a heel lift by week 8 to 10.

Goals

- Restore normal gait mechanics without heel lifts in shoes
- Full active ankle ROM

Protection

- Discontinue walking boot for ambulation

Management of Pain and Swelling

- Same as Phase I
- For swelling, cryotherapy as needed.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Grades II and III talocrural, subtalar, distal tibiofibular, and mid-foot joint mobilizations

Soft Tissue Techniques

- Achilles tendon soft tissue mobilizations

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Towel calf stretch
- Gentle standing calf stretch (straight and bent leg). DF should be compared with the uninvolved LE with education of avoidance of overstretching.

Other Therapeutic Exercises

- Stationary bike
- Aquatic therapy: swimming, gait training, deep water aqua jogging with floatation device/belt
- Stair climber[7,8]
- TLS: leg press, static lunges, step-ups, OKC hamstring curls and knee extensions

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Resistance band exercises—DF, PF, EV, INV
- Sitting heel raises progression to bilateral standing calf raises at week 7 to 8

Sensorimotor Exercises

- In-line tandem walking
- Single limb stance progression
- Standing BAPS
- Walking on mini-trampoline

Techniques to Increase Muscle Strength, Power, and Endurance

- Wall sits
- Step-up, lateral step up, and forward step down

Functional Exercises

- Gait training
- Stair climbing
- Backward walking on treadmill
- Side stepping using agility ladder or cones

Milestones for Progression to the Next Phase

- Perform Phase III exercises without pain or swelling
- Ambulate without heel lift
- Full ankle AROM
- Able to perform bilateral calf raises
- Symmetrical unilateral stance

TIMELINE 38-4 Postoperative Rehabilitation for Acute Achilles Tendon Rupture (Continued)

PHASE IV (weeks 10 to 14)	PHASE V (weeks 14 to 24)	PHASE VI (weeks 24 to 52)
• Elliptical trainer • Walk-jog progression • PREs for all motions • OKC eccentric Achilles loading • Bilateral standing heel raises • SL balance and reach • Patient reported outcome measures	• SL heel raises • SL squats • Jog progression to running/sprint drills • Form running drills • Plyometrics @ 20 wks • Olympic style lifts @ 20–24 wks • Agility and sport-specific drills • Hop testing • Patient-reported outcome measures	• Individual strength and flexibility program based off impairments • Running/sprint drills • Plyometrics • Agility and sport-specific drills (skipping → hopping → jumping) • Return to sport

Phase IV (weeks 10 to 14)

Clinical Pearl

Walk-jog progression may begin at 10 to 12 weeks. Initiation of jogging is contingent upon normal walking gait, full AROM, ability to perform bilateral concentric heel raising, and at least 4+/5 strength of all lower extremity muscle groups (except gastrocsoleus). Begin agility and sport specific drills at week 12 if athlete has been able to resume jogging.

Goals

- Restore normal gait mechanics.
- Continue lower chain strengthening.
- Begin jogging and agility training.

Techniques for Progressive Increase in Range of Motion

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Same as Phase III

Other Therapeutic Exercises

- Outdoor biking
- Elliptical trainer
- Stair machine
- TLS: deadlifts, squats, lunges
- Core stability: woodchopper, diagonal chop and lift patterns, front and side planks

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Seated progressing to standing single leg calf (heel) raises
- Eccentric Achilles loading exercises in non–weight bearing using a resistance band or stretch strap
- Bilateral standing calf (heel) raises

Sensorimotor Exercises

- Hurdle step over
- In-line lunges
- Single leg balance and reach in the sagittal plane, frontal plane, and diagonal patterns

Techniques to Increase Muscle Strength, Power, and Endurance

- Bodyweight squats and lunges, leg press.
- Lateral step-up/down, sagittal plane step-up/down

Plyometrics

- Form walking with high knees and heel raises

Functional Exercises

- Walk to jog progression
- Jogging to running drills

Sport-Specific Exercises

- Lower extremity drills in controlled environment, such as figure-eight jogging, side shuffles, and cutting (i.e., 45° change of direction)

Milestones for Progression to the Next Phase

- Perform Phase IV exercises without pain or swelling
- Able to perform concentric single leg heel raise
- Able to jog

Outcome Measure

- Patient reported outcome measures should be implemented at week 12. Outcome measures may include the Foot and Ankle Disability Index (FADI), Foot and Ankle Disability Index Sport, Lower Extremity Functional Scale (LEFS), and Achilles tendon Total Rupture Score (ATRS).

Phase V (weeks 14 to 24)

Clinical Pearl

Exercise progression in the final stages of rehabilitation should incorporate changes increases in amplitude of movement (ROM), rate of movement (speed), and volume (repetitions or time of activity). Additionally exercises should include transitioning from simple to more complex (multiplanar) movement patterns.

Goals

- Continue agility and sport specific training
- Continue lower extremity strengthening

Techniques for Progressive Increase in Range of Motion

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Same as Phase IV

Other Therapeutic Exercises

- Progression of Phase IV exercises

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Single leg calf raises
- Eccentric Achilles loading in bilateral stance progressing to single leg eccentric loading between weeks 20 to 24

Sensorimotor Exercises

- Progression of phase IV exercises

Techniques to Increase Muscle Strength, Power, and Endurance

- Olympic lifting techniques (i.e., push-press, cleans, snatches) may begin at around 20 weeks beginning with light weight.
- Single leg squats

Plyometrics

- Gravity reduced jumping (Figure 38-26)
- Skipping
- Line jumping (sagittal and frontal plane)
- Tuck jumps
- Box jump up with step-down progressing to jump up and jump off at week 20 to 24
- Single leg hopping in the frontal, sagittal, and transverse planes
- Bounding

Functional Exercises

- Form running drills
- Ladder drills
- Change of direction drills (i.e., forward to backward running)
- Increasing speed of jogging/running
- Outdoor running

Sport-Specific Exercises

- Lower extremity drills in controlled environment, such as cutting, side shuffles, jumping, hopping
- Reactionary drills (i.e., change of direction in running in response to whistle, transition from running to jumping upon random signal).
- Sport specificity drills should include progression toward total work requirements of sport (duration, volume, and intensity of exercises).

Milestones for Progression to the Next Phase

- Performance of Phase V activities without pain or swelling



FIGURE 38-26. Gravity reduced plyometric exercise.

- Performance of agility and sport specific drills without pain or movement asymmetry
- Limb symmetry index (LSI) of greater than 85% for hop testing.
  - LSI = Involved limb distance/uninvolved limb distance × 100
- Running gait without asymmetry
- Less than 10% side-to-side deficit on isokinetic testing

Phase VI (weeks 24 to 52)

Criteria for Return to Sport

General

- Athletes should be pain free and demonstrate symmetrical ROM and strength.
- Symmetry of gait with running, cutting, and pivoting movements
- Symmetry of LE jumping (unloading) and landing (loading).
- Hop tests may include any combination of the following and may be selected based upon specificity related to the athlete's sport. Single hop for distance, crossover triple hop for distance, triple hop for distance, and vertical jump should be at least 90% of the distance or height performed on the unaffected limb.

Sport-Specific

- Limb symmetry observed in the rested state does not guarantee acceptable symmetry throughout the performance of sport. Athletes should be closely monitored for asymmetrical limb performance during jumping, landing and running tasks upon returning to sport. Asymmetry of limb performance is likely to manifest with increasing levels of fatigue.
- American football and soccer athletes should be able to perform sport-specific performance testing (i.e., pro-agility run, T-drill, and on field maneuvers) with symmetry (no indication of favoring the involved LE).
- Needs analysis must be performed for any given sport. The rehabilitation specialist should be able to determine the demands of the sport in question and determine optimal tests and exercises to ensure readiness for return to sport.

After Return to Sport

Continuing Fitness or Rehabilitation Exercises

- Total body strengthening exercises, including lower extremity and core stability
- Single leg eccentric Achilles training

Exercises and Other Techniques for Prevention of Recurrent Injury

- Prevent injury reoccurrence by maintaining strength, mobility, and neuromuscular control/stability.
- Continuing sport-specific training is recommended for optimal performance upon returning to sports.

Evidence

Bhandari M, Guyatt GH, Siddiqui F, et al: Treatment of acute Achilles tendon ruptures: A systematic overview and metaanalysis. *Clin Orthop Relat Res* 190–200, 2002.

A systematic review and metaanalysis of the literature to determine the effect of surgical versus conservative treamtent of acute Achilles tendon rupture. Surgical treatment was associated with a lower re-reputure rate, but higher risk of infection when compared with conservative therapy. (Level I evidence)

Gigante A, Moschini A, Verdenelli A, et al: Open versus percutaneous repair in the treatment of acute Achilles tendon rupture: A randomized prospective study. *Knee Surg Sports Traumatol Arthrosc* 16:204–209, 2008.

This prospective, randomized study of 40 patients compared open versus percutaneous Achilles tendon repair. At 12 months, Short Form-12 questionnaire, ultrasound scanning for tendon integrity, and isokinetic testing did not show significant differences between groups. (Level I evidence)

Henriquez H, Munoz R, Carcuro G, et al: Is percutaneous repair better than open repair in acute Achilles tendon rupture? *Clin Orthop Relat Res* 470(4):998–1003, 2012.

This retrospective review of 32 cases compared outcomes of patients treated with open versus percutaneous repair techniques. They conclude that percutaneous repair provides similar postoperative ROM and strength with no apparent difference in re-rupture rate, with better cosmesis and fewer wound complications. (Level III evidence)

Maffulli N, Longo UG, Maffulli GD, et al: Achilles tendon ruptures in elite athletes. *Foot Ankle Int* 32:9–15, 2011.

This retrospective case series of 17 patients evaluates outcomes after percutanous Achilles tendon repair in elite athletes. They report an average time to return to full sports of 4.8 ± 0.9 months and conclude that percutaneous repair is a good option for elite athletes. (Level IV evidence)

McCoy BW, Haddad SL: The strength of achilles tendon repair: A comparison of three suture techniques in human cadaver tendons. *Foot Ankle Int* 31:701–705, 2010.

This cadaveric study compares three suture repair techniques for Achilles tendon ruptures regarding strength; no significant difference was found.

Metz R, Verleisdonk EJ, van der Heijden GJ, et al: Acute Achilles tendon rupture: Minimally invasive surgery versus nonoperative treatment with immediate full weightbearing—a randomized controlled trial. *Am J Sports Med* 36:1688–1694, 2008.

This randomized controlled trial of 83 patients evaluates complications other than re-rupture in patients treated with minimally invasive surgery versus nonoperative treatment. They conclude that although a clinically important difference in the rate of complications exists, the data did not reach statistical significance. (Level II evidence)

Mullaney MJ, McHugh MP, Tyler TF, et al: Weakness in end-range plantar flexion after Achilles tendon repair. *Am J Sports Med* 34:1120–1125, 2006.

This study assessed plantar flexion strength and dorsiflexion stiffness following Achilles tendon repair in 20 patients. Passive joint stiffness was 34% lower on the involved side and plantarflexion weakness was 20% to 34% weaker. Additionally, nearly 75% of the patients were unable to perform a decline heel rise at follow up (average 1.8 years postoperative). (Level III evidence)

Reddy SS, Pedowitz DI, Parekh SG, et al: Surgical treatment for chronic disease and disorders of the achilles tendon. *J Am Acad Orthop Surg* 17:3–14, 2009.

A general overview of Achilles tendinopathy and rupture.

Rettig AC, Liotta FJ, Klootwyk TE, et al: Potential risk of rerupture in primary achilles tendon repair in athletes younger than 30 years of age. *Am J Sports Med* 33:119–123, 2005.

This retrospective review of 89 patients evaluated the risk of Achilles tendon rerupture in patients under 30 years old versus patients over 30. They observed four re-ruptures, for an overall rate of 4.5%. All of the re-ruptures occurred in the younger population, giving a re-rupture rate of 16.6% in patients less than 30 years old. They conclude that caution should be taken during rehabilitation of younger patients. (Level IV evidence)

Saltzman CL, Tearse DS: Achilles tendon injuries. *J Am Acad Orthop Surg* 6:316–325, 1998.

A general overview of Achilles tendinopathy and rupture.

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Multiple Choice Questions

QUESTION 1. When is the earliest the walking boot can be discontinued?

A. Week 2
B. Week 4
C. Week 6
D. Week 8

QUESTION 2. When is agility and sport specific training begun?

A. Week 8
B. Week 10
C. Week 12
D. Week 14

QUESTION 3. When can running activities begin?

A. Week 6
B. Week 8
C. Week 10
D. Week 12

QUESTION 4. When is the patient able to ambulate in shoes without no heel lifts?

A. Week 6
B. Week 7
C. Week 8
D. Week 9

QUESTION 5. When performing an open repair for an acute Achilles tendon rupture, where do you make the incision to avoid inadvertent damage to the sural nerve?

A. Posterolateral
B. Posteromedial
C. Direct posterior
D. Transversely at the rupture site

QUESTION 6. How has surgical repair of the ruptured Achilles been demonstrated to be superior to conservative management?

A. Improved ROM
B. More rapid return to running
C. Fewer complications
D. Lower re-rupture rate

Answer Key

QUESTION 1. Correct answer: **C** (see Phase II)

QUESTION 2. Correct answer: **C** (see Phase IV)

QUESTION 3. Correct answer: **C** (see Phase IV)

QUESTION 4. Correct answer: **C** (see Phase III)

QUESTION 5. Correct answer: **B** (see Surgical Technique)

QUESTION 6. Correct answer: **D** (see Indications for Surgical Treatment)

BEYOND BASIC REHABILITATION: RETURN TO BASKETBALL AFTER TREATMENT OF ACHILLES TENDON RUPTURE

Bradley Wells, PT, DPT, Michael D. Rosenthal, PT, DSc, SCS, ECS, ATC, CSCS, James H. Flint, MD, LCDR, MC USN, and John-Paul H. Rue, MD, CDR, MC USN

Introduction

ASPECTS OF BASKETBALL THAT REQUIRE SPECIAL ATTENTION IN REHABILITATION

- Jumping
- Running
- Pivoting/cutting
- Acceleration/deceleration movements

- Achilles tendon rupture secondary to athletic activity specifically racquet or ball sports has been noted in 75% to 80% of cases.[1,2]
- Achilles tendon ruptures are most common in sports, such as basketball, which require high power output and increased force production for activities such as running, jumping, and cutting.
- Studies report a high level of return to sport following Achilles rupture, deficits in strength and performance measures have been noted at 1 to 2 years following both surgical and conservative management.
- After an Achilles tendon rupture extensive rehabilitation is recommended to optimize return to function and sport.

Literature

- Mandelbaum et al. described an accelerated rehabilitation program for athletes who have incurred an Achilles tendon rupture.[3]
- It was found that by adhering to this accelerated program 93% of athletes returned to sports by 6 months with only small deficits (2% to 3%) of preinjury power and strength, and all patients (100%) returned to sports by 12 months.
- In this program passive range of motion (ROM) exercises begin 72 hours postoperatively, at 2 weeks ambulation in a walking boot was allowed, and full weight bearing began at 6 weeks.

Phase I: Advanced Strength and Conditioning Programs

Periodization

- Mesocycle: weeks 2 to 8

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- Training continuum
- Flexibility/joint mobility for joint stability

- Cardiorespiratory training
- Training for optimum muscle functional strength

Training Principles Used in the Design of the Program

- Principle of progression
- Principle of overload

Application of Acute Training Variables

- Acute training variables include choice of exercises, order of exercises, amount of load, number of sets, performance speed of the exercise, magnitude of movement during the exercise (ROM), type of contraction, and rest period.
- During Phase I, exercises are limited and focus on gradual return of mobility and strength in the localized region of the injury/surgery, sustainment of mobility in strength in proximal joints, and limited cardiorespiratory training.
- Exercises include simple/isolated movement patterns progressing to integrated/complex movement integration toward the latter portion of Phase I.
- Speed and amplitude of movement will initially be slow with limited ROM, with both variables increasing throughout the training program.
- Phase I resistance exercises progress from isometrics to light concentric and eccentric loading with light loads.
- Repetitions are high, with a work-to-rest ratio of 1:1.
- Repetitions: 10 to 15
- Sets: two to four
- Rest interval: 1 to 3 minutes
- Intensity: low
- Repetition tempo: rate of repetitions is initially slow and progresses to moderate speed
- Training frequency: 2 to 4 days per week (allow 1 to 2 days recovery between sessions)
- Training duration: 30 to 60 minutes
- Training volume: total number of repetitions completed in training session will vary
- Specific exercises used in the training:
  - Four-way hip exercises (straight leg raises or resistance machine) beginning at week 2 to 3
  - Pool therapy:
    - Walking beginning at week 2 to 3
    - Double leg (DL) heel raises beginning at week 4 progressing to single leg (SL) heel raises in chest deep water at week 6
  - Isometric ankle inversion and eversion exercises beginning at week 3
  - Seated active dorsiflexion and plantar flexion exercises beginning at week 3
  - Resistance band inversion and eversion exercises at week 4
  - Pain-free WB DF at week 5
  - Gait training: In splint until week 5; out of splint at week 5
  - Standing DL heel raises at week 5
  - Stationary bike in splint until week 5, out of splint at week 5
  - Initiate submaximal isokinetic DF and PF focusing on endurance

Application of Chronic Training Variables

- Chronic training variable considerations include aerobic capacity, anaerobic capacity, strength, speed, agility, quickness, flexibility, and power.
- In this early stage low intensity cardiorespiratory training can be implemented.
- Flexibility and strength of the uninvolved joints should be maintained while the focus is on gradual increase of these two variables about the lower leg.
- Cardiorespiratory training.
  - Upper body ergometer beginning at week 1
  - Belt or vest suspended (deep water) pool walking and jogging beginning at week 2 to 3 for nonoperative management and when surgical incisions are well healed for postoperative management
- Appropriate response to manipulation of exercise variables may include localized musculotendinous soreness that resolves before increasing levels of tissue stress.

TIMELINE 38-5: **Return to Basketball after Achilles Tendon Rupture**

PHASE I (weeks 0 to 1)	PHASE II (weeks 2 to 8)

• PROM PF 10–20° progressing toward 5° PF
• Toe curls/spreads
• In splint when not performing PROM
• Elevation
• Ice
	• AROM ankle exercises: circles/ ABC's/ DF to PF limiting DF to neutral at 4 weeks 10° at 6 weeks, and symmetry at 8–10 weeks
	• Pain-free resisted ankle exercises beginning with isometrics and progressing to resistance bands
	• Gait training in splint
	• Stationary bike in splint
	• Resistance exercises for proximal LE muscle groups (4-way hip ex)
	• Upper body ergometer
	• Week 3: PROM (gentle) DF stretch with towel
	• Week 5:
	  • Weight-bearing CKC DF
	  • Gait training out of splint
	• Week 6:
	  • Double-leg toe raises
	  • Stationary bike without splint
	• Pool therapy: week 5: Double-leg → Single-leg toe raise in chest-deep water
	• Walk→ Run at full emersion (non–weight-bearing)

Phase II: Performance Enhancement Training Techniques

Periodization

- Mesocycle: weeks 8 to 20

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- Training continuum
- Flexibility/joint mobility for joint stability
- Core training
- Sensorimotor and balance training
- Multiplanar training activities
- Training for optimum muscle functional strength
- Training for optimum muscle functional power

Olympic Lifts Used in the Training Program

- Olympic lifts are not integrated until Phase III.

Training Principles Used in the Design of the Program

- Principle of progression
- Principle of overload
- Principle of variation
- Principles of specificity: specific adaptation to imposed demands (SAID)

Application of Acute Training Variables

- During Phase II, now that the Achilles tendon is ready for weight bearing and increased loading, exercise options significantly expand and the focus is now on restoration of normal mobility, increase in strength, and progressive implementation of integrated movement patterns.
- Speed and amplitude of movement include slow and moderate speeds with increasing.
- Phase II resistance exercises include moderate intensity isometrics and light, progressing to moderate intensity concentric and eccentric loading with light loads.
- Repetitions per set are moderate, with a work to rest ratio increasing to 1:2 to 3 to promote neuromuscular recovery between sets.
- Research does not indicate a singular optimal approach to regaining strength and power. Most recently, eccentric training has been widely reported in the literature for restoration of optimal function following Achilles tendon injury.[4]
- When performing an eccentric contraction protocol Stanish et al. found that using three sets of 10 repetitions, worked well for building strength.[5]
- Alfredson et al. proposed an eccentric loading protocol of three sets of 15 repetitions conducted twice daily as long as the pain did not exceed the level of pain experienced with the exacerbating activity or sport.[4]
- The DeLorme program which was developed for resistance exercise and has been advocated in the use of rehabilitation uses three sets of 10 repetitions with a pyramid type design.[6] This program was developed in 1945 and is still used today for the rehabilitation of athletes and has been proved to strengthen muscle.
- Intensity should be kept to submaximal to allow the musculotendinous tissue to adapt to increased force demands while still healing.
- Strengthening exercise sessions should be separated by at least one full day to allow the muscle to fully heal from any breakdown caused by training.
- Repetitions: 8 to 12 repetitions per set
- Repetition tempo: combination of slow to moderate speed loading
- Sets: three to five
- Rest interval: at least 1 minute between sets
- Intensity: moderate, working to 80% of full strength by end of phase II
- Training frequency: three to four times per week (no consecutive days)
- Training duration: 30 to 60 minutes

TIMELINE 38-5 **Return to Basketball after Achilles Tendon Rupture** (Continued)

PHASE III (weeks 8 to 20)	PHASE IV (weeks 17 to 36)
• Continue with strengthening from previous phase for individual impairments • Submaximal isokinetics • Stationary biking, elliptical, rowing machine • Core training • Single leg balance exercises • Body weight strength training (squats/lunges) • Balance and reach exercised • Gait training on treadmill (Alter G): Level surface → Incline walking if symptom free • Treadmill jogging beginning at 12 weeks if good mobility and LE strength • Pool therapy: Gentle hopping → jumping in waist-deep water	• Individual strength and flexibility program based off impairments • Return to Running Program if symptom free • Plyometrics: skipping → hopping → jumping if symptom free • Sport specific exercises: agility drills, court drills • Outcome testing and assessment

- Specific exercises used in the training:
  - Continue with Phase I activities focusing predominantly on mobility and strength impairments.
  - Pool therapy: hopping and jumping beginning in chest deep water and progressing to waist-deep water
  - Gait training: Progress treadmill walking from flat surface to 2% to 5% incline. Use the Alter-G treadmill to progress the rate and duration of walking with body weight off-loading as needed for normal gait.
  - Submaximal isokinetic, concentric and light eccentric, DF and PF, focusing on endurance
  - Core training: lower extremity resistance (Figure 38-27), upper extremity resistance (Figure 38-28), or planks (front and side)
  - SL balance exercises: Progression from static stance with increasing levels of difficulty (i.e., transition from standing on firm surface to foam mat to ½ cylinder roller) to SL stance with dynamic movement initiated by the upper extremities or uninvolved lower extremity (Figure 38-29)
  - Balance and reach activities in the frontal, sagittal, and transverse planes with increasing training volume, amplitude, and rate of movement (Figure 38-30).
  - Bodyweight squats and lunges. Squats with varying base of support (Figure 38-31). Static lunges transitioning to dynamic multiplanar lunges (Figure 38-32).



FIGURE 38-28. Ball chest press. Core exercise with upper extremity resistance.

Application of Chronic Training Variables

Phase II includes an increase in aerobic training, early anaerobic training, and increasing focus on strength development. Training speed manipulations are also incorporated throughout the latter half of this phase.

- Cardiorespiratory training
  - Pool walking, progressing to jogging, in chest-high water
  - Stationary cycling using pre-programmed settings and mild to moderate resistance to enhance variability of training. Cycling duration may vary from 15 to 40 minutes. On training days with minimal strength training, cycling sessions may be of greater duration.
- Gait training
  - Treadmill walking progressing to lateral stepping, backward walking, ladder drills (i.e., shuffle steps, high knees) (Figure 38-33) at walking pace.
  - Schepsis et al. suggest that light jogging can begin at 3 months if the patient has regained full dorsiflexion.[7]



FIGURE 38-27. Lateral stepping with Thera-Band. Core exercise with lower extremity resistance.



FIGURE 38-29. Single leg stance with frontal plane well-leg movement.

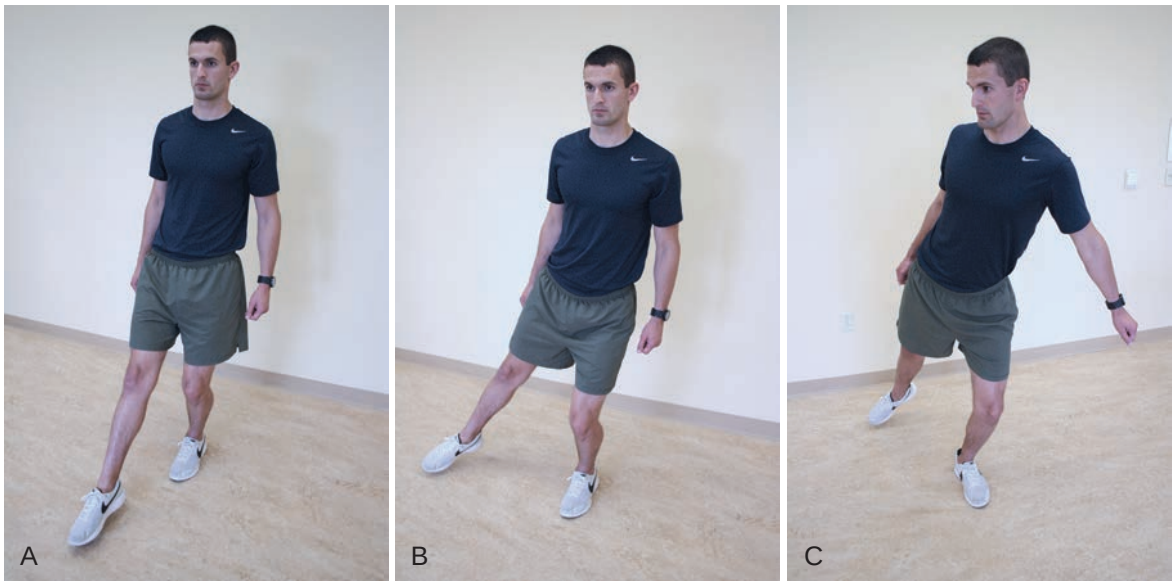

FIGURE 38-30. A, Sagittal plane reach (with well-leg). **B,** Frontal plane reaches. **C,** Transverse plane reach.



FIGURE 38-31. A, Narrow based body weight squats. **B,** Wide stance or split stance body weight squats.



FIGURE 38-32. A, Static lunge. **B,** Dynamic lunge.

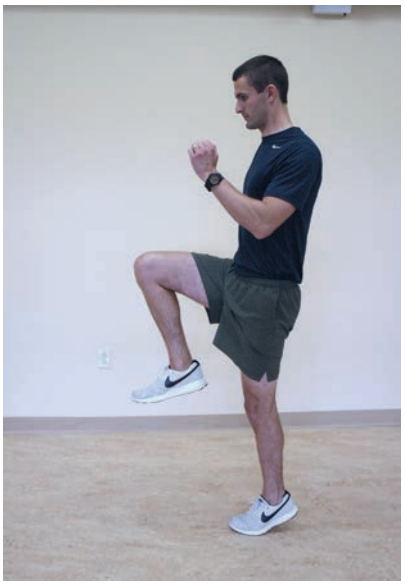

FIGURE 38-33. High knee walking.

Phase III: Sport-Specific Training

Periodization

- Mesocycle: weeks 17 to 36

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- Training continuum
- Multiplanar training activities
- Training for optimum muscle functional strength
- Training for optimum muscle functional power
- Neuromuscular dynamic stability exercises
- Plyometric training
- Functional training

Olympic Lifts Used in the Training Program

- Snatch
- Power/hang clean

Training Principles Used in the Design of the Program

- Principle of progression
- Principle of overload
- Principle of variation
- Principle of individualization
- Principles of specificity: specific adaptation to imposed demands (SAID)

Application of Acute Training Variables

- During this final rehabilitation stage the focus is on increasing speed of movement, normal amplitude of movements (symmetrical movement patterns to uninvolved limb).
- Force, load, number of sets, performance speed of the exercise, magnitude of movement during the exercise (ROM), type of contraction, and rest period.
- Exercises are predominantly integrated/complex and sport-specific movement patterns.
- Resistance exercises include a combination of concentric and eccentric loading.
- Repetitions of strength and power training are relatively low, with an increasing rest period to support neuromuscular recovery (work-to-rest ratio of 1:3 to 5).
- Essential to this final stage of rehabilitation is the integration of plyometric activities. The intensity for plyometrics varies depending on the activity and should start from relatively easy exercises, such as skipping, and progress to include higher-intensity exercises such as box jumps.
- The frequency of plyometric training should range from one to three sessions per week, allowing 48 to 72 hours of recovery between sessions.
- Rest between sets is generally 2 to 3 minutes, allowing a work-to-rest ratio of 1:5 to 1:10.
- Determination of training volume includes size of the athlete, prior plyometric training experience, and ultimately healing time for athletes recovering from injury.
- Training volume is determined by how many times the athlete's foot contacts the floor and the rehabilitation of an athlete may begin with 30 to 40 foot contacts.
- Athletic development training typically includes 80 to 140 contacts depending on the stage of training.[8]
- Repetitions: Plyometrics, 30 to 140 contacts per session. Lifts, three to six repetitions
- Sets: three to five
- Rest interval: work-to-rest ratio of 1:5 to 1:10 for plyometrics, 1:3 to 5 for lifts
- Intensity: moderate to high
- Training frequency: one to three times per week (no consecutive days)
- Training duration: 30 to 90 minutes
- Olympic lifts and strengthening: power/hang clean, jump squats, front squats, lunges, step-ups, calf raises (standing), eccentric gastroc-soleus (Figure 38-34)
- Phase I Plyometrics (weeks 2 to 4 of the final phase): two foot ankle hop, quick skipping, squat jump, jump over obstacle (forward and lateral)
- Phase II Plyometrics (weeks 4 to 10 of the final phase): Skip to power skip, alternate leg bounding (sagittal and frontal plane), single foot hops (i.e., line hops with side-to-side comparison, dot hops), and vertical jumps.
- Phase III Plyometrics (weeks 8 to 20 of the final phase): tuck jumps, countermovement jump, box drills (jump up/step down, step up/jump down), depth jump with vertical or lateral movement beginning with both legs and advancing to single leg
- Specific exercises used in training:
  - Progression of jogging to full weight bearing on basketball court. Jogging advances to involve increasing running speed, decreasing duration (i.e., line drills)
  - Sport-specific drills include lateral and diagonal agility drills, ladder drills, and inclusion of reactionary basketball court drills
  - Individualized strength and conditioning program focusing on individual impairments



FIGURE 38-34. A, Eccentric gastrocnemius biased loading. **B,** Eccentric soleus biased loading.

Application of Chronic Training Variables

- The final training phase focus is on anaerobic power, normalization of strength, speed, agility, quickness, flexibility, and power.
- This is the longest phase of recovery and requires attention to detail to ensure normalized movement patterns as the athlete begins sports. Enabling compensatory movement patterns is likely to delay full recovery and increase the risk of reinjury or creation of an injury elsewhere in the kinetic chain due to the compensation.
- Careful modification of these training variables is necessary to provide adequate overload without developing of symptoms of tendinopathy.
- Training sessions may include exercises distributed to address all the chronic factors or the training sessions may focus on one to two chronic factors (i.e., Monday—agility and quickness, Wednesday—strength and power).

Sports Performance Testing

General Information

- General history: training background, future occupational and sport demands/goals
- Subjective questionnaires: SF 12/36.
- Outcome surveys: Victorian Institute of Sport Assessment (VISA-A), Foot and Ankle Ability Measure (FAAM), Lower Extremity Functional Scale, Foot and Ankle Outcome Score, Achilles Tendon Total Rupture Score (ATRS)[5]
- Medical history: treatment in the past 12 months with fluoroquinolones
- Sports injury history: spine or other lower extremity injuries. Mechanism of injury. When injuries occurred (what part of season, what period of game or practice)
- Surgical history: spine or other lower extremity surgeries
- Chronic conditions/medications: soft tissue conditions, systemic disease

Objective Tests

- Physiological assessments
  - 20-meter sprint and suicide sprint beginning at 5 to 6 months with monthly reassessment
- Dynamic muscle performance testing
  - SL heel raise endurance assessing the number of repetitions beginning at 4 to 5 months with monthly reassessment
- Movement performance testing:
  - Ankle ROM to include closed kinetic chain assessment of DF beginning at 3 months and monthly thereafter
  - Functional Movement Screen: first assessment at approximately 3 months, and then every 4 to 6 weeks thereafter
- Sport-specific testing:
  - Single leg hop for distance at 5 to 6 months and monthly thereafter
  - SL vertical jump at 5 to 6 months and monthly thereafter
  - Triple hop for distance at 5 to 6 months and monthly thereafter
  - 6 meter timed SL hop at 5 to 6 months and monthly thereafter
  - Vertical jump test at 6 months and monthly thereafter
  - Agility T-test at 5 to 6 months and monthly thereafter
  - Drop counter movement jump at 6 months and monthly thereafter
- Others: isokinetic testing of ankle DF/PF and INV/EV if available

Specific Criteria for Progression to the Next Stage to Determine Readiness for Basketball

- Progression from one phase to the next is performance, not time, based.
- Progression to Phase II begins when the patient demonstrates ease with full weight-bearing ambulation, has closed kinetic chain dorsiflexion of 15°, and can do double leg heel raise without pain.
- Progression to Phase III begins when the patient displays a normal walking gait, able to descend stairs symmetrically, can squat and lunge with normal mechanics and absence of pain, is able to do 10 single leg heel raises, and is able to jog for a short duration without pain.

Specific Criteria for Release to Unsupervised Complete Participation in Basketball

- A minimum of 85% side-to-side symmetry is required on all testing before clearance for unrestricted sport.
- We recommend that testing be formed following a brief warm-up and again following a simulated, one-half basketball game at a moderate level of intensity.
- Following completion of the simulated game sport-specific testing and dynamic muscle performance testing should be reassessed to evaluate performance decrement on the involved side and comparison with the uninvolved lower extremity.

Recommended Ongoing Exercises

- Long-term training of muscles and movements should incorporate power lifts such as countermovement jumps, eccentric gastroc-soleus strengthening, triplanar SL hopping, and multi-planar dynamic lunges for successful sport performance and injury prevention.
- Additional sport specific training should include change of direction agility drills (i.e., line drills, T-drill).

Evidence

Alfredson H, et al: Heavy-load eccentric calf muscle training for the treatment of chronic Achilles tendinosis. *Am J Sports Med* 26:360–366, 1998.

This prospective study applied a heavy-load eccentric training program versus conventional treatment to 15 recreational athletes (in each group) with chronic Achilles tendinosis. Following the 12-week program all patients in the eccentric training group had returned to preinjury levels of activity. None of the patients in the conventional treatment group returned to preinjury activity levels. (Level II evidence)

DeLorme TL, Watkins AL: Technics of progressive resistive exercise. *J Bone Joint Surg* 27:163–173, 1945.

This landmark manuscript introduced the terms "progressive resistance exercise" and the "10 repetition maximum." The exercise program introduced in the this manuscript of three sets of 10 repetitions, with increasing amount of resistance, provides a systematic approach to muscular strengthening that is still used more than 65 years later. (Level V evidence)

Kannus P, et al: Etiology and pathophysiology of tendon ruptures in sports. *Scand J Med Sci Sports* 7:107–112, 1997.

This publication reviews the etiology and pathophysiology of Achilles tendon ruptures in sport related activity. The authors found that out of 430 cases of Achilles tendon rupture, 14% were suffered while playing basketball. It is also stated that 75% of all Achilles tendon ruptures are related to sport. (Level III evidence)

Mandelbaum B, et al: Achilles tendon ruptures: A new method of repair, early range of motion, and functional rehabilitation. *Amer J Sports Med* 23:392–396, 1995.

This prospective study treated 29 athletes with Achilles tendon ruptures according to a functional rehabilitation protocol. At 6 weeks 90% of patients had full ROM and 87% were able to perform a single-leg toe raise by 3 months postop. At 6 months 93% of patients had a full return to sport and 100% returned to sport by 12 months. (Level II evidence)

Nilsson-Helander K, et al: The Achilles Tendon Total Rupture Score (ATRS). *Am J Sports Med* 35:421–426, 2007.

This cohort study developed and validated a new patient report instrument for measuring outcome following Achilles tendon rupture. Multiple tests for statistical analysis concluded that the ATRS had high reliability, validity, and sensitivity outcome measurement in patients with a total Achilles tendon rupture. (Level I evidence)

Schepsis A, et al: Achilles Tendon Disorders in Athletes. *Am J Sports Med* 30:287–305, 2002.

This article reviews the anatomy and biomechanics of the Achilles tendon and the multiple different factors which can lead to injury. The authors suggest that Achilles tendon ruptures be treated through surgical intervention and rehabilitation focus on gradually increasing dorsiflexion through serial casting. At 3 months, if full dorsiflexion is gained, then the patient is permitted to perform light jogging. (Level V evidence)

Stanish WD, et al: Eccentric exercise in chronic tendinitis. *Clin Orthop Rel Res* 208;65–68, 1986.

This article proposes that eccentric loading is appropriate and necessary loading for optimal rehabilitation of chronic tendon injuries. The proposed eccentric training included various speed and amplitude of movement while producing minimal pain. (Level V evidence)

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6. DeLorme TL, Watkins AL: Technics of progressive resistive exercise. *J Bone Joint Surg* 27:163–173, 1945.
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Multiple Choice Questions

QUESTION 1. Achilles tendon rupture secondary to athletic activity, specifically racquet or ball sports, has been noted in _____ of cases.

A. 50%
B. 65%
C. 75%
D. 95%

QUESTION 2. In the rehabilitation protocol for athletes who have suffered an Achilles tendon rupture, range of motion (ROM) exercise begins _____ postop.

A. 24 hours
B. 72 hours
C. 7 days
D. 2 weeks

QUESTION 3. When should low intensity jogging be initiated after an Achilles tendon rupture?

A. When sutures are removed
B. At 17 weeks if full plantar flexion strength is gained
C. When a single leg toe raise can be performed
D. At 3 months if full dorsiflexion is gained

QUESTION 4. When should gait training out of the splint begin following an Achilles tendon rupture in the athlete?

A. 5 weeks
B. 2 months
C. 10 weeks
D. 3 months

QUESTION 5. Which of the following is suggested as a sport-specific functional test for return to basketball following an Achilles tendon rupture?

A. Single leg toe raise
B. Counter movement jump
C. Pain free jogging
D. Skip to power skip

Answer Key

QUESTION 1. Correct answer: **C** (see Introduction)

QUESTION 2. Correct answer: **B** (see Introduction)

QUESTION 3. Correct answer: **D** (see Phase II)

QUESTION 4. Correct answer: **A** (see Phase I)

QUESTION 5. Correct answer: **B** (see Sports Performance Testing)

Chapter 39



Ankle Sprains, Fractures, and Chondral Injuries

INTRODUCTION

Annunziato Amendola, MD, Sebastiano Vasta, MD, and Biagio Zampogna, MD

Epidemiology

Age

- Under the age of 35 with a peak of incidence of 15 to 19 years of age.

Sex

- Slightly higher incidence of ankle sprain in males (1.04).

Sport

- Ankle sprains are the most common injury in all sports involving running and pivoting; basketball is the most common sport in the United States associated with ankle sprain but other include football, soccer, running, volleyball, softball, baseball, and gymnastics. Ice and water sports are less likely to cause an ankle sprain.

Position

- Among soccer players, defenders and attackers have a higher risk of ankle injury as a result of contact with opponents.

Pathophysiology

Intrinsic Factors

- Muscle strength imbalance: increased eversion-to-inversion ratio and plantarflexion-to-dorsiflexion
- Increased BMI
- Higher risk for dominant ankle in soccer
- History of previous ankle sprains
- Pes cavus or calcaneovarus alignment (Figure 39-1)

Extrinsic Factors

- Certain shoewear may predispose to ankle injury: air heels, poor fit
- Inadequate warmup with poor flexibility
- Artificial turf increases the risk of ankle injury



FIGURE 39-1 Assessing foot alignment: varus hindfoot alignment may predispose to recurrent ankle sprains.

Traumatic Factors

- Pronation-external rotation, pronation-abduction, and infrequently the supination external rotation mechanism are responsible for tibiofibular syndesmotic injuries and high fibular fractures.
- Supination and adduction (inversion) of the plantarflexed foot for lateral ligament injury and fibular avulsion fractures; same as a lateral ankle sprain.
- Rarely, eversion, external rotation, or abduction mechanism cause an isolated injury of the deltoid ligament, otherwise it is injured together with the other ligaments through the same pathway. Type B fracture (Weber classification) or Lauge-Hansen (supination-external rotation) could also be caused by these patterns of trauma.
- Osteochondral injuries occur most commonly in association with sprains and fractures. Direct axial loading with shear to the ankle with or without sprain could be responsible for osteochondral lesions, but is less common (Figure 39-2).

Classic Pathological Findings

- Ankle sprains are usually lateral and involve the anterior tibiofibular ligament (ATFL) 100% of the time (grade I), whereas the calcaneofibular ligament (CFL) is involved in 50% to 75% of more severe sprains (grade II and III).
- Syndesmosis sprains usually occur with external rotation and have a spectrum of severity: from a few fibers of the distal antero-inferior tibiofibular ligament (AITFL) (stable) to complete AITFL injury and interosseus membrane (unstable) with or without deltoid involvement (Figure 39-3*A-C*).
- OCLs occur in the medial (50%) and lateral (50%) talar dome: medial lesions are cup-shaped, usually posteromedial, and often related to chronic inversion trauma; lateral lesions are flat and anterolateral, usually following an acute sprain (Figure 39-4*A,B*).
- Ankle fractures have been classified by many authors. The most commonly used are the Denis-Weber and the Lauge-Hansen classifications. The Denis-Weber classification is based on the location of the fibular fracture. Lauge-Hansen classifies the fractures according to the foot position and the direction of the force determining the trauma.



FIGURE 39-2 Anterior-posterior view of the ankle following an ankle sprain: lateral osteochondral lesion flake shaped acute.

Clinical Presentation

History

- For an ankle sprain, patients usually describe an inversion-type twist of the foot and ankle, or less frequently, eversion, followed by pain and swelling.
- Swelling, ecchymosis, and tenderness laterally for lateral sprains and lateral malleolar fractures (Figure 39-5).
- Differentiate between ligamentous tenderness (ATFL, CFL, syndesmosis, deltoid) versus bony tenderness on examination.
- Decreased range of motion (ROM) with all injuries, more with fractures.
- Deformity may be present with displaced fractures.
- With sprains and osteochondral lesions (OCLs) it may be difficult to weight bear on the injured limb because of pain, but it is usually still possible to walk on the foot. Inability to weight bear on the injured foot usually indicates the presence of a fracture (Ottawa Ankle Rules).
- An osteochondral lesion or a loose body should be considered when persistent pain is present together with intermittent locking, stiffness, and limping (Figure 39-6).

Physical Examination

Abnormal Findings

- Knowledge of anatomy for palpation is essential. Pain and tenderness at the area of injury: ATFL and CFL in lateral sprains, bony tenderness and/or deformity and crepitus with fractures; AITFL, interosseus membrane and deltoid tenderness with syndesmosis injury.
- Positive anterior drawer test and talar tilt test in the setting of a lateral ankle injury; these are usually best in the subacute stage, a few days after injury.
- Positive squeeze test, external rotation stress test, cotton test, fibula translation test, and crossed-leg test for an acute syndesmotic injury. In the setting of a chronic injury, the stabilization test will be positive (Figure 39-7*A,B*).
- Osteochondral lesions usually determine tenderness in their common location site and joint line with the ankle in plantarflexion, anterolateral lesions will cause pain when palpating the anterolateral talar dome, whereas a posteromedial lesion will be tender behind the medial malleolus when palpating the posteromedial talus with the ankle in dorsiflexion.
- Possible deformity and\or skin laceration in the presence of a fracture.

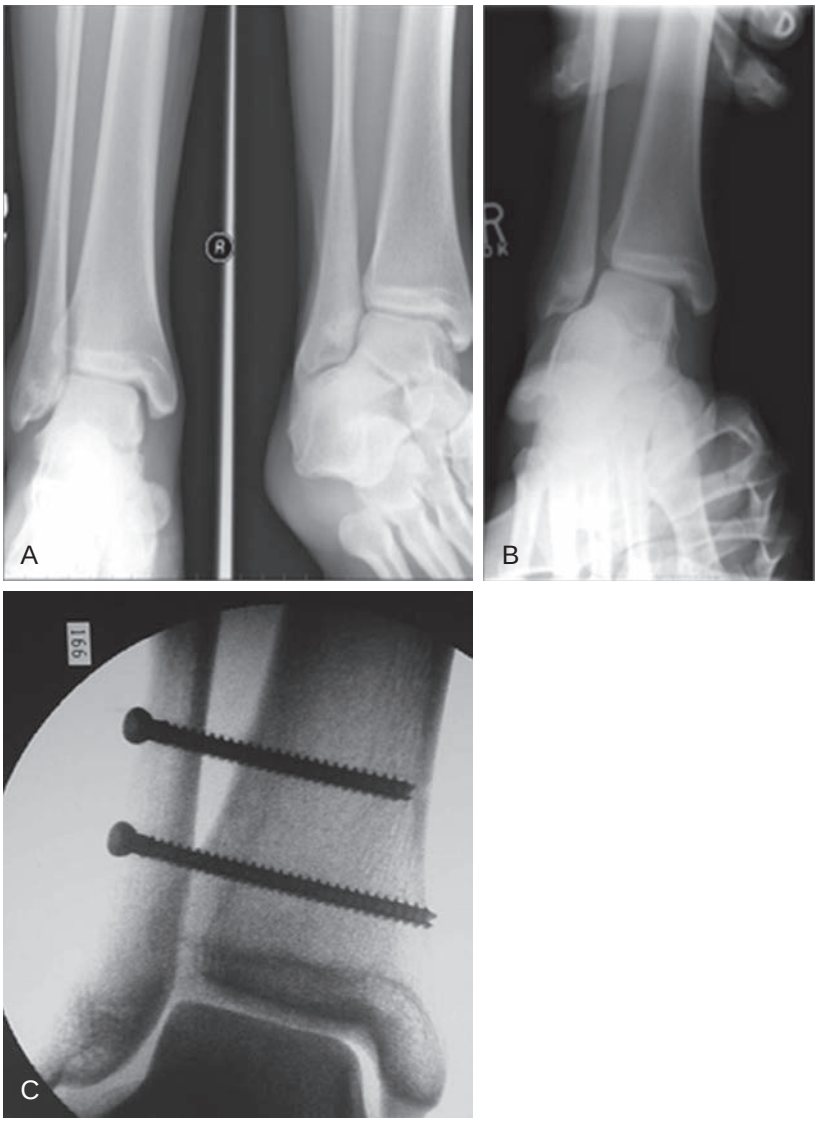


FIGURE 39-3 A, Anterior-posterior and mortise view: eversion external rotation ankle sprain, unable to weight bear. **B,** External rotation stress test; view confirms an unstable injury. **C,** Fixation of unstable syndesmosis (grade III) injury.

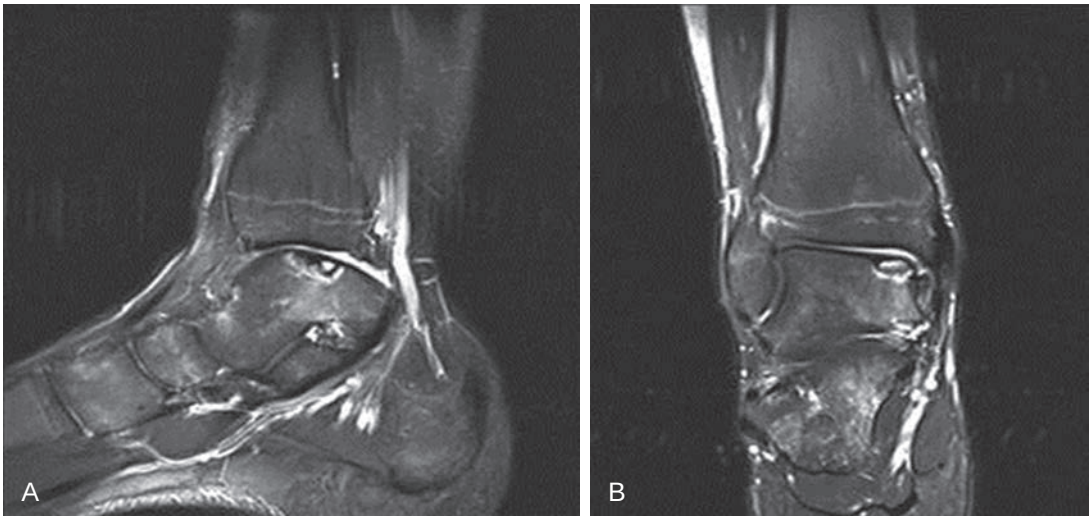


FIGURE 39-4 A, Magnetic resonance imaging (MRI) sagittal view: cup-shaped osteochondral lesion of the medial talar dome. **B,** MRI, Coronal view showing a cup-shaped osteochondral lesion of the talar dome.



FIGURE 39-5 Swelling and ecchymosis following a severe sprain of the left ankle.

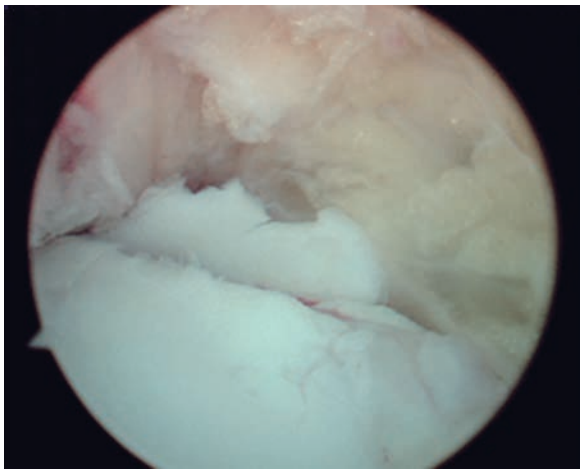


FIGURE 39-6 Arthroscopic view: chondral lesion following a severe ankle sprain.

Pertinent Normal Findings

- Normal neurovascular status
- In the setting of an ankle sprain, the patient should be able to walk even if painful. If not, a fracture should be investigated.

Imaging

- Routine plain radiographs with weightbearing anterior-posterior (AP), lateral, and mortise view to assess the presence of a concomitant fracture; the lateral view should include the base of the fifth metatarsal.
- External rotation stress views may be performed to assess the severity of syndesmotic or deltoid injury (Figure 39-3*B*).
- Magnetic resonance imaging (MRI) may be used to assess the extent of ligament injury (deltoid and syndesmosis) and the presence of nondisplaced fractures, bony edema from stress fractures, or osteochondral injury. It is indicated if the diagnosis is not clear, or if the athlete has persistent pain and loss of function (Figure 39-4*A*,*B*).
- Computed tomography (CT) scanning is useful to assess the extent of bone injury: intraarticular fractures, OCLs, or to evaluate bone healing in a fractured ankle.
- Triple-phase bone scintigraphy (bone scan) has been supplanted by MRI in the diagnosis of stress fracture, but may be useful for the investigation of diffuse bone or joint pain.

Differential Diagnosis

- Tendinopathy: peroneal tendons most commonly, tibialis posterior, flexor halluces longus (FHL) impingement, midportion and insertional achilles Achilles tendon ruptures.
- Stress fractures

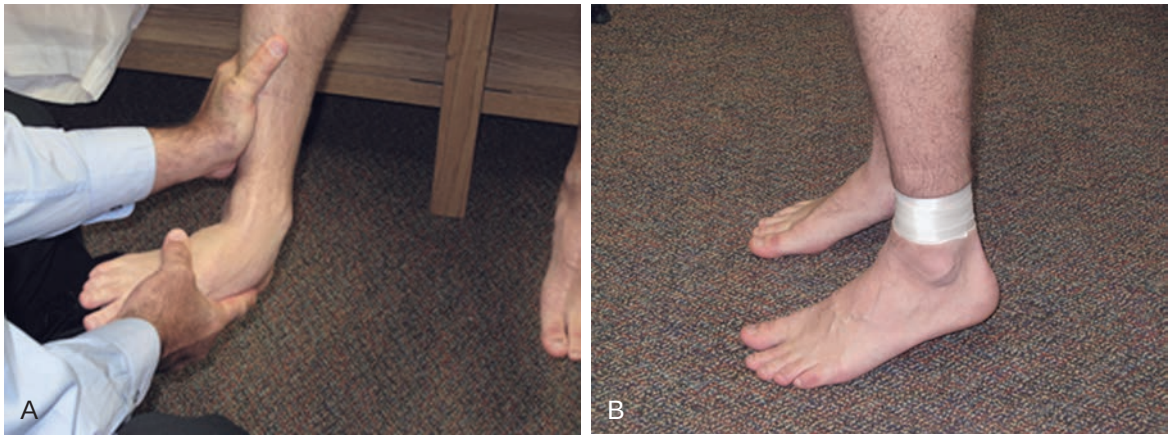


FIGURE 39-7 A, External rotation stress test. **B,** Stabilization test after taping technique just above the ankle joint; perform provocative activity to test syndesmotic stability.

Treatment

Nonoperative Management

- Lateral ankle and mild syndesmotic sprains are usually treated with rest, ice, compression, and elevation (RICE): nonsteroidal antiinflammatory drugs may be used for pain and swelling; a short period (1 to 2 weeks) of immobilization or comparable rigid support for grade I and II ankle sprains.
- Use of short leg cast or removable brace period for nondisplaced ankle fracture.
- Physical therapy aiming to regain ROM, strength, and proprioceptive function when appropriate for healing.

Guidelines for Choosing among Nonoperative Treatments

- All lateral ankle sprains, nonoperative treatment is preferred
- Grade I and grade II syndesmotic ligamentous injuries with a competent deltoid and posterior inferior tibiofibular ligament (PITFL) are generally treated using conservative measures.
- Stable and nondisplaced fractures
- Stable and nondisplaced osteochondral injuries
- In the setting of displaced osteochondral injuries, conservative measures are often unsuccessful, and surgical treatment (arthroscopy) may be more effective.

Surgical Indications

- Grade III injuries and fractures with syndesmotic instability (absolute indication)
- Weber A/supination-adduction (SA) 2 with associated vertical medial malleolar fracture
- Unstable Weber B/supination-external rotation (SER) 4 or Weber C/all pronation-external rotation (PER) 1–4 fractures
- Osteochondral lesion (relative indication)
- Failure of conservative measures resulting in chronic instability

Aspects of History, Demographics, or Exam Findings That Affect Choice of Treatment

- Stability of the injury pattern in fractures and syndesmotic injuries
- Level of competition and desire to return to sport
- Time point of the injury relatively to the season

Aspects of Clinical Decision Making When Surgery is Indicated

- Likelihood of success with nonoperative versus operative treatment
- Failure of rehabilitative programs
- Grade III injuries or fractures with syndesmotic instability
- Symptoms preventing ability to participate: i.e., complaints of ankle stiffness or catching with osteochondral injuries; recurrent sprains despite optimal rehabilitation
- Fracture displacement and joint instability/incongruity

Evidence

Baumhauer JF, Alosa DM, Renstrom AF, et al: A prospective study of ankle injury risk factors. *Am J Sports Med* 23:564–570, 1995.

This study examined the ankle injury risk factors on 145 college-aged athletes. The athletes were assessed before the athletic season and monitored throughout the season. (Level III evidence).

Beynnon BD, Renstrom PA, Alosa DM, et al: Ankle ligament injury risk factors: a prospective study of college athletes. *J Orthop Res* 19:213–220, 2001.

This is a prospective study on 118 Division I collegiate athletes who participated in soccer, lacrosse, or field hockey. The study furnishes interesting data about epidemiology and risk factors. (Level III evidence).

Choi GW, Choi WJ, Youn HK, et al: Osteochondral lesions of the talus: Are there any differences between osteochondral and chondral types? *Am J Sports Med* 41:504–510, 2013.

This is a retrospective study on 298 ankles that underwent arthroscopic marrow-stimulating procedures for OLTs. The purpose was to compare the clinical outcomes, demographics, and characteristics of osteochondral- and chondral-type lesions of OLTs. (Level III evidence).

Cloke DJ, Ansell P, Avery P, et al: Ankle injuries in football academies: a three-center prospective study. *Br J Sports Med* 45:702–708, 2011.

This well designed epidemiology study described the incidence of ankle injuries and studied the factors associated with increase of injury rate of young soccer players of three different Football Association (FA) academies. (Level III evidence).

Colvin AC, Walsh M, Koval KJ, et al: Return to sports following operatively treated ankle fractures. *Foot Ankle Int* 30:292–296, 2009.

This study investigated which variables influence patients' return to sports after operative fixation of an unstable ankle fracture from 243 patients that were identified as participating in vigorous activity. (Level IV evidence).

Kaminski TW, Hertel J, Amendola N, et al: National Athletic Trainers' Association position statement: conservative management and prevention of ankle sprains in athletes. *J Athl Train* 48:528–545, 2013.

This is a recent position statement of the NATA. The recommendations for athletic trainers and other allied healthcare professionals in the conservative management and prevention of ankle sprains in athletes are presented. (Level IV evidence).

Kerkhoffs GM, van den Bekerom M, Elders LA, et al: Diagnosis, treatment and prevention of ankle sprains: an evidence-based clinical guideline. *Br J Sports Med* 46:854–860, 2012.

This work furnishes recommendations for diagnosis, treatment, and prevention of ankle sprain based on evidence from published scientific research. (Level II evidence).

Lauge-Hansen N: Fractures of the ankle: II: combined experimental-surgical and experimental-roentgenologic investigations. *Arch Surg* 60:957–985, 1950.

This is the original paper of Lauge-Hansen describing his classification of ankle fractures. (Level IV evidence).

Mintz DN, Tashjian GS, Connell DA, et al: Osteochondral lesions of the talus: a new magnetic resonance grading system with arthroscopic correlation. *Arthroscopy* 19:353–359, 2003.

This study, by using arthroscopy as the standard, demonstrated that magnetic resonance imaging can be used to evaluate the articular cartilage covering osteochondral lesions of the talus with a high degree of accuracy. (Level II evidence).

Rolf CG, Barclay C, Riyami M, et al: The importance of early arthroscopy in athletes with painful cartilage lesions of the ankle: a prospective study of 61 consecutive cases. *J Orthop Surg* 1:4, 2006.

This is a prospective study on 61 consecutive athletes over a 4-year period. The authors evaluated clinical presentation and outcomes of surgery for symptomatic chondral injuries of the talocrural joint in athletes. Secondly, in applicable cases, they evaluated the accuracy of MRI in detecting these injuries.

They found that arthroscopy should be taken into account as an early diagnostic and therapeutic tool in athletes complaining of exertion ankle pain. (Level IV evidence).

Sanders DW, Tieszer C, Corbett B, Canadian Orthopedic Trauma Society: Operative versus nonoperative treatment of unstable lateral malleolar fractures: a randomized multicenter trial. *J Orthop Trauma* 26:129–134, 2012.

This randomized multicenter clinical trial compared functional outcomes after operative and nonoperative treatment of undisplaced, unstable, isolated fibula fractures without any differences between the two groups, but with a higher risk of displacement and problems with union in the nonoperative managed group. (Level I evidence).

Stiell IG, Greenberg GH, McKnight RD, et al: Decision rules for the use of radiography in acute ankle injuries. Refinement and prospective validation. *JAMA* 269:1127–1132, 1993.

This study was conducted to validate the Ottawa Rules that aid the efficient use of radiography in acute ankle injuries. (Level I evidence).

Stufkens SA, Knupp M, Horisberger M, et al: Cartilage lesions and the development of osteoarthritis after internal fixation of ankle fractures: a prospective study. *J Bone Joint Surg Am* 92:279–286, 2010.

The aim of this study was to assess the role of the location and severity of initial cartilage lesions associated with an ankle fracture in the development of posttraumatic osteoarthritis. The authors found that the initial cartilage damage seen arthroscopically following an ankle fracture is an independent predictor of the development of posttraumatic osteoarthritis. (Level IV evidence).

van Dijk CN, Lim LS, Bossuyt PM, et al: Physical examination is sufficient for the diagnosis of sprained ankles. *J Bone Joint Surg Br* 78:958–962, 1996.

This study aimed to assess the diagnostic accuracy of physical examination to diagnose ankle sprain. It demonstrated that delayed physical examination gives information of diagnostic quality which is equal to that of arthrography, and causes little discomfort to the patient. (Level II evidence).

Weber BG: *Die verletzungen des oberen sprunggelenkes*, ed 2, Berne, 1972, Verlag Hans Huber.

This is the original paper in which Weber describes his classification of the ankle fracture based on the one proposed by Denis in 1949. (Level IV evidence).

Zengerink M, Struijs PA, Tol JL, et al: Treatment of osteochondral lesions of the talus: a systematic review. *Knee Surg Sports Traumatol Arthrosc* 18:238–246, 2010.

This is a systematic review of studies comparing the effectiveness of treatment strategies for osteochondral defects (OCD) of the talus. The authors concluded that debridement and bone marrow stimulation is the most effective treatment strategy for symptomatic osteochondral lesions of the talus.

Multiple-Choice Questions

QUESTION 1. Which of the factors below increase the risk for ankle sprain?

A. High-top shoes
B. Pes planus
C. Previous history of ankle sprain
D. Shoes with a heel counter
E. None of the above

QUESTION 2. A 20-year-old male basketball player suffered an inversion ankle sprain 4 weeks ago. He continues to have ankle pain and swelling despite optimal physical therapy. X-rays were normal. What would be the next step in management?

A. Nonsteroidal antiinflammatory drugs (NSAIDs) medication
B. Corticosteroid injection
C. Immobilize in a boot for 4 weeks
D. Magnetic resonance imaging (MRI) of the ankle
E. Arthroscopic surgery

QUESTION 3. Among the following findings, which one is strongly suggestive for an ankle fracture ?

A. Pain
B. Swelling
C. Inability to bear any weight on the injured foot
D. Hematoma
E. Decreased ankle range of motion

QUESTION 4. Which are the most important parameters that guide the type of treatment in an ankle fracture?

A. Mechanism of trauma
B. Type of sport activity level
C. Displacement and stability of the joint
D. Type of fracture

Answer Key

QUESTION 1. Correct answer: **C** (see Pathophysiology)

QUESTION 2. Correct answer: **D** (see Clinical Presentation)

QUESTION 3. Correct answer: **C** (see Clinical Presentation)

QUESTION 4. Correct answer: **C** (see Treatment)

NONOPERATIVE REHABILITATION OF LATERAL AND SYNDESMOTIC SPRAINS

Paul J. Pursley, PT, SCS, CSCS, and Annunziato Amendola, MD

GUIDING PRINCIPLES OF NONOPERATIVE REHABILITATION

- Protection of injured structures/prevent reinjury
- Reduction of effusion/edema/pain control/regain normal joint motion
- Normalization of gait/joint control
- Return to preinjury activity levels

Phase I (week 0 to 1)

Protection

- Protected weightbearing with crutches (see Box 39-1: Ottawa Rules), immobilization boot for pain control.

Management of Pain and Swelling

- PRICE principles: Protection, Rest, Ice, Compression, Elevation
  - See Figure 39-8: Lateral sprain
  - See Figure 39-9: Syndesmotic sprain

BOX 39-1 Ottawa Rules Classification

X-rays are only required if there is pain in the malleolar zone and if there is:

- bone tenderness along the distal 6 cm of the posterior edge of the tibia or tip of the medial malleolus, OR
- bone tenderness along the distal 6 cm of the posterior edge of the fibula or tip of the lateral malleolus, OR
- an inability to bear weight both immediately, and in the emergency department for four steps



FIGURE 39-8 Day 2 status post (s/p) lateral ankle sprain.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Anterior to posterior fibular mobilization (lateral sprains)

Soft Tissue Techniques

- Distal to proximal soft tissue mobilization/edema massage

Stretching and Flexibility Techniques for the Musculotendinous Unit

- OKC ankle motion for all planes
- Nonweightbearing dorsiflexion stretch with UE assist, for syndesmotic sprains, axial traction to hindfoot during stretch to improve comfort.

TIMELINE 39-1: **Conservative Care Following Lateral or Syndesmotic Sprain**

PHASE I (days 0 to 5)	PHASE II (days 6 to 12)
• Protected weightbearing-crutches/immobilization boot • Ice/compression/elevation • Nonweightbearing AAROM for eversion/dorsiflexion/plantarflexion • Seated BAPS board proprioceptive training • Isometric strengthening in midrange • Stationary biking	• Progressive weightbearing as tolerated • Icing as needed for edema/pain control • Soft brace/taping for stability • OKC AROM for all planes • Anterior to posterior talocrural joint mobilization • Isotonic strengthening with band resistance • Standing bilateral heel raises • Progressive weightbearing BAPS training • Bilateral unstable surface stance (sport-specific perturbations as tolerated) • Machine-based leg strengthening • Elliptical trainer • Progressive walking speeds on levels



FIGURE 39-9 Day 2 s/p lateral and syndesmotic sprain. Note: ecchymosis more proximal and anterior.

Other Therapeutic Exercises

- TBS, core stability, contralateral TLS
- Initiate isometrics progressing to isotonics with elastic band resist for inversion/eversion/DF/PF as tolerated by pain.

Activation of Primary Muscles Involved

- Peroneus longus/brevis (lateral and syndesmotic)
- Tibialis anterior (syndesmotic)
- FHL/tibialis posterior/EHL
- Gastrosoleus

Sensorimotor Exercises

- Intrinsic foot motion (toe extension with ankle PF/toe flexion with ankle DF)
- Seated circle board progressing to bilateral limb stance balance progression (as tolerated by pain, generally will be initiated earlier for lateral vs. syndesmotic)

Open and Closed Kinetic Chain Exercises

- Isometric ankle inversion/eversion
- Band-resisted inversion/eversion/PF/DF
- Manual-resisted ankle motions with variable speed/pressure
- CKC wall sits, partial squats
- OKC ipsilateral hip/knee exercise

Techniques to Increase Muscle Strength, Power, and Endurance

- Biking
- Swimming with limited kicking
- Pool exercises in the deep end to limit weightbearing; focus on hip knee and ankle active ROM

Neuromuscular Dynamic Stability Exercises

- Static hold to manual perturbation in open kinetic chain
- Seated BAPS/circle board

Functional Exercises

- Functional stepping as tolerated by pain

Milestones for Progression to the Next Phase

- Symmetrical and pain-free gait at self-selected pace on even surfaces
- Full AROM, minimal pain with passive overpressure
  - Dorsiflexion/eversion (syndesmotic)
  - Plantarflexion/inversion (lateral)
- Full and symmetrical unilateral heel raise

Phase II (Lateral sprains: weeks 1 to 3; Syndesmotic sprains: weeks 2 to 4)

Protection

- Protective bracing (lace up or Velcro strapping)

Management of Pain and Swelling

- Continued compression and icing/cooling as needed

TIMELINE 39-1: **Conservative Care Following Lateral or Syndesmotic Sprain** (Continued)

PHASE III (days 13 to 21)	PHASE IV (weeks 3 to 6)
• CKC gastroc/soleus stretching • CKC heel raises in single limb stance • Bilateral to unilateral stance progression (stable-unstable) • Jogging as tolerated • Progressive speed lateral shuffling • Ladder drills A/P/lateral • Bilateral hopping	• Progressive speed running • Lateral change of direction drills • Unilateral directional hopping • Sport-specific reaction drills • Practice-based drills • Return to sport as tolerated • Continue proprioceptive exercise for injury prevention

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Anterior to posterior talocrural mobilization to improve dorsiflexion

Soft Tissue Techniques

- Distal to proximal soft tissue mobilization/edema massage; advance tissue mobilization depth as needed.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Standing gastroc-soleus (G-s) stretching for lateral sprains
- Manual G-s stretching while maintaining traction on the ankle joint to prevent impingement pain with syndesmotic sprains.

Other Therapeutic Exercises

- Isotonics for involved ankle (band, cords, manual resistance by ATC/PT
- Bilateral standing toe raises through full range (angle board, stairs)
- Nonimpact TLS for involved side
  - Leg press, machine based hips/quads/hamstrings

Activation of Primary Muscles Involved

- Peroneus longus/brevis (lateral and syndesmotic)
- Tibialis anterior (syndesmotic)
- FHL/tibialis posterior/EHL
- Gastrosoleus

Sensorimotor Exercises

- Progression for bilateral to unilateral stance with sport-specific perturbation (chest pass/overhead pass, volleyball passing, hand fighting for football/wrestling)
- Bilateral stance on unstable surfaces, adding modifications such as active ankle motion, squats, or perturbations as tolerated
- Light intensity ladder drills, starting with A/P motion, progressing to diagonals and laterals and tolerated by pain and movement patterns
- Star Excursion Balance Test (SEBT). Initiate with posterior reaching to reduce pain associated with dorsiflexion.

Open and Closed Kinetic Chain Exercises

- Progress OKC isotonics w/band or manual resist
- CKC squats, lunges, lateral lunges, step-ups

Techniques to Increase Muscle Strength, Power, and Endurance

- Elliptical
- Walk to jog on treadmill or level surfaces
- Lateral slide board
- Swimming with full kicking
- Pool-based running

Neuromuscular Dynamic Stability Exercises

- Static hold to manual perturbation in closed kinetic chain

Plyometrics

- Bilateral partial anterior jumping
- Pool-based jumping bilateral to unilateral as tolerated by pain

Functional Exercises

- Step-ups/step-downs with free weight resistance

Sport-Specific Exercises

- Ball-based activity (passing/catching/fielding)
- Ground-based stick work (field and ice hockey)

Milestones for Progression to the Next Phase

- Minimal to no effusion/edema
- Symmetrical running gait
- No reports of pain or instability with bilateral anterior hopping
- Full, pain-free AROM. Full PROM with minimal pain (<2/10 per VAS)

Phase III (Lateral sprains: weeks 3 to 6; Syndesmotic sprains: weeks 4 to 6)

Protection

- Soft bracing as needed for stability and injury prevention

Management of Pain and Swelling

- Icing as needed

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Continued AP talocrural mobilization for dorsiflexion

Soft Tissue Techniques

- Deep soft tissue mobilization at peroneus longus/brevis as needed for tissue release

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Generalized ankle stretching in closed chain

Other Therapeutic Exercises

- Return to previous global strengthening program
- Modify foot position as needed per reports of pain for dynamic lifts where involved leg is trail leg. This will be most problematic for syndesmotic sprains (split position).

Sensorimotor Exercises

- Unilateral stance on unstable surfaces (See Figure 39-10*A*,*B*)
- Unilateral stance with perturbation on stable/unstable surfaces
- Full speed planned movement drills
  - Ladder drills
  - Cone drills
- Unilateral jumps to unstable surfaces (foam pad/BOSU)

Open and Closed Kinetic Chain Exercises

- Weighted squats/lunges/lateral lunges/step-ups
- Olympic lifts with cuing for good technique
- Standing-resisted hip movement without UE assist

Techniques to Increase Muscle Strength, Power, and Endurance

- Treadmill running levels and inclines
- Sport cord resisted sprint intervals anterior/posterior/lateral
- Cord resisted lateral slide board
- Cord resisted skate sprints (as applicable per sport and facilities)

Plyometrics

- Box jumps
- Bounding
- Hurdle drills bilateral to unilateral
- Split jumps
- Directional jumping
  - Planned
  - Reaction based on command

Sport-Specific Exercises

- Sport-specific multidirectional movement progressing from planned to reactive drills

Milestones for Progression to the Next Phase

- Symmetrical and pain-free sprints
- Unilateral hopping <90% of contralateral LE
- Full passive range without pain
- SEBT <95% contralateral LE

Phase IV (weeks 6 to 18)

Protection

- Prophylactic soft bracing

Techniques for Progressive Increase in Range of Motion

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Stretch program/ maintenance

Other Therapeutic Exercises

- Maintain global strengthening program

Activation of Primary Muscles Involved

- Peroneus longus/brevis (lateral and syndesmotic)
- Tibialis anterior (syndesmotic)

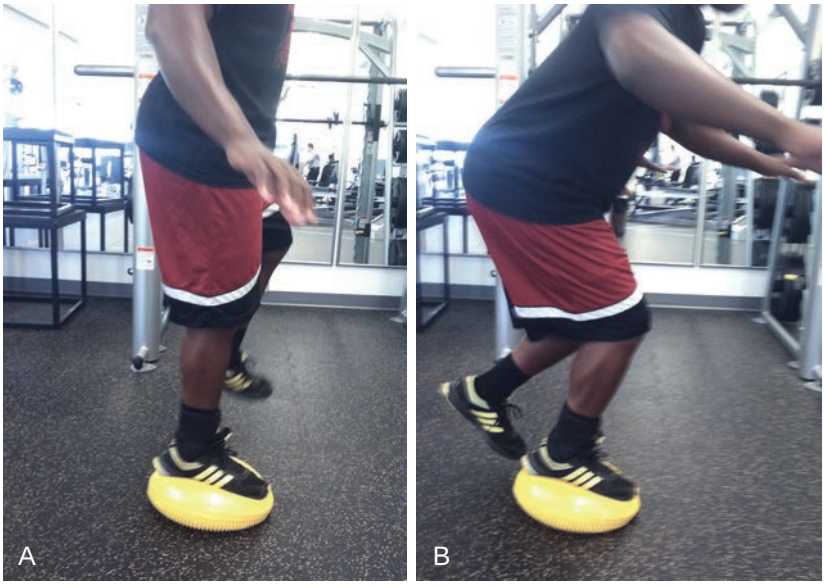


FIGURE 39-10 Single limb stance on disk for proprioception with progression of dorsiflexion and sport-specific positioning. Upright position (**A**); flexed position (**B**).

- FHL/tibialis posterior/EHL
- Gastrosoleus

Sensorimotor Exercises

- Unilateral balance activities for injury prevention

Sport-Specific Exercises

- Return to full competitive sport/ prophylactic soft bracing or taping

Milestones for Progression to Advanced Sport-Specific Training and Conditioning

- Able to function maximally for activity
- No swelling, little or no pain with activity, able to perform near previous levels

Criteria for Abandoning Nonoperative Treatment and Proceeding to Surgery or More Intensive Intervention

- Instability during sport-based activity
- Giving way episodes consistent with inversion instability for lateral ankle sprains; continuing pain with dorsiflexion and external rotation loading of the ankle
- Intractable pain due to impingement or instability or osteochondral injury
- Limited ROM due to scarring or impingement.

Tips and Guidelines for Transitioning to Performance Enhancement

- Be cautious with transition to resisted or plyometric exercise as the involved LE is the trail leg. The foot/ankle complex will be forced into dorsiflexion, which can be more painful, especially following a syndesmotic sprain.
- No exercise should be advanced or progressed until the exercise can be performed with good technique.
- With high demand activity and sport-specific exercises, prophylactic bracing is recommended

Performance Enhancement and Beyond Rehabilitation: Training/Trainer and Optimization of Athletic Performance

- Ankle sprains, both high and low (lateral) predispose athletes to recurrent injury.
- Prophylactic maintenance of balance, neuromuscular control, strength and flexibility is important to minimize re-injury
- Prophylactic bracing is recommended

Specific Criteria for Return to Sports Participation: Tests and Measurements

- No reported instability while braced during high level practice situations
- Symmetrical gait for maximum speed sprints and shuffles
- Unilateral hopping/jumping < 90% of contralateral side

Evidence

Bleakley CM, O'Connor SR, Tully MA, et al: Effect of accelerated rehabilitation on function after ankle sprain: randomised controlled trial. *BMJ* 10(340):c1964, 2010.

A blinded, randomized controlled trial of 101 patients sustaining grade I or II lateral ankle sprain. The accelerated exercise group demonstrated improved function during the first 2 weeks following injury.

Hubbard T, Denegan C: Does cryotherapy improve outcomes with soft tissue injury? *J Athl Train* 39:278–279, 2004.

Specific search criteria identified 55 articles for review, of which 22 were eligible randomized, controlled clinical trials. Based on the available evidence, cryotherapy seems to be effective in decreasing pain. High-quality studies are required to create evidence based guidelines on the use of cryotherapy. These must focus on developing modes, durations, and frequencies of ice application that will optimize outcomes after injury.

Hupperets MD, Verhagen EA, van Mechelen W: Effect of unsupervised home-based proprioceptive training on recurrences of ankle sprain: Randomised controlled trial. *BMJ* 339:b2684, 2009.

Randomized controlled trial studying the effects of a home-based proprioceptive program to reduce the recurrence of ankle sprains over a one-year time frame; 522 athletes randomized into intervention and control groups; 22% of intervention group.

Konradsen L, Olesen S, Hansen HM: Ankle sensorimotor control and eversion strength after acute ankle inversion injuries. *Am J Sports Med* 26:72–77, 1998.

Forty-four subjects immediately postlateral ankle sprain were tested and retested with regard to maximal eversion strength and joint position sense at weeks 1, 3, 6, 12 after acute injury. Joint position sense can be affected up to 12 weeks post injury. Isometric eversion strength was significantly decreased at 3 weeks after injury, but had returned to normal values at 6 weeks after injury.

Nyanzi CS, Langridge J, Heyworth JR, et al: Randomized controlled study of ultrasound therapy in the management of acute lateral ligament sprains of the ankle joint. *Clin Rehabil* 13:16–22, 1999.

Randomized controlled trial of 51 patients receiving either placebo or active ultrasound following acute ankle sprain. No differences noted between groups, however, both groups improved in pain control and edema within the variable of time.

Thacker SB, Stroup DF, Branche CM, et al: The prevention of ankle sprains in sports. A systematic review of the literature. *Am J Sports Med* 27:753–760, 1999.

This systematic review identified 113 studies reporting the risk of ankle sprains in sports, methods to provide support, the effect of these interventions on performance, and comparison of prevention efforts. The most common risk factor for ankle sprain in sports is history of a previous sprain. Based on the review, it was recommended that athletes with a sprained ankle complete supervised rehabilitation before returning to practice or competition, and those athletes suffering a moderate or severe sprain should wear an appropriate orthosis for at least 6 months.

Van Rijn RM, van Os AG, Bernsen RM, et al: What is the clinical course of acute ankle sprains? A systematic literature review. *Am J Med* 121:324–331, 2008.

This review presents the clinical course of pain, objective and subjective instability, and subjective recovery of adult patients with conventionally treated ankle sprains. In total, 31 studies were included, from which 24 studies were of high quality. A risk factor for residual symptoms might be sports activity at a high level, but more studies evaluating prognostic factors in patients with acute ankle sprains are needed.

Verhagen E, van Mechelen W, de Vente W: The effect of preventive measures on the incidence of ankle sprains. *Clin J Sports Med* 10:291–296, 2000.

A systematic review from 1980 to 1998 with eight studies meeting the criteria. The review suggested evidence for taping and prophylatic bracing to reduce incidence and severity of ankle sprains. There was also evidence that preventative measures are as effective at reducing ankle sprain in both athletes with and without a history of recurrent sprain.

Wikstrom EA, Naik S, Lodha N, et al: Balance capabilities after lateral ankle trauma and intervention: a meta-analysis. *Med Sci Sports Exerc* 41:1287–1295, 2009.

A total of 37 articles were included in a meta-analysis of postural sway following acute and chronic lateral ankle sprain. Postural control impairments are present in patients with both a short and a long history of lateral ankle sprains. Balance/coordination training programs improve the postural control scores of patients with an acute lateral ankle sprain and with CAI. Further research needs to determine the optimal dosage, intensity, and type of training needed to maximize postural control improvements and to reduce recurrent ankle injuries. Further research also needs to evaluate a risk reduction/preventative effect associated with balance training after both acute and chronic ankle trauma.

Multiple-Choice Questions

QUESTION 1. Which of the following is important in preventing a recurrent ankle sprain?

A. Prophylactic bracing
B. Decreased range of motion
C. Hop test less than 50% the opposite side
D. Presence of joint swelling

QUESTION 2. Which of the following indicates that it is safe to return to sport?

A. Pain during jumping activity
B. No pain or swelling of the ankle after a heavy workout with sport-specific exercises
C. Daily antiinflammatory medication is still required for pain control after sport-specific exercises
D. A mild limp with sport-specific exercises

QUESTION 3. Which of the following is the most significant difference between a high ankle sprain and a lateral ankle sprain?

A. Rehab protocol
B. Likelihood of recurrent injury
C. Expected time to return to sport
D. Likelihood of surgery

QUESTION 4. Which of the following modalities is not recommended following an ankle sprain?

A. Immobilization
B. Heat therapy
C. Cold therapy
D. Antiinflammatory medication

QUESTION 5. Which of the following is an indication for surgical management of a lateral ankle sprain?

A. Pain at 3 weeks following the sprain
B. Decreased ROM at 3 weeks following a sprain
C. Recurrent ankle sprains after optimal rehabilitation
D. Presence of a small avulsion fracture off the distal fibula

Answer Key

QUESTION 1. Correct answer: **A** (see Protection)

QUESTION 2. Correct answer: **B** (see Milestones for Progression to Advanced Sport-Specific Training and Conditioning)

QUESTION 3. Correct answer: **C**

QUESTION 4. Correct answer: **B**

QUESTION 5. Correct answer: **C** (see Criteria For Abandoning Nonoperative Treatment and Proceeding to Surgery or More Intensive Intervention)

POSTOPERATIVE REHABILITATION AFTER LATERAL ANKLE LIGAMENT REPAIR/RECONSTRUCTION

Scot A. Youngblood, MD, CDR, MC, USN, and William E. Burns, Jr., DPT, OCS, SCS

Indications for Surgical Treatment

- Recurrent lateral ankle instability despite an appropriate course of nonoperative care: rehabilitative exercises and ankle supportive (lace-up) bracing.

Brief Summary of Surgical Treatment

Major Surgical Steps

- Examination under anesthesia—anterior drawer and talar tilt testing for confirmation of excessive laxity
- Open surgical approach to anterior talofibular ligament (ATFL) and calcaneofibular ligament (CFL)
- Inspection of peroneal tendons as appropriate
- Shortening and repair of native tissue to anatomic attachment points on the fibula of both the ATFL and CFL
- Imbrication of the repair with the inferior extensor retinaculum (Gould modification)

Factors That May Affect Rehabilitation

Anesthetic

- For the vast majority of cases, rehabilitation is delayed until at least the 2-week mark. Barring any anesthetic complication, there should by this time be no persistent impact of the choice of anesthetic at the first rehabilitation session.

Surgical

- Arthroscopy of ankle: Some experts recommend a routine diagnostic arthroscopy of the ankle before the ligament repair. Intraarticular lesions encountered are treated as appropriate: osteochondral lesion of the talus microfracture, synovectomy, or postinjury scar debridement.
- Tissue augmentation: In the setting of atrophic native tissues, the surgeon may opt to perform a reconstruction with tendon autograft or allograft (most commonly a gracilis or semitendinosus hamstring tendon). Most experts recommend a slower progression of activities after implantation of grafted tissue, especially allograft (donated tissue).
- Peroneal tendon repair or tenodesis: Peroneal tendinopathy (tendinitis and tears) can occur with inversion injuries to the ankle. Chronic pain or swelling in the area of the tendons and preoperative imaging may demand exploration of the tendons at the time of the surgery. Indicated treatment can include a tenosynovectomy, tendon repair, or tenodesis (removal of the diseased tendon and suturing of the remaining tendon ends to the other peroneal tendon).
- Hindfoot or forefoot realignment: Some patients with ankle instability have a predisposing architecture to their foot: cavovarus (inverted heel and a high arch). Realignment osteotomies of the heel and/or the forefoot may be indicated to protect the repair and prevent additional inversion injuries. Typically these osteotomies are kept nonweightbearing for 6 weeks before progression of weightbearing.

Other Surgical Techniques and Options

- It has been said that many foot and ankle surgeons perform a "Brostrom", but every one of them performs it slightly differently. Choices available to the operative surgeon beyond those listed in the section above include repairing only the anterior talofibular ligament (and not the calcaneofibular ligament), performing a midsubstance repair versus reattaching the ligaments to bone, using suture anchors versus drill holes in the bone to accomplish the repair, choosing not to incorporate the inferior extensor retinaculum, sacrificing a portion of a peroneal tendon in order to reinforce the repair, and choice of suture (absorbable suture versus second generation high tensile strength polyethylene braided suture). These multiple variables underscore the importance of communicating with the operative surgeon regarding the planned rehabilitation protocol to ensure it is neither too aggressive nor too restrictive for the specific repair that was performed.

Before Surgery: Overview of Goals, Milestones, and Guidelines[1]

- Resolution of any residual swelling in the involved ankle
- Restoration of full active range of motion in all directions
- Normalize gait pattern
- Maximize static and dynamic single-limb standing balance in the involved ankle
- Maximize strength of the peroneals, gastrocnemius/soleus complex, and tibialis anterior and posterior muscles

[1]*Prehabilitation, if appropriate, is described in the Nonoperative Rehabilitation section of this chapter.*

GUIDING PRINCIPLES OF POSTOPERATATIVE

- Understand the anatomical basis of the surgical repair performed
- Understand any additional procedures performed and their implications for the patient's specific postoperative rehabilitation
- Know the positions and activities that will stress the repaired structures, and avoid these until the appropriate timeframe
- Progressive advancement of activities with adequate protection of healing structures

Phase I: Immediate Postoperative Period (days 0 to 14)

Clinical Pearls

- Patients should be encouraged to keep their operative extremity elevated in their nonweightbearing splint, especially for the first 3 to 5 days after their surgery, during which swelling peaks.
- No study has shown an advantage to motion before the 2-week point, at which skin sutures are often removed. The desire to aggressively begin therapy in the anxious patient must be balanced by the potentially significant complications of wound dehiscence and infection. Most patients have healed their incisions adequately by 2 weeks to have their sutures removed, Steri-Strips applied, and gently begin progressive range of motion.

Goals

- Allow adequate resolution of swelling and pain with appropriate soft tissue rest after the surgical procedure.
- Allow the incision to heal adequately before the institution of motion and aggressive advancement of range of motion exercises.
- Preserve full range of motion of the ipsilateral hip, knee, and digits.

Protection

- Nonweightbearing in a posterior splint secured with elastic bandage.
- Crutch ambulation

Management of Pain and Swelling

- Oral analgesic medication and ice
- Rest, ice, compression, and elevation
- Commercially available sequential compression cryotherapy devices may be used to control and reduce swelling

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Active range of motion activities for the ipsilateral hip, knee, and digits during the protection phase

Other Therapeutic Exercises

- Upper body ergometry to maintain cardiovascular fitness

Milestones for Progression to the Next Phase

- Healing of the surgical incision with reduction of postoperative swelling.

Phase II (weeks 2 to 6)

Clinical Pearls

- Ensure normal mobility of the surgical incision and underlying tissues in order to prevent the development of adhesions that could impede the progression of range of motion.
- Neuromuscular electrical stimulation (NMES) can be used to facilitate activation of the peroneus longus and brevis as well as the tibialis anterior muscles in cases of inhibition.
- If available and when the surgical incision is fully healed, aquatic therapy, particularly water walking, can help facilitate lower extremity strengthening and the return to a normal walking pattern.
- Articulated Cam Walker Range of Motion Progression. Another option for rehabilitation in this timeframe is to utilize an articulated cam walker with adjustable range of motion stops to allow protected early motion. During the third and fourth weeks postoperatively, 10° of dorsiflexion and 20° of plantarflexion are allowed while the patient is weightbearing as tolerated. During the fifth and sixth weeks, 20° of dorsiflexion and 40° of plantarflexion are allowed. (See Evidence References, Karlsson et al.) Obviously this rehabilitative option would be dependent on the availability of an articulated cam walker and would be in addition to the therapy discussed in this section.

Goals

- Resolution of postoperative swelling
- Transition to Weight Bearing As Tolerated (WBAT) in cam walker
- Increase dorsiflexion in the operative ankle to at least 10°
- Increase plantarflexion in the operative ankle to at least 30°
- Increase strength in the peroneals, gastrocnemius/soleus complex and tibialis anterior and posterior muscles to at least 3+/5

Protection

- WBAT with the use of a cam walker
- A standard cam walker can be used or, if available, an articulated cam walker may be employed to allow for the progression of functional yet protected range of motion in the talocrural joint (see Clinical Pearls).

Management of Pain and Swelling

- Acetaminophen and/or NSAIDs as needed
- Ice and elevation following physical therapy and other periods of prolonged standing and/or walking
- Commercially available sequential compression cryotherapy devices may be used to control and reduce swelling

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

Tarsometatarsal and intermetatarsal joint mobilization in the operative foot

Soft Tissue Techniques

- Scar mobilization and retrograde massage to prevent adhesions at the surgical site and mobilize edema

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Active-assisted range of motion of the talocrural joint to 10° of dorsiflexion and 30° of plantarflexion

Other Therapeutic Exercises

- Upper body ergometry to maintain cardiovascular fitness
- Upper body strengthening activities as tolerated (preferably in a seated or supine position)

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Isometric activation of the peroneus longus, brevis and tertius
- Isotonic dorsiflexion and plantarflexion through a protected range of motion (10° of dorsiflexion and 30° of plantarflexion)

Sensorimotor Exercises

- Seated active plantarflexion to 30° and dorsiflexion to 10° using a rockerboard (see Figure 39-11)

Techniques to Increase Muscle Strength, Power, and Endurance

- Multi-angle isometrics to 10° dorsiflexion and 30° of plantarflexion

Neuromuscular Dynamic Stability Exercises

- Rhythmic stabilization in all directions (dorsiflexion, plantarflexion, inversion, and eversion)

Functional Exercises

- Ambulation in cam walker

TIMELINE 39-2 **Postoperative Rehabilitation After Lateral Ankle Ligament Reconstruction/Repair (Brostrom Procedure)**

PHASE I (weeks 1 to 2)	PHASE II (weeks 2 to 6)
• Splint for protection of surgical repair • Non–weightbearing with crutches • PT modalities to reduce pain and swelling • Active range of motion for the ipsilateral hip, knee and digits • Upper body ergometry for cardiovascular fitness	• Cam walking boot • Weightbearing as tolerated without assistive device • PT modalities to reduce pain and swelling • Neuromuscular electrical stimulation to facilitate neuromuscular reeducation • Tarsometatarsal and intermetatarsal joint mobilization • Scar mobilization • Active assisted range of motion to at least 10° dorsiflexion and 30° plantarflexion • Isometric activation of the peroneus longus, brevis and tertius • Multiangle isometrics to 10° of dorsiflexion and 30° of plantarflexion • Seated active dorsiflexion to 10° and plantarflexion to 30° with rockerboard • Rhythmic stabilization in all directions (dorsiflexion, plantarflexion, inversion and eversion) • Upper body strengthening activities as tolerated (seated or supine)

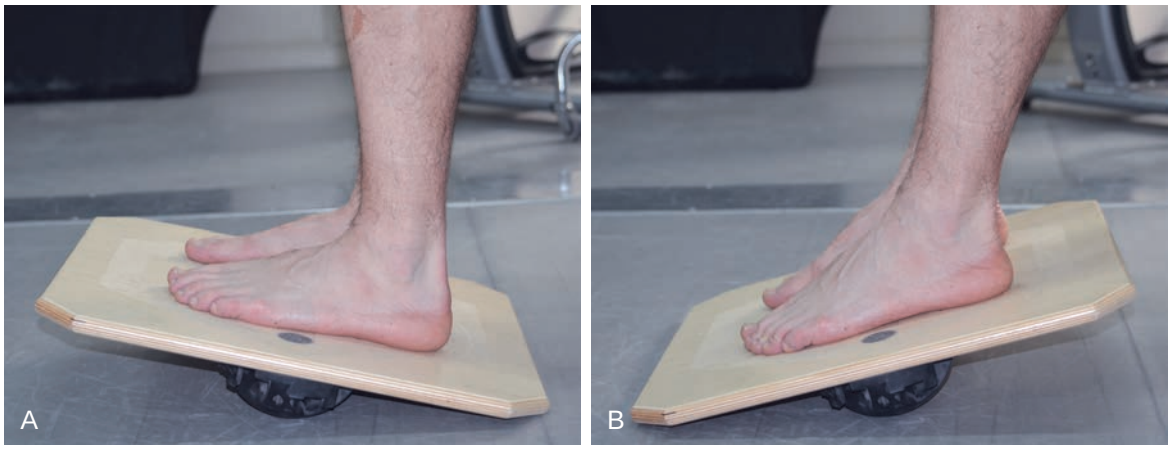


FIGURE 39-11 The rockerboard can be used in the initial stages of rehabilitation for reestablishment of dorsiflexion (**A**) and plantarflexion (**B**) in the operative ankle.

Milestones for Progression to the Next Phase

- Resolution of postoperative swelling
- No pain with full weightbearing and ambulation in cam walker
- Active range of motion to at least 10° of dorsiflexion and 30° of plantarflexion
- 3+/5 strength in the involved peroneus longus, brevis and tertius; gastrocnemius/soleus complex and tibialis anterior and posterior

Phase III: Immediate Postoperative Period (weeks 6 to 12)

Clinical Pearls

- The use of a treadmill for gait training can be effective in facilitating the normalization of the patient's gait pattern and ambulatory cadence.
- Ensure supplementation of the patient's outpatient treatment course with a comprehensive home exercise program of progressive range of motion and strengthening exercises.

TIMELINE 39-2 Postoperative Rehabilitation After Lateral Ankle Ligament Reconstruction/Repair (Brostrom Procedure) (Continued)

PHASE III (weeks 6 to 12)	PHASE IV (weeks 12 to 16)	PHASE V (weeks 16 to 24)
• Discontinue cam walking boot • Transition into lace-up figure-8 ankle brace • PT modalities as needed to reduce residual pain and swelling • Advance to full active range of motion in all directions • Mobilizations as needed to address particular motion restrictions • Scar mobilization as needed • Standing BAPS exercise: level 1 or 2 • Single-limb static standing balance on firm surface • Sagittal and coronal plane weightshifting on rocker board • Multi-directional ankle strengthening with resistance band • Double-limb calf press (body weight only) • Rhythmic stabilization in all directions • Single-limb standing on affected leg while pulling against resistance band with unaffected leg (sagittal plane) • Wall squats • Single-limb stepping (4″ step) • Treadmill walking • Stationary cycling	• PT Modalities as needed • Continue use of lace-up figure-8 brace • Mobilizations as needed • Double-limb and single-limb leg press • Shallow and deep water exercise or swimming • Upper body strengthening activities as tolerated • Stationary cycling • Standing BAPS exercise: level 3 or 4 • Single-limb static standing balance on foam mat • Single-limb standing balance on wobble board or disc • Double-limb and single-limb calf press • Resisted lunges • Lunges onto BOSU • Single-limb balance with Plyoball toss (front facing) • Medicine ball toss standing on wobble board with wide base of support • Single-limb standing on affected leg on foam mat while pulling against resistance band with unaffected leg (four directions) • Interval running	• Maintain full motion of ankle and all uninvolved joints • Mobilizations as needed • Advance weight/resistance as tolerated for previous OKC and CKC exercises • Treadmill running • Elliptical trainer for cross training • Standing BAPS exercise: level 3 or 4 • Single-limb static standing balance on foam mat with perturbation such as multidirectional reaching • Resisted lunges onto BOSU • Single-limb balance with Plyoball toss (side facing) • Medicine ball toss standing on wobble board with narrow base of support • Box jumps • Double-limb and single-limb plyometric hops • Straight line sprints • Shuttle run • Crossover and cutting drills • Sport specific drills

Goals

- Transition to full weightbearing in lace-up figure-8 ankle brace
- Advance to full active range of motion in all directions
- Increase strength in the involved peroneus longus and brevis, gastrocnemius/soleus complex and tibialis anterior and posterior to 4/5
- Normalize gait pattern and ambulatory cadence
- Initiate single-limb activities for strength, balance and proprioception training

Protection

- Lace-up figure-8 ankle brace

Management of Pain and Swelling

- Oral analgesic medication or NSAIDs as needed.
- Ice and elevation following physical therapy and other periods of prolonged standing and/or walking
- Commercially available sequential compression cryotherapy devices may be used to further control and reduce swelling

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Tarsal, tarsometatarsal, and intermetatarsal joint mobilization as needed to address particular mobility restrictions.

Soft Tissue Techniques

- Scar mobilization as needed

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Active assisted range of motion exercises through the normal range of motion in all directions. Care must be taken not to advance beyond the normal ligamentous endfeel of the surgically repaired anterior talofibular and calcaneofibular ligaments in dorsiflexion, plantarflexion or inversion.



FIGURE 39-12 Standing Biomechanical Ankle Platform System (BAPS) board. The patient rotates the board in both clockwise and counterclockwise directions. The BAPS system incorporates an adjustable half-dome base by which the degree of motion and instability can be advanced (Levels 1 to 5). Refer to postoperative phases for appropriate advancement of levels.

Other Therapeutic Exercises

- Stationary cycling
- Upper body strengthening activities as tolerated (preferably in a seated or supine position)

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Peroneus longus, brevis and tertius

Sensorimotor Exercises

- Standing Biomechanical Ankle Platform System (BAPS) exercise: clockwise and counterclockwise, level 1 or 2 (Figure 39-12)

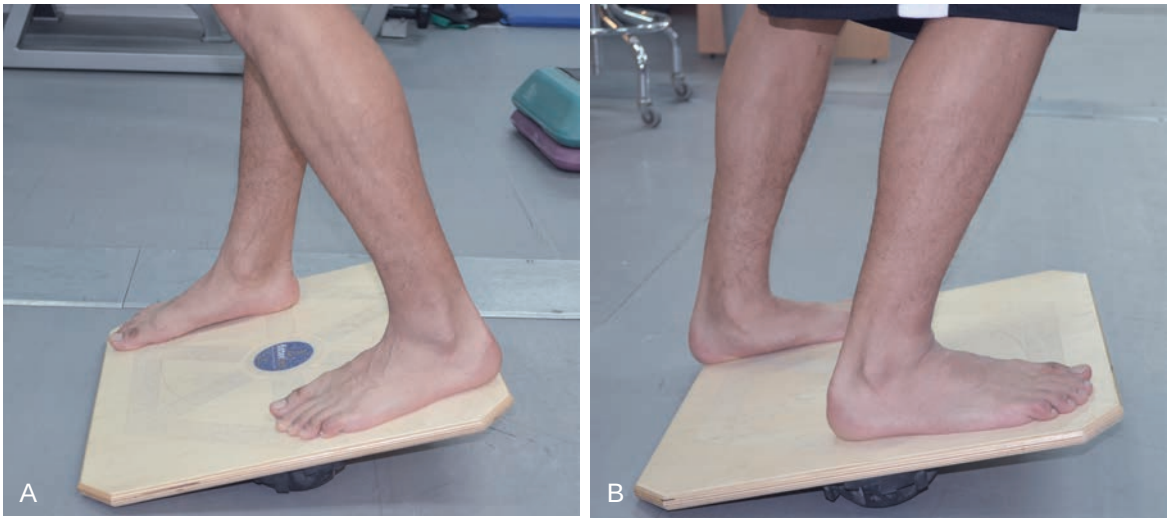


FIGURE 39-13 Sagittal plane weight shifting on a rockerboard isolating ankle plantarflexion (**A**) and dorsiflexion (**B**). Coronal plane weight shifting for eversion and inversion can also be incorporated utilizing the rockerboard.

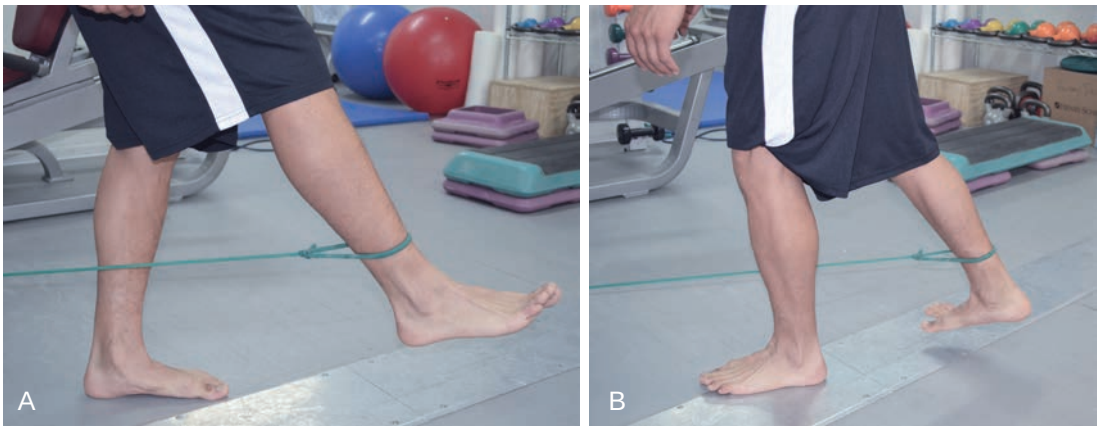


FIGURE 39-14 Resisted hip flexion (**A**) and extension (**B**) while standing on single limb. These exercises can also be advanced to standing on a foam mat with the single limb.

- Single-limb static standing balance on firm surface
- Sagittal and coronal plane weight shifting on rocker board (Figure 39-13)

Open and Closed Kinetic Chain Exercises

- (OKC) Multi-directional ankle strengthening with resistance band
- (CKC) Double-limb calf press (body weight only)

Techniques to Increase Muscle Strength, Power, and Endurance

- Treadmill walking

Neuromuscular Dynamic Stability Exercises

- Rhythmic stabilization in all directions
- Single-limb standing on operative leg while pulling against resistance band with nonoperative leg (sagittal plane) (Figure 39-14)

Functional Exercises

- Wall squats
- Single-limb stepping (4″ step)

Milestones for Progression to the Next Phase

- Full active range of motion in all directions
- Strength in the involved peroneus longus, brevis and tertius; gastrocnemius/soleus complex and tibialis anterior and posterior to 4/5
- Normal gait pattern and ambulatory cadence

Phase IV (weeks 12 to 16)

Clinical Pearls

The use of a structured return to running program utilizing intervals is essential for minimizing injury risk and facilitating safe progression. Refer to the sample program in Box 39-2. The patient is advanced to the next stage when the running intervals are performed without pain and with a normal running pattern.

BOX 39-2 Sample Structured Return to Running Program

STAGE	WALK	RUN	REPETITIONS	TOTAL TIME
Stage 1	5 minutes	1 minute	5	30 minutes
Stage 2	4 minutes	2 minutes	5	30 minutes
Stage 3	3 minutes	3 minutes	5	30 minutes
Stage 4	2 minutes	4 minutes	5	30 minutes
Stage 5	1 minute	5 minutes	5	30 minutes

The patient is advanced to the next stage when the running intervals are performed without pain and with a normal running pattern.

Goals

- Increase strength in the involved peroneus longus, brevis and tertius; gastrocnemius/soleus complex and tibialis anterior and posterior to at least 4+/5
- Equal static single-limb standing balance bilaterally
- Ability to perform all rehabilitation activities without bracing
- Return to straight-line running

Protection

- Use of lace-up figure-8 ankle brace as needed during periods of prolonged ambulation especially on uneven terrain.

Management of Pain and Swelling

- OTC analgesics or NSAIDs as needed
- Ice as needed following rehabilitation activities or when residual swelling is noted

Other Therapeutic Exercises

- Double-limb and single-limb leg press
- Shallow and deep water exercise or swimming (if aquatics are available)



FIGURE 39-15 Static single-limb standing balance for the operative extremity utilizing foam mat.



FIGURE 39-16 Single-limb standing balance on wobble board.

- Upper body strengthening activities as tolerated
- Stationary cycling

Sensorimotor Exercises

- Standing BAPS exercise: clockwise and counterclockwise, level 3 or 4
- Single-limb static standing balance on foam mat (Figure 39-15)
- Single-limb standing balance on wobble board or disc (Figure 39-16)

Open and Closed Kinetic Chain Exercises

- (CKC) Double-limb and single-limb calf press (Figure 39-17)
- (OKC) Multi-directional ankle strengthening utilizing a commercially available weighted device such as the Ankle Isolator® (Figure 39-18)

Techniques to Increase Muscle Strength, Power, and Endurance

- Resisted lunges (Figure 39-19)



FIGURE 39-17 Single-limb Closed Kinetic Chain (CKC) calf press. This can also be performed in double-limb support.

Neuromuscular Dynamic Stability Exercises

- Lunges onto BOth Sides Up (BOSU)® (Figure 39-20)
- Single-limb balance with Plyoball toss (front facing) (Figure 39-21)
- Plyoball toss standing on wobble board with wide base of support

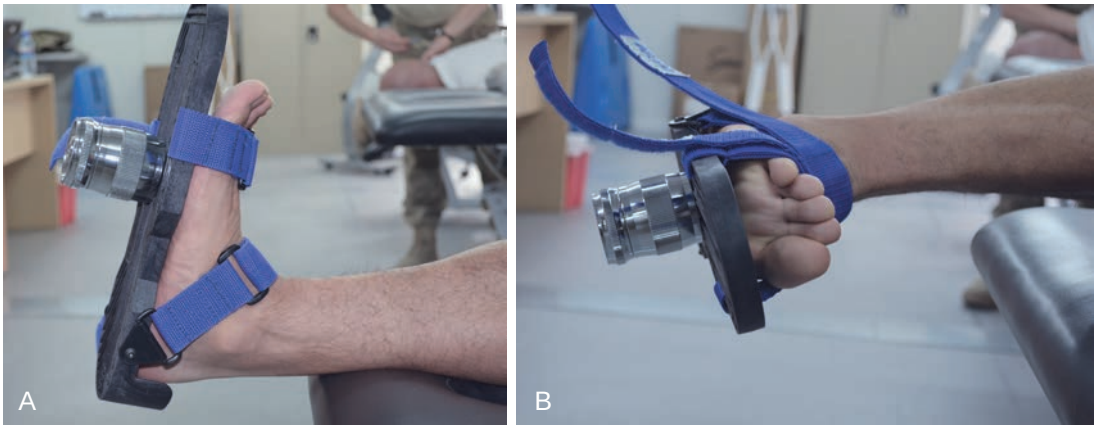


FIGURE 39-18 Resisted Open Kinetic Chain (OKC) ankle dorsiflexion (**A**) and eversion (**B**). Shown is a commercially-available weighted foot platform that can be used to strengthen the tibialis anterior and peroneal muscles respectively.

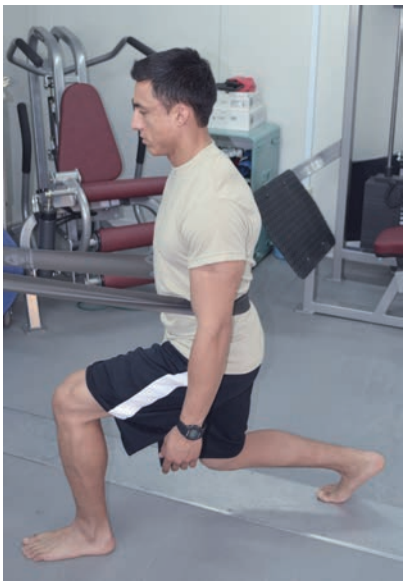


FIGURE 39-19 Resisted lunges. Patient should alternate leading with the operative and nonoperative extremity.

- Single-limb standing with operative leg on foam mat while pulling against resistance band with nonoperative leg (four directions) (Figure 39-22)

Functional Exercises

- Single-limb step

Milestones for Progression to the Next Phase

- Strength in the involved peroneus longus, brevis and tertius; gastrocnemius/soleus complex and tibialis anterior and posterior equals 4+/5
- Equal static single-limb standing balance bilaterally
- Ability to perform all rehabilitation activities without bracing

Phase V (weeks 16 to 24)

Goals

- Increase strength in the involved peroneus longus, brevis and tertius; gastrocnemius/soleus complex and tibialis anterior and posterior to 5/5
- Equal dynamic single-limb standing balance bilaterally
- Engage in sport-specific training
- Straight-line running at full speed without limitations
- Full speed cutting and crossover without limitations
- Fully controlled rapid deceleration, stopping and starting activities
- No limitations in jumping or landing activities
- Return to full sports participation

Protection

- Lace-up figure-8 ankle brace for sports and activities that require rapid stops/starts and/or changes in direction (i.e., cutting)

Management of Pain and Swelling

- OTC analgesic medication or NSAIDs as needed
- Ice as needed

Other Therapeutic Exercises

- Double-limb and single-limb leg press
- Shallow and deep water exercise or swimming (if aquatics are available)



FIGURE 39-20 Lunges onto BOSU facing forward (**A**) and to the side (**B**).



FIGURE 39-21 Single-limb balance on foam mat with Plyoball toss (front facing). This exercise can also be performed with double-limb support if patient is unstable in single-limb stance.

- Upper body strengthening activities as tolerated
- Stationary cycling
- Use of the elliptical trainer for cross training

Sensorimotor Exercises

- Standing BAPS exercise: clockwise and counterclockwise, level 4 or 5
- Single-limb standing balance on foam mat with perturbation such as multi-directional reaching (Figure 39-23)
- Single-limb standing balance on wobble board or disc

Open and Closed Kinetic Chain Exercises

- Advance weight/resistance as tolerated for previous OKC and CKC exercises

Techniques to Increase Muscle Strength, Power, and Endurance

- Straight-line sprints
- Shuttle run
- Crossover and cutting drills

Neuromuscular Dynamic Stability Exercises

- Resisted lunges onto BOSU® (See Figure 39-20)
- Single-limb balance with Plyoball toss (side facing)
- Medicine ball toss standing on wobble board with narrow base of support
- Single-limb standing on affected leg on foam mat while pulling against resistance band with unaffected leg (four directions)

Plyometrics

- Shuttle® System
- Box jumps
- Two-leg ankle hops: in place
- Two-leg ankle hops: forward/backward
- Two-leg ankle hops: side to side
- Unilateral ankle hops: in place
- Unilateral ankle hops: forward/backward
- Unilateral ankle hops: side to side
- Unilateral broad jump

Functional Exercises

- Single-limb stepping (6″ step)
- Running

Sport-Specific Exercises

- Practice of key elements of the patient's particular sport/event

Milestones for Progression to Advanced Sport-Specific Training and Conditioning

- Strength in the involved peroneus longus, brevis and tertius; gastrocnemius/soleus complex and tibialis anterior and posterior equals 5/5
- Equal dynamic single-limb standing balance bilaterally

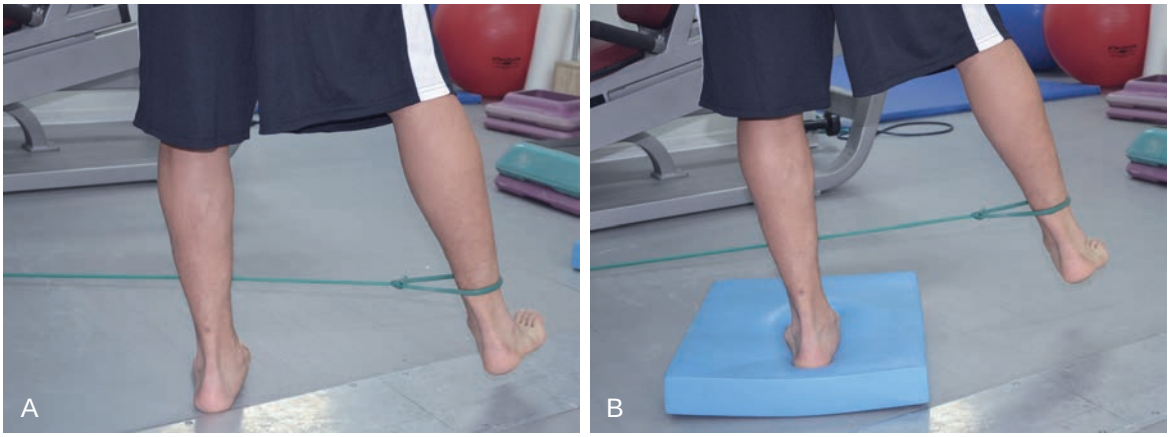


FIGURE 39-22 Single-limb standing on affected leg off (**A**) and on (**B**) a foam mat while pulling against resistance band with unaffected leg (hip flexion, extension, abduction and adduction).



FIGURE 39-23 Single-limb standing balance on foam mat with perturbation such as multi-directional reaching for a weight.

- Return to running without limitations
- Return to sports without limitations

Criteria for Return to Sport

General

- Full active range of motion in the operative ankle
- Normal (5/5) strength in the musculature in the operative ankle
- Straight-line running at full speed without limitations
- Full speed cutting and crossover drills
- No limitations in jumping or landing activities

Sport-Specific

- With respect to return to sport criteria for specific sports, the rehabilitation specialist must analyze the physical demands of the respective sport on the ankle and employ a series of tests and exercises to ensure readiness for return to pre-injury levels of activity.

After Return to Sport

Continuing Fitness or Rehabilitation Exercises

- Continue to maximize lower extremity strength with particular attention on the peroneals
- Continue to maximize balance and proprioception with ongoing perturbation training

Exercises and Other Techniques for Prevention of Recurrent Injury

- Employ cross-training techniques to minimize the risk of overuse injury
- Continue with bracing during high-level sports

Evidence

Kannus P, Renstrom P: Treatment for acute tears of the lateral ligaments of the ankle. Operation, cast, or early controlled mobilization. *J Bone Joint Surg Am* 73:305–312, 1991.

In this current concepts review, 12 prospective randomized studies are assessed in order to find the optimal treatment for grade III (complete) lateral ligament sprains. Of the three treatment modalities, the authors conclude that functional rehabilitation of acute sprains is superior to acute surgical repair or cast immobilization alone. Functional rehabilitation offers the earliest return to work and sports with maintenance of excellent range of motion, and avoids surgical complications. Furthermore, patients with persistent instability after functional rehabilitation do well with delayed surgical repair. (Level I evidence).

Karlsson J, Rudholm O, Bergsten T, et al: Early range of motion training after ligament reconstruction of the ankle joint. *Knee Surg Sports Traumatol Arthrosc* 3:173–177, 1995.

In a prospective, randomized study, 40 patients were randomized postoperatively after lateral ankle ligament repair to cast immobilization for 6 weeks or early range of motion in a walker boot at 2 weeks. Both groups then began the identical postoperative therapy regimen. The early mobilization group had less sick leave (6.5 vs. 8.5 weeks for the cast group) and an earlier return to sports (9.5 vs. 12.5 weeks). At 2 years final follow-up, 80% of the cast-immobilized patients were deemed to have satisfactory results on the scoring scale used versus 90% for the early range of motion group. (Level I evidence).

Kaumeyer G, Malone TR: Ankle injuries: anatomical and biomechanical considerations necessary for the development of an injury prevention program. *J Orthop Sports Phys Ther* 1:171, 1980.

The authors review the anatomy and biomechanics of the ankle joint and make recommendations on an injury prevention program for athletes returning to play after an ankle sprain. (Level V evidence).

Kirk KL, Campbell JT, Guyton GP, et al: ATFL elongation after Brostrom procedure: a biomechanical investigation. *Foot Ankle Int* 29:1126–1130, 2008.

In a cadaveric study, the anterior talofibular ligaments of six specimens were meticulously dissected. A differential variable reluctance transducer (DVRT) was attached to the ligament endpoints and the ligament lengths were examined pre- and postrepair. Elongation was measured in a load frame with protected motion of 30° plantarflexion and 10° dorsiflexion for the intact and sectioned ATFL and for the repaired specimen with and without protected motion. Initial elongation in the unprotected, repaired group was significantly higher than initial elongation in the intact ($p < 0.01$), sectioned ($p = 0.02$), and repaired, protected ($p < 0.01$) groups. Final elongation in the unprotected repaired group was also greater than final elongation in all other groups ($p < 0.01$ for all comparisons). This study provides biomechanical support for protected plantarflexion and dorsiflexion range of motion protocols after lateral ankle ligament reconstruction.

Lee AJ, Lin WH: Twelve-week biomechanical ankle platform system training on postural stability and ankle proprioception in subjects with unilateral functional ankle instability. *Clin Biomech* 23:1065–1072, 2008.

In this therapeutic study, 12 university students with unilateral functional ankle instability underwent a 12-week biomechanical ankle platform training program. Baseline and posttraining measurements of static postural stability and ankle reposition sense were taken. The mean radius of the center of pressure excursion recorded during single-leg standing with a force platform (an indicator of static postural instability) was significantly reduced after the 12-week training program ($p < 0.05$). The absolute error from a preselected ankle angle as measured by an isokinetic dynamometer was also significantly reduced after the training program, indicated an improvement in ankle reposition sense ($p <$

0.05). This study lends support to the notion that as ankle proprioception (position sense) improves with training, so does functional joint stability. (Level II evidence).

Lentell G, Baas B, Lopez D, et al: The contributions of proprioceptive deficits, muscle function, and anatomic laxity to functional instability of the ankle. *J Orthop Sports Phys Ther* 21:206–215, 1995.

Forty-two subjects with unilateral chronic ankle instability were evaluated in order to quantitate the role of decreased proprioception, eversion weakness and anatomic laxity of the unstable ankle versus the contralateral normal ankle. Analysis revealed a significant difference in proprioception and radiographic laxity in the chronically unstable ankles compared to the opposite normal ankles. Ankle eversion isokinetic strength differences were not significant. The authors conclude that proprioception and anatomic laxity play the greatest roles in contributing to the chronically unstable ankle, and thus should be the focus of treatment. (Level III evidence).

Li X, Killie H, Guerrero P, et al: Anatomical reconstruction for chronic lateral ankle instability in the high-demand athlete: functional outcomes after the modified Brostrom repair using suture anchors. *Am J Sports Med* 37:488–494, 2009.

In this case series, 52 patients, all high-level athletes, were followed after a lateral ankle ligament repair (modified Brostrom) with the use of modern suture anchors. The postoperative therapy protocol is documented. At final follow-up at 2 years after the index surgery, 94% had returned to their preoperative level of sporting activity (Tegner scores) and the mean Karlsson score for ankle function was 95 (possible 100 points). Only 6% of patients had decreased motion of the ankle, and there was a 6% rerupture rate, all occurring more than one year after surgery in competitive sports. The authors conclude that anatomical surgical reconstruction utilizing suture anchors with early mobilization postoperatively is associated with a return to previous sporting level in high-level athletes. (Level IV evidence).

Pijnenburg AC, Van Dijk CN, Bossuyt PM, et al: Treatment of ruptures of the lateral ankle ligaments: a meta-analysis. *J Bone Joint Surg Am* 82:761–773, 2000.

The authors conducted a meta-analysis of available randomized controlled trials comparing operative treatment, functional treatment and cast immobilization after grade III lateral ligament sprains of the ankle. Twenty-seven studies were included in the review. The authors conclude that operative treatment was associated with a lower risk of recurrent instability than functional treatment, although with the associated risks of operative complications. Furthermore, operative treatment followed by brief immobilization (3 weeks) followed by functional treatment was associated with better results than 6 weeks of postoperative cast immobilization followed by functional treatment. (Level I evidence).

Sefton JM, Yarar C, Hicks-Little CA, et al: Six weeks of balance training improves sensorimotor function in individuals with chronic ankle instability. *J Orthop Sports Phys Ther* 41:81–89, 2011.

In this prospective cohort study, 12 patients with chronic ankle instability (CAI) and 9 healthy volunteers were studied. The patients with CAI received a 6-week balance training program while the healthy subjects did not. At the end of 6 weeks, the CAI patients posttraining demonstrated enhanced dynamic balance (anteromedial direction $p = 0.021$, medial direction $p = 0.048$, posteromedial direction $p = 0.030$), improved inversion joint position sense, and beneficial changes in motoneuron pool excitability compared to healthy controls who did not train. No systematic differences were detected for static balance or plantar flexion joint position sense tasks. (Level II evidence).

Multiple-Choice Questions

QUESTION 1. Name the two lateral ankle ligaments that are most commonly responsible for chronic lateral ankle instability to inversion and are tested manually by the anterior drawer test and the talar tilt test.

A. Posterior talofibular ligament and calcaneofibular ligament
B. Deltoid ligament and subtalar interosseus ligament
C. Anterior talofibular ligament and calcaneofibular ligament
D. Anterior tibiofibular ligament and posterior tibiofibular ligament

QUESTION 2. Common concomitant surgical procedures on patients with lateral ankle instability in addition to a Brostrom (lateral ankle ligament repair/reconstruction) include all the following except:

A. Peroneal repair, debridement, or tenodesis
B. Posterior tibial tendon reconstruction or repair
C Hindfoot osteotomy for excessive heel varus
D. Ankle arthroscopy with or without osteochondral lesion of the talus treatment

QUESTION 3. In an early range of motion therapy protocol in the 2- to 6-week period, rehabilitation goals for this period include all the following except:

A. Dorsiflexion to at least 10° and plantarflexion to 30°
B. Increase active inversion to 20°
C. Increase strength in peroneals, tibialis anterior and posterior to at least 3+/5
D. Resolution of postoperative swelling

QUESTION 4. Return to straight-line jogging on an even surface after a Brostrom lateral ligament repair/reconstruction is appropriate at what postoperative phase or time point

A. Phase II (2 to 6 weeks)
B. Phase III (6 to 12 weeks)
C. Phase IV (12 to 16 weeks)
D Phase V (16 to 24 weeks)

QUESTION 5. In a landmark Level 1 study, Karlsson et al. in 1995 showed all of the following occurred with early motion at 2 weeks postoperatively versus immobilization until 6 weeks except:

A. Less sick leave (6.5 weeks versus 8.5 weeks) in the early motion group
B. A higher rate of "satisfactory" scores (90% versus 80%) in the early motion group
C. Earlier return to sports (9.5 weeks versus 12 weeks) in the early motion group
D. A higher failure / recurrent instability rate (24% versus 10%) in the early motion group

Answer Key

QUESTION 1. Correct answer: **C** (see Surgical Technique)

QUESTION 2. Correct answer: **B** (see Surgical Technique)

QUESTION 3. Correct answer. **B** (see Phase II Rehabilitation)

QUESTION 4. Correct answer. **C** (see Phase IV Rehabilitation)

QUESTION 5. Correct answer. **D** (see References)

POSTOPERATIVE REHABILITATION AFTER TREATMENT OF LATERAL AND MEDIAL ANKLE FRACTURES

Joseph M. Miller, PT, DPT, OCS, SCS, CSCS, and Brett D. Owens, MD

Indications for Surgical Treatment

- It has been reported that between 15% to 25% of all athletic injuries are to the ankle.[1-5] During athletic performance the foot and ankle absorbs significant stress in a multitude of directions. Forces transmitted through the ankle can reach up to six times the body weight during dynamic activity. These large forces imparted across the ankle occasionally lead to fracture and/or ligament disruption. Approximately 5.2% of high school athletes in the United States were diagnosed with ankle fractures from 2005 to 2006.[6] Fractures and/or ligament disruption of the ankle can result in long-term disability and greatly impede or prevent return to sports. Because of the stresses and potential for disability, stabilization and complete healing are essential for medial and lateral fractures and/or ligament disruptions of the ankle.
- Anatomic reduction of the ankle joint is the primary factor that determines long-term success of treatment, regardless of the intervention method.[2,4,6] Fracture type, joint surface alignment, age of the person and presence of cartilage injury also influence long-term outcomes.[4] Three-view radiographs (A/P, lateral, and mortise view) are utilized to assess displacement. Stress views are indicated for suspected ligamentous and syndesmosis injuries. Medial clear space has been shown to be a reliable indicator of instability in the ankle joint.[3] Nonoperative criteria are minimal displacement and stability of fracture/joint.[3] Nonoperative management routinely consists of immobilization in a hard cast or removable splint. Nonoperative immobilization and healing times range from 6–12 weeks.[1-3,5]
- Operative management of ankle fractures and/or ligament disruptions offer the potential for quicker recovery, increased stabilization and better alignment. Additionally, fixation may be indicated if nonoperative care fails for certain injuries. Indications for operative treatment are specific to each type of injury.[2] For isolated lateral malleolar fractures displacement greater than 2 to 4 mm, significant external rotation or shortening of the fibula are indications for surgical stabilization. For displacements of 2 to 4 mm, operative fixation may be offered when the athlete prefers a quicker return to sport. Bimalleolar fractures or equivalent are inherently unstable injuries and require reduction and fixation. Instability of the syndesmosis is diagnosed by assessing the cartilage interval between the medial talus and medial tibia while applying external rotation stress to the ankle.[3] This interval should be no more than 2 mm greater than the interval between the distal tibia and proximal talus. Syndesmotic injuries that are unstable on radiographs or fluoroscopy require fixation across the tibiofibular joint.

Return to Sport

Return to sport after unstable ankle repair is challenging due to the large forces that the ankle joint must endure in most athletic competitions. Also, time frames for return to competition and adequate healing are not consistent across the age range of athletes. There are a limited number of studies that have investigated return to sports after unstable ankle injuries.[1-3,5] However, predictors of return to sport at 1 year have been reported.[1] They include: younger age, male gender, mild to no systemic disease and less severe ankle fractures. Syndesmosis injuries are especially complicated and require longer recovery times. It has been shown the 4.5 mm cortical screws have provided sufficient stabilization of the syndesmosis in young healthy athletes and allowed return to sports as quickly as 6 weeks without complications.[3,5] Additionally, young healthy athletes with bimalleolar or equivalent injuries who underwent stabilization surgeries have been able to return to competition on average of 13 weeks. Eighty-eight percent of healthy older (average age 35 years old) recreational athletes have been able to return to competition within 1 year of stabilization surgery versus only 11% of competitive sport athletes.[1] Despite the age disparity in return to sport time frames, operative repair with immediate progressive weightbearing and progressive functional rehabilitation have allowed for safe and complete return to competition.[1,2,4,5]

Major Surgical Steps

- Anatomic reduction of malleolar fractures
- Rigid internal fixation
- Assessment of syndesmotic injury
- Reduction and fixation of syndesmotic injury

Factors That May Affect Rehabilitation

Surgical

- Lateral malleolus ORIF only versus bimalleolar ORIF versus malleolus + syndesmotic fixation
- Tibial plafond or talus involvement
- Rigidity of fixation construct and quality of patient bone

Other Surgical Techniques and Options

Appropriate surgical treatment of ankle fractures in athletes is facilitated by early evaluation of these injuries. Plain radiographic assessment guides surgical treatment and rehabilitation, therefore is the first recommended step. If easily accessible, radiographs should be obtained before any reduction maneuver. However, if not readily accessible, any joint deformity should be urgently reduced in order to preserve vascularity to the foot and relieve tension of the neurologic structures and soft tissues. The three standard radiographic views are used: AP, lateral, and mortise (Figure 39-24*A*). The mortise view is essential to evaluate the relationship between the tibia, fibula, and talus. As mentioned previously, fracture displacement greater than 2 mm is an indication for surgery, as well as syndesmotic disruption. An argument could be made for earlier return-to-play for nondisplaced fractures treated with rigid fixation; however, there is no literature to support this approach.

The timing of surgery is critical. The healing process does not begin for the bone until ORIF is performed as any clot is typically removed to facilitate anatomic reduction. Therefore, early fixation means earlier return to sport. If fractures are evaluated within minutes to hours, emergent surgery can be performed. This is necessary in cases of fracture dislocations or open injuries. However, if not possible within 12 hours, swelling may preclude the surgeon's ability to safely manage the soft-tissues and surgery may be delayed for 3 to 7 days until swelling improves.

Delicate handling of the soft tissues is critical, but adequate incision is necessary to ensure visualization of the fracture. Anatomic reduction is achieved and fixation is performed. We typically recommend interfragmentary screw fixation using lag technique and 3.5-mm cortical screws. Two screws orthogonal to the fracture line may be enough for rigid fixation, but a low threshold should exist for supplementary plate fixation in athletes attempting an early return to sport. We prefer use of 1/3 semitubular plates due to their low-profile. Syndesmosis integrity may then be tested with an external rotation stress in the mortise position under fluoroscopy. If a question of the syndesmotic integrity exists, we prefer 4.5-mm cortical screw fixation but have also used suture and button constructs. Postfixation radiographs ensure adequacy of reduction and hardware position and provide a comparison view for future radiographs (Figure 39-24*B*).

The soft-tissues are closed in layers and the patient is placed into a splint. This splint is maintained for 1 to 2 weeks and removed for wound check and suture removal (Figure 39-25). At this time, the patient is placed into a cast-boot, allowing for range-of-motion of the ankle to begin.

Before Surgery: Overview of Goals, Milestones, and Guidelines

To Minimize Debilitation and Atrophy

- **Exercises:** For ankle fractures/ligament disruptions, immobilization to protect the area is of key

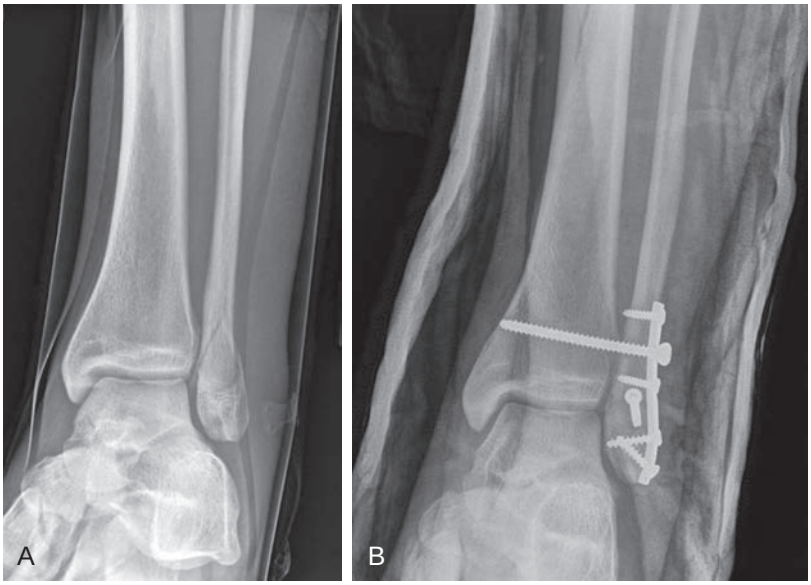


FIGURE 39-24 A, A mortise preoperative view; **B,** a mortise postoperative view.



FIGURE 39-25 Two weeks after suture removal.

importance. Minimizing direct stress to the area in order to avoid displacement and complications should also be a priority before surgery. Maintaining strength and ROM of the hip and knee should be addressed only if external stabilization of the ankle is sufficient. Timely surgical intervention is also important to minimize atrophy.
  - Supervised: Quad sets, four-way straight leg raise, knee and hip AROM, gait nonweightbearing with crutches
  - Home: Nonweightbearing with crutches
- **Modalities:**
  - During treatment: Compression and cryotherapy device use
  - Home use: Ice with elevation three to five times daily for 20 minutes; compression; stabilization with Aircast or similar splint

To Relieve Disability of Injury

- **Acute injury**
  - Exercise Hip ROM and knee ROM
  - Modalities Ice, compression, elevation and immobilization

Phase I: Immediate Postoperative Period (days 0 to 14)

Protection

- Postoperative immobilization is achieved via short leg cast (changed at 7 days if necessary)
- Toe touch weightbearing with bilateral crutches

Management of Pain and Swelling

- Oral pain medication as prescribed
- Application of ice (if feasible)
- Elevation of the limb at rest
- Patient education to minimize lower extremity time in the dependent position
- Casting provides swelling control
- Additional instruction of elevation and avoiding the dependent position

Techniques for Progressive Increase in Range of Motion

Stretching and Flexibility Techniques for the Musculotendinous Unit

- AROM Knee and hip
- Hamstring stretching with an assistive strap

Other Therapeutic Exercises

- Athletes are encouraged to participate in upper body ergometry as tolerated five times a week for cardiovascular conditioning
- Four-way straight leg raise, short arc quadriceps, prone hamstring curls
- All strengthening should be done starting with low resistance (TheraBand or ankle weight), high repetitions, and nonpainful range of motion

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- AROM phalanges to mitigate stiffness, increased muscle pumping action of fluid and activation of foot musculature while immobilized in the cast

Milestones for Progression to the Next Phase

- Goals of the immediate postoperative phase:
  - Protection of repaired structures
  - Minimize effects of immobilization
  - Decrease pain and inflammation
- Progression to the next phase
  - Primarily time based—dependent on the quality of surgical fixation and specific structures repaired

Phase II (weeks 3 to 6)

Goals

It has been shown that immobilization of the ankle for as little as 2 weeks can cause significant atrophy and weakness of the posterior and anterior muscle of the lower leg.[7] In the first 2 weeks after immobilization, the cross-sectional area (CSA) of the posterior compartment decreased by 14% and the anterior compartment by 10%. After an additional 5 weeks, the posterior compartment CSA was a total of 24% less and the anterior compartment was a total of 19% less. Typically, wasting of the musculature is noted when compared to the contralateral side (Figure 39-26). An additional finding was that specific torque of the plantar flexors was also significantly lower in the immobilization group versus matched

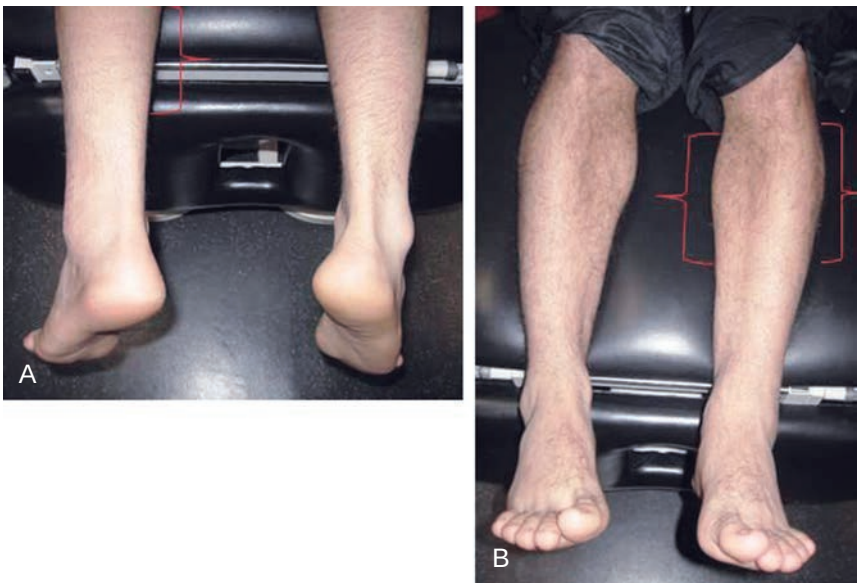


FIGURE 39-26 Atrophy of the left leg is denoted by the brackets.

controls (59% decrease in torque production immediately after immobilization versus matched controls).[7]

Progressive weightbearing, endurance, and resistance exercises have been shown to improve strength and girth measurements after a period of immobilization.[7-10] Plantar flexion specific torque also improved over the 10-week period, but there was still a 5% deficit compared to the contralateral side and a 20% deficit compared to healthy controls.[7] Therefore, minimizing complete immobilization and initiating progressive strengthening, weightbearing, and endurance are the major goals of the rehabilitation during this timeframe. Additional goals include: normalizing gait, restoration of full pain-free movement and restoring proprioceptive input.

Protection

- Progress as tolerated based on symptoms and surgical fixation

Management of Pain and Swelling

- Oral medications as prescribed
- Therapeutic modalities for pain and muscle guarding to include: TENS, Hi-Volt, IFC, and ice
- Patient education: Using pillow or similar apparatus for elevation and positioning for comfort
- Cryotherapy and compression
  - Game ready, cryo cuff, cryo press, ice with compression wrap

TIMELINE 39-3 **Postoperative Rehabilitation after Treatment of Lateral and Medial Ankle Fractures**

PHASE I (weeks 0 to 2)	PHASE II (weeks 3 to 6)
• Short leg cast (changed at 7 days if necessary) • AROM knee and hip • 4-way straight leg raise, short arc quadriceps, prone hamstring curls • AROM phalanges	• Ace wrap with or without horseshoe padding once in camboot • PT Modalities • Scar mobilization once incisions have closed • Conservative to deep tissue techniques to gastocnemius, soleus and peroneals as needed • Stretching/flexibility techniques for the musculotendinous unit • AROM: plantar flexion and dorsiflexion as tolerated 2–3 weeks after surgery with inversion and eversion added at 3–4 weeks • PROM: plantar flexion and dorsiflexion as tolerated 2–3 weeks after surgery with inversion/eversion added at 3–4 weeks • Ankle circles and alphabet 3–4 weeks • Gastrocnemius/soleus stretching: 3–4 weeks with assisted stretching strap supine or long sitting, 4–5 weeks standing with contralateral leg forward • Plantar flexion and dorsiflexion submaximal Isometrics and light resistance 2–3 weeks • Toe crunch with towel as resistance as needed 2–3 weeks • Add inversion and eversion resistance with progression to maximal isometrics • Standing 4 way straight leg raise 5–6 weeks • Double leg tandem stance 4–5 weeks • Single leg stance 5–6 weeks

- Ace wrap with or without horseshoe padding once in camboot
- Continue to avoid the dependent position when not active

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

Manual therapy techniques may provide increased ROM in the ankle with relatively low risk of adverse effects.[5] ROM deficits in dorsiflexion have been shown to be positively affected by manual therapy.[5,12]

- **Precautions:**
- No active or passive eversion or inversion till 3 to 4 weeks
- Grade I–II mobilization Plantar flexion and dorsiflexion till 3 to 4 weeks then add Inversion/Eversion
  - Anatomical motion only 3 to 4 weeks
- Grade III mobilizations 5 to 6 weeks
  - Can add accessory joint manual therapy

Soft Tissue Techniques

- Scar mobilization once incisions have closed
- Conservative to deep tissue techniques to gastocnemius, soleus and peroneals as needed
- Stretching/flexibility techniques for the musculotendinous unit
- AROM: Plantar flexion and dorsiflexion as tolerated 2 to 3 weeks after surgery with inversion and eversion added at 3 to 4 weeks
- PROM: plantar flexion and dorsiflexion as tolerated 2 to 3 weeks after surgery with inversion/eversion added at 3 to 4 weeks
- Ankle circles and alphabet 3 to 4 weeks
- Gastrocnemius/Soleus stretching: 3 to 4 weeks with assisted stretching strap supine or long sitting, 4 to 5 weeks standing with contralateral leg forward

Other Therapeutic Exercises

- Hip strength Four-Way SLR add ankle weights
- Core strengthening
  - 3 weeks bent knee plank abdominal crunches and limb unsupported abdominal work
  - 4 to 6 weeks long leg planks, can progressively add limb supported abdominal work
  - Stability abdominal strengthening

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- 2 to 3 weeks
  - Plantar flexion and dorsiflexion submaximal Isometrics and light resistance
  - Toe crunch with towel as resistance as needed
- 3 to 4 weeks
  - Add inversion and eversion resistance with progression to maximal isometrics and progress resistance
- 5 to 6 weeks
  - Standing four-way straight leg raise

Sensorimotor Exercises

Proprioception has been theorized as a central processing of afferent sensory input from somatosensory, vestibular and visual inputs. Proprioception has been shown to be compromised with ankle injuries and after immobilization[3]. Training can improve dynamic and static instability and reduce the incidence of re-injury. Principles of proprioception training are:

- Progress from double leg to single leg
- Progress from single plane to multiplanar movements
- Progress from static to dynamic
- Progress from conscious focus balance to more automatic

TIMELINE 39-3 Postoperative Rehabilitation after Treatment of Lateral and Medial Ankle Fractures (Continued)

PHASE III (weeks 6 to 10)	PHASE IV (weeks 10 to 14)	PHASE V (weeks 15 to 21)
• Continue previous as needed • DC camboot to semirigid brace • Full AROM and PROM • PT modalities as needed • PROM-full • Mobilizations as needed • Lower stretching • Core strengthening/activation • Weightbearing strengthening • Light agility and begin walk/jog progression if appropriate • Light power training and sports specific	• Continue previous as needed • PT modalities as needed • PT manual therapy as needed • Stretching and mobility as needed • Progressive core activities • Olympic lifting • Progressive agility • Progress walk/jog to full jogging	• Mobilizations as needed • Progressive sports specific • Progress sprinting and agility • Progress to preinjury strength and Olympic training

- Decrease visual inputs
- Progress from basic to functional activities
- Double leg tandem stance 4 to 5 weeks
  - Progress from eyes open to eyes close tandem
  - Progress from even surface to uneven surface
  - Rebounder or ball toss with a partner progress from straight throw and catch to throw and catch with rotation
- Single leg stance 5 to 6 weeks
  - Progress from eyes open to eyes closed
  - Progress from even surface to uneven surface
  - Rebounder or ball toss with a partner progressing from straight throw and catch to throw and catch with rotation

Open and Closed Kinetic Chain Exercises

- CKC
  - Step-ups and step-downs at 3 to 4 weeks
  - Mini-squats 5 to 6 weeks
  - Shuttle MVP, leg press or equivalent 4 to 5 weeks (can initiate low level plyometrics with double leg to single depending on injury and healing)
  - Heel raise progression 5 to 6 weeks
- OKC
  - Leg curls, leg extensions 4 to 6 weeks
  - Ankle resistance with tubing 4 to 6 weeks all directions

Techniques to Increase Muscle Strength, Power, and Endurance

- Stationary bike light 3 weeks
- Aggressive stationary bike 4 weeks
- Elliptical trainer/stair stepper at 5 to 6 weeks
- Light jogging intervals (Table 39-1) 6 weeks with Aircast or equivalent (***depending on level of healing and fixation***) (Figure 39-27)

For muscle hypertrophy, power and endurance of any muscle group the following guidelines are recommended:

Table 39-1 Walk/Run Interval Performed Every Other Day on Track or Treadmill After Week 11 Progress Time by 10% a Week

Week	Walk	Jog	Repetitions	Total Time
6	4 min	2 min	5	30 min
7	3 min	3 min	5	30 min
8	4 min	2 min	5	30 min
9	5 min	1 min	5	30 min
10	5 min	10 min	2	30 min
11		15 min	1	15 min

- Hypertrophy
  - Volume: 3 to 5 sets of 6 to 12 reps with 1-minute rest between sets
  - Intensity: 60% to 80% 1 RM
  - Frequency 2 to 4 times a week
- Power
  - Volume 3 to 5 sets 1 to 5 reps with 2 to 3 minutes rest between sets
  - Intensity 30% to 60% 1RM
  - 1 to 2 times per week
- Endurance
  - Volume 2 to 5 sets 15+ reps with <90 seconds rest between sets
  - Intensity 50% to 65% 1RM
  - 3 to 5 times a week

Neuromuscular Dynamic Stability Exercises

- BAPS/ wobble board
  - 3 weeks seated
  - 4 to 6 weeks increased weightbearing
- Single-leg stance leg swings 5 to 6 weeks (Figure 39-28*A,B*)
- 4 to 6 weeks proprioception machine (cat eye balance, Proprio 5000, etc.)



FIGURE 39-27 Light jogging in an Aircast (*arrow*).



FIGURE 39-28 Single leg stance leg swings. **A,** Starting position is standing on the affected leg with the knee slightly bent. **B,** Swing the unaffected leg back and forth from the 5 o'clock position to the 11 o'clock position. Adjust swinging as needed.

1. Starting position is standing on the affected leg with the knee slightly bent
2. Swing the unaffected leg back and forth from the 5 o'clock position to the 11 o'clock position
3. Adjusting swinging as needed

Functional Exercises

- Gait training
  - Retro walk, side shuffle walk, back pedal walk, carioca walk, S-turns walk, etc. 4 to 5 weeks
  - Progress speed and add resistance to the above 5 to 6 weeks

Milestones for Progression to the Next Phase

- Normal gait, stair ambulation, full range of motion, ability to light jog with minimal pain (if cleared to jog)
- Additionally, should be able to perform walking agility drills without pain and difficulty
- Follow-up with surgeon for clearance to progress to the next phase

Note: Testing ankle flexibility in standing with standing dorsiflexion lunge test[3,12]

A strip of tape is placed perpendicular to a wall and the heel and big toe are aligned alongside the tape (Figure 39-29*A,B*). The patient's foot should be aligned so that the second toe and heel are kept perpendicular to the wall. The patient is instructed to not let the heel lose contact with the ground. The subject then lunges until the knee touches the wall. The distance is measured from the tip of the hallux to the wall.

Phase III (weeks 7 to 10)

Note: For older athletes the progress may need to be slowed due to slower rate of healing, this should be discussed amongst sports medicine team

Goals

Rehabilitation at this time should focus on progression toward athletic competition. Progressive strengthening should be continued with transition to more single leg activities. Functional testing should be incorporated before consideration of return to sport[3]. Return to sport can occur in a limited and minimal risk capacity for more severe ankle instability repairs (i.e., specialty players such as face-off man in lacrosse or long snapper in football can perform specialty then leave the field) or in almost normal capacity for isolated lateral malleolar fractures. The athlete should have stable hardware on three view radiographs and wear an Aircast equivalent even if returning in a limited capacity. Normalizing motor control, strengthening of supporting musculature for return to sport, conditioning of supporting musculature for return to sport, pain free plyometrics and able to initiate sports specific drills are the main goals for this timeframe.

Protection

- Aircast splint (especially if returning to competition) to ankle lace up brace

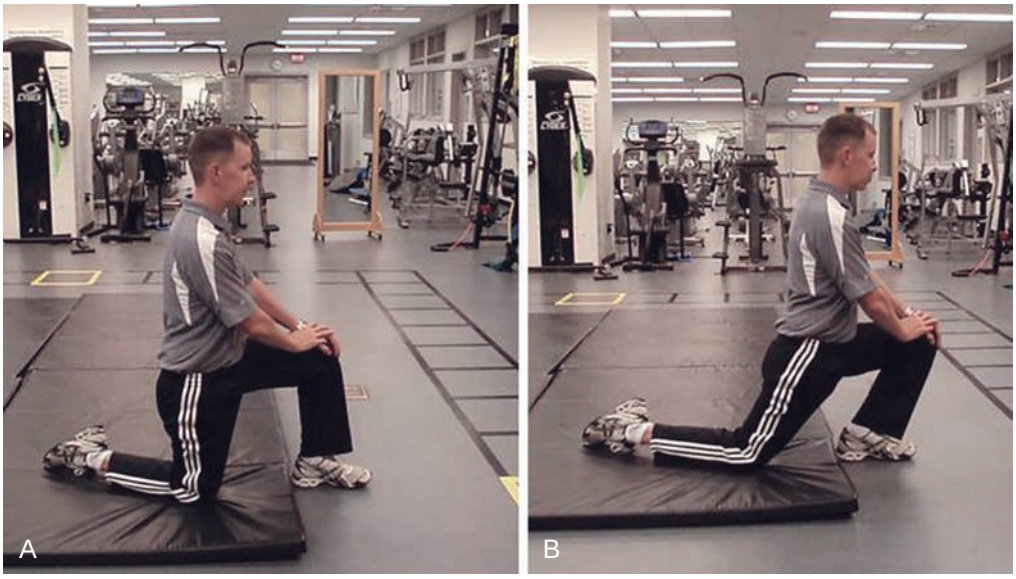
Management of Pain and Swelling

- Oral medications as needed
- Ice as needed
- Cryotherapy and compression

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Grade IV mobilizations: To include accessory motion of the ankle joint (A/P, P/A, Side glides, etc.)



1. Starting position is split kneeling with the affected leg forward
2. Place both hands on the knee of the affected lower extremity
3. Move the hips and trunk forwards as far as possible without lifting the heel
4. Hold in the forward position for 1-3 seconds
5. Repeat for repetitions as in dicated

FIGURE 39-29 Kneeling ankle dorsiflexion mobilization and soleus lengthening. **A,** Starting position is split kneeling with the affected leg forward. Place both hands on the knee of the affected lower extremity. **B,** Move the hips and trunk forwards as far as possible without lifting the heel. Hold in the forward position for 1 to 3 seconds. Repeat for repetition as indicated.

- Mobilizations with movement (MWM) in standing to increase weightbearing motion with a mobilization belt
  - Mulligan taping techniques may need to be incorporated in order to facilitate gains of motion
- Manual stretching as needed
- Self techniques
  - Single stance leg swings
  - Standing or kneeling dorsiflexion lunge rocking (Figure 39-30)

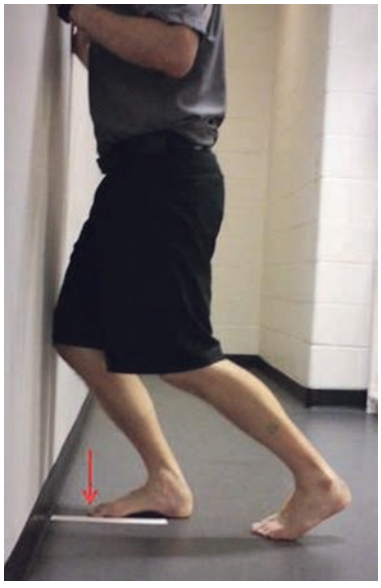


FIGURE 39-30 Standing dorsiflexion lunge rocking test. The red arrow is pointing to the tip of the hallux.

Soft Tissue Techniques

- Aggressive deep tissue techniques to gastroc, soleus and/or peroneals as needed
- More aggressive techniques such as ischemic release, foam roller, deep tissue massage and dry needling may be incorporated as needed.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Standing gastrocnemius stretch (add slant board or assist at 8 weeks)
- Standing soleus stretch (add slant board or similar assist at 8 weeks)
- Anterior tibialis stretch
- Progress to single leg

Other Therapeutic Exercises

- Upper body strengthening as prior to surgery
- Core strengthening
  - Full planks (front/sides/reverse)
  - Cable chops and lifts
  - Stability ball knee to chest, lateral rolls, and Russian twists
  - Medicine ball exercises
  - Turkish get up progression
  - Farmers walk or weight carry for development of hip stability

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Standing four-way SLR
- Isokinetic or isotonic strengthening plantarflexion, inversion, eversion and dorsiflexion

- Heel raise single leg
- Four-way strengthening with ankle isolator

Sensorimotor Exercises

- Double leg balance on foam to single leg
- Squatting or lunging on BOSU or half foam roller (double leg to single leg)
- Single leg clock reach with or without resistance
- Windmill toe touches in place

Open and Closed Kinetic Chain Exercises

- OKC
  - Leg curls: machine, TRX, slide board, stability ball, etc.
  - Hip strengthening four-way hip machine or TRX
- CKC
  - Step-ups with plantar flexion ipsilateral leg and contralateral knee high knee high
  - Double leg squat progressing to assisted single leg squat with devices such as the TRX, Cooke bands or similar

Techniques to Increase Muscle Strength, Power, and Endurance

- Romanian dead lifts for hip extension development (single leg)
- Push press for reeducation of triple extension
- Hang cleans with bar initially and progress for reeducation of triple extension
- Progress jogging program alternating with low impact activities such as stationary bike, swimming, elliptical or stair stepper
- Push-jerk

Neuromuscular Dynamic Stability Exercises

- Clock reach or Star Excursion Balance Test reaching
- Fitter, slide board or equivalent
- Walking lunge with medicine ball twist
- Walkout side step lunge with resistance band around the waist
- Progress in difficulty with balancing machines
- Windmill toe touch single leg moving

Plyometrics

Plyometrics utilize the stretch reflex, muscle elasticity and the elasticity of related noncontractile structures. Plyometric training increases power and explosiveness which are required for sports. Plyometrics should be tailored to the specific sport or activities for the athlete. Considerations for initiation of plyometric training include:

- Pretraining: Age, bodyweight, strength, and experience
- Program considerations: Warmup, sport, frequency, and foot contacts
- Movements: Jumps, hops, bound, and shock
- Progression: Hops and jumps in place to standing jumps to multiple jumps or hops to depth jump to box jumps and bounding (Table 39-2)

Functional Exercises

With an Aircast or ankle lace up brace worn:

- Ladder drills
  - High knees forward
  - Side shuffle
  - Forward shuffle
  - Shuffle and stick
  - Slalom
- Agility T-Test
- 20 meter shuttle
- Hop testing
  - 6 meter for time
  - Single leg hop for distance
  - 6 meter single leg crossover hop
- Speed drill
  - First step acceleration

Table 39-2 Sample Workout for 4 Weeks (performed twice a week with 1 to 2 minute rests between sets)

	Week 1	Week 2	Week 3	Week 4
Volume	60 Foot contacts	70 Foot contacts	80 Foot contacts	90 Foot contacts
Exercises	Line hops 3×10	Line hops 2×10	Power skip 1×10	Squat jump 2×10
	Ankle Hops 1×10 side to side	Ankle Hops 2×5	Squat jump 2×10	Multiple long jumps 5×2
	Ankle Hops 1×10 front to back	Cone hops 3×5	Split Squat jump 3×5	Lateral long jump 5×1
	Cone hops 2×5	Long jump 5×1	Tuck jump 1×5	6–8 inch depth jump 5×1
	Squat jump 2×5	Split Squat Jumps2×5	Lateral long jump 1 1×10 (5 each)	Ice Skater 3×10
		Squat jumps 2×5	Box jump 2×5 front	Double leg lateral hop 2×10
			Box jump 2×5 side	

Note: Height of jumps and hops can be adjusted by size of box or cone. Length of jump can be adjusted as well. Effort should be almost maximal without pain but soreness and discomfort may be experienced. Individuals weighing 200 to 250 pounds should have their touches decreased by 25% and 250+ individuals should have their touches decreased by 50%.

Sport-Specific Exercises

With an Aircast or ankle lace up brace worn:
- Reaction drills
  - Facing partner, the partner throws the ball and once the ball goes overhead turn and retrieve
  - Facing away from the partner, the partner throws the ball and once the ball goes overhead retrieve
  - Facing wall, partner throws the ball and athlete has to react and catch (use a soft compliant ball such as a tennis ball, racquet ball, kick ball)
- Agility drills with sprint
- Partner assisted shadow drills for defense

Milestones for Progression to the Next Phase

- Y-Balance (modified SEBT) anterior reach side to side difference no greater than 6 cm and posteromedial plus posterolateral side to side difference no greater than 8 cm with minimal pain and no giving out of ankle
- Hop testing within 80% (acceptable level for return to play especially for low contact or specialist) of contralateral limb (crossover, hop for distance and 6 meter hop for time)
- Full ankle strength
- Be able to perform sports drills with little pain, discomfort and no sensation of rolling/giving out

Note: If there is a more severe injury, then progression may need to be slower. This should be based on collaboration of all members of the sports medicine team with the treating surgeon (if they are not the team physician).

If the above milestones are reached, the athlete may resume practice and/or game depending on clearance by physician and level of contact of the sport.

The younger athletes and/or less severely injured may be returning to sport by this time and will need to be progressed back into practice and training. Training with team should start out with mostly skills training and no contact for the first few sessions. If the athlete is able to tolerate these first few sessions, slowly add harder drills and light contact. Progress to full contact as the athlete is able. For the older athlete or the athlete with less than optimal fixation, the rehabilitation may need to follow the more traditional approach until fixation and healing are deemed sufficient.

Phase IV (weeks 11 to 14)

- *For syndesmosis injuries hardware removal may occur at this time and will have to allow for healing of wound for 7 to 10 days. After that can initiate rehabilitation to tolerance.*

Protection

- Continue Aircast or ankle lace up brace

Management of Pain and Swelling

- Oral analgesic as directed
- Cryotherapy as needed
- TENS as needed
- Compression and cryotherapy
- If hardware removed re-emphasize elevation

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- As needed for range of motion

Soft Tissue Techniques

- As needed for range of motion

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Gastrocnemius stretch and soleus stretch with slant board
- General lower extremity flexibility as needed
- Single leg gastrocnemius stretch in modified pushup position
- Single leg soleus stretch in modified push-up position

Other Therapeutic Exercises

- Progressive core activities
  - Pushups to side plank (Figure 39-31)
  - Side plank with straight lower extremity and hip abduction (Figure 39-32)
  - 45° to 90° walkouts to a pushup
  - TRX or similar device knee to chest (Figure 39-33)
  - Pushup position plank elbow to opposite knee (Figure 39-34)
  - TRX standing rotation pull from horizontal to vertical (Figure 39-35)

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Progressive activities if deficits still exist

Sensorimotor Exercises

- Continue training as previous increasing speed and decrease stability of surface two to three times a week

Open and Closed Kinetic Chain Exercises

- Progress to preinjury activities or engage in preinjury activities

Techniques to Increase Muscle Strength, Power, and Endurance

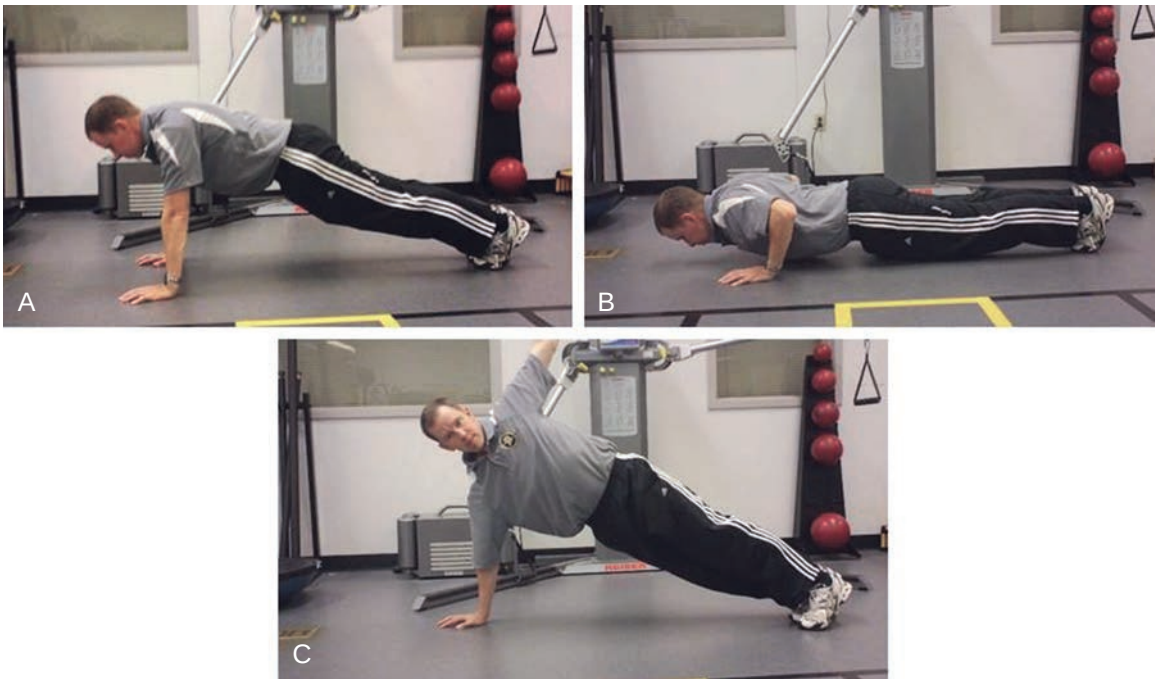
- Olympic lifts or modified
- Hybrid workouts
- Tabatas (20 second work, 10 second rest for 8 reps/4 minutes)
- Continue running fitness and progression

Neuromuscular Dynamic Stability Exercises

- Continue to progress
- Single leg activities

Plyometrics

- Multiple jumps or hops adding hurdles
- Dot drills



1. Starting position is in the push-up position (upper right)
2. Do a push-up (upper left) then come up and rotate into a side plank (bottom)
3. Alternate sides with each push-up.

FIGURE 39-31 Pushups to side plank exercise. **A,** Starting position is in the push-up position. **B,** Do a pushup. **C,** Come up and rotate into a side plank. Alternate sides with each pushup.



1. Starting in a side plank position (top)
2. Abduct upside hip and leg (bottom)

FIGURE 39-32 Side plank with straight lower extremity and hip abduction. Starting in a side plank position (**A**), abduct upside hip and leg (**B**).



1. Starting is with your feet in the handles of a TRX or similarin a push-up position
2. Alternate knees to at least waist level maintaining stability
3. Can alternate knees or bring both to waist level at the same time

FIGURE 39-33 TRX knee to chest exercise. Starting with feet in the handles of a TRX or similar device in the a push-up position (**A**), alternate knees to at least waist level maintaining stability (**B**). Can alternate knees or bring both to waist level at the same time.



1. Starting position is in a push-up position
2. While maintaining balance, bring opposite knee to opposite elbow
3. Return to push-up position and repeat with other knee and elbow

FIGURE 39-34 Pushup position plank elbow to opposite knee exercise. **A,** Starting position is in a pushup position. **B,** While maintaining balance, bring opposite knee to opposite elbow. Return to pushup position and repeat with other knee and elbow.

- Box drills
- Split Box or Bench jumps

Functional Exercises

- Sprinting drills
- More complex agility test such as Illinois agility test
- More complex ladder drills

Sport-Specific Exercises

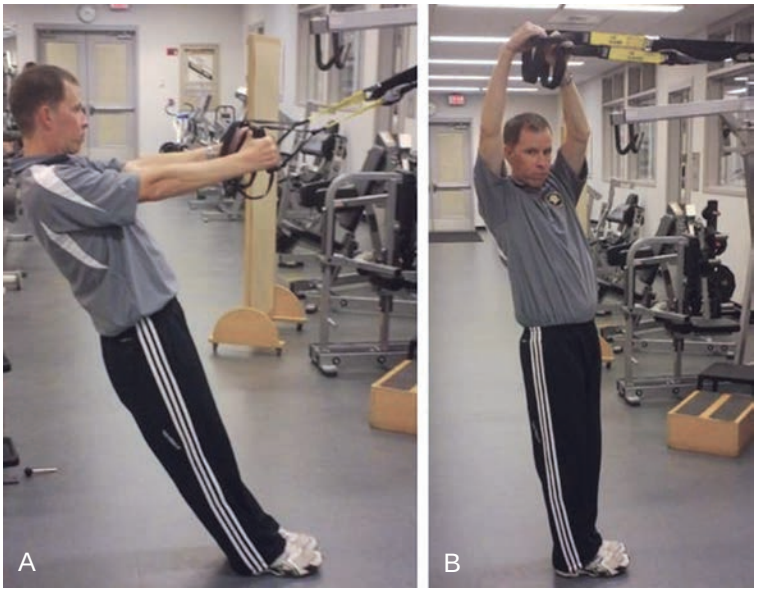
- Should be able to practice at this point

Milestones for Progression to the Next Phase

- Y-Balance (SEBT) anterior reach side to side difference less than 4 cm and posteromedial plus posterolateral side to side difference less than 6 cm.
- Hop testing within 90% (optimal level for return to sport) of contralateral limb (crossover, hop for distance and 6 meter hop for time)
- Full ankle strength
- Be able to perform sports drills with little pain, discomfort and no sensation of rolling/giving out
- At this time, most of the younger athletes will be ready to return to sport.

Phase V (weeks 15 to 24)

- Continue to rehabilitate and progress through activities/conditioning.



1. Staiting position is standing, holding TRX straps w/shoulders flexed to 90
2. Slightly leaning back to provide body-weight resistance
3. Perform trunk rotation with combined shoulder flexion motion maintaining elbows in extension

FIGURE 39-35 TRX standing rotation pull from horizontal to vertical exercise. **A,** Starting position is standing, holding TRX straps with shoulders flexed to 90°. **B,** Lean back slightly to provide bodyweight resistance. Perform trunk rotation with combined shoulder flexion motion maintaining elbows in extension.

Milestones for Progression to the Next Phase

- Return to practice/competition for older adults may occur in this timeframe. Training with team should start out with mostly skills training and no contact for the first few sessions. If the athlete is able to tolerate these first few sessions, slowly add harder drills and light contact. Progress to full contact as the athlete is able.

Criteria for Return to Sport

General

- Y-Balance (SEBT) anterior reach side to side difference no greater than 4 cm and posteromedial plus posterolateral side to side difference no greater than 6 cm.
- Hop testing (within 90% optimal, 80% acceptable for low contact and specialist) of contralateral limb (6 m single leg crossover, single leg hop for distance and 6 meter single leg hop for time)
- Full ankle strength
- Be able to perform sports drills with little pain, discomfort and no sensation of rolling/giving out
- Clearance by surgeon and/or team physician

Sport-Specific

- The above criteria
- No report of instability or giving out during specific sports drills and progressing back to practice

After Return to Sport

Continuing Fitness or Rehabilitation Exercises

- Total fitness per team training or athlete's needs

Exercises and Other Techniques for Prevention of Recurrent Injury

- Single leg proprioception and dynamic stability incorporated into weekly routines

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Evidence

Colvin AC, Walsh M, Koval KJ, et al: Return to sports following operatively treated ankle fractures. *Foot Ankle Int* 30:292–296, 2009.

A retrospective cohort study of 243 patients status postoperative fixation of an unstable ankle fracture investigating variables that influence return to sports. At 3, 6, and 12 months complications, weightbearing status, and function using the Short Musculoskeletal Functional Assessment and American Orthopaedic Foot and Ankle Society ankle-hindfoot scale were assessed. Males were more likely to return to sports by 3 months, younger age predictive of return to sports by 3 months, at 12 months bimalleolar injuries were more likely to return to sports than unimalleolar and patients without associated syndesmotic injury were more likely to return to sports. (Level II evidence).

Honigmann P, Goldhahn S, Rosenkranz J, et al: Aftertreatment of malleolar fractures following ORIF—functional compared to protected functional in a vacuum-stabilized orthesis: a randomized controlled trial. *Arch Orthop Trauma Surg* 127(3):195–203, 2007.

A prospective, randomized study of 45 patients with isolated malleolar fractures, comparing vacuum-stabilized orthoses with full weightbearing for 6 weeks to short-term immobilization with partial weightbearing for 6 weeks. Assessments at 6 to 10 weeks included activity limitation questionnaire, quality of life, patient satisfaction, pain, ankle dorsiflexion and plantarflexion range of motion, swelling, adverse event, return to work, and duration of hospitalization. Swelling was reduced and the ability to walk stairs confidently was shorter with the orthoses group. Otherwise, the groups were the same with no adverse events. (Level I evidence).

Hudson Z: Rehabilitation and return to play after foot and ankle injuries in athletes. *Sports Med Arthrosc* 17:203–207, 2009.

An evidence-based literature review of ankle rehabilitation in athletes. Presents the progression back to activity based on phases of healing and review of evidence. (Level II evidence).

Jelinek JA, Porter DA: Management of unstable ankle fractures and syndesmosis injuries in athletes. *Foot Ankle Clin N Am* 14:277–298, 2009.

An evidence-based literature review of management of unstable ankle fractures and syndesmosis injuries in athletes.

Presents the diagnosis, classification, treatment, and rehabilitation of the ankle fractures and syndesmosis injuries in athletes with review of evidence with regards to time to return to competition and progression of rehabilitation. (Level II evidence).

Lin CW, Moseley AM, Refshauge KM: Effects of rehabilitation after ankle fracture: a Cochrane systematic review. *Eur J Phys Rehabil Med* 45:431–441, 2009.

A systematic review of literature of rehabilitation after ankle fractures. Two reviewers using the Cochrane criterion rated prospective randomized and quasi-randomized control trials with adults undergoing any interventions for rehabilitation after ankle fracture. Activity limitation and adverse events were the main outcomes. Commencing exercises in a removable brace or splint significantly improved activity limitations but led to higher incidence of adverse events (RR 2.61) and most other interventions showed little to no effect size with activity limitations. Manual therapy showed some improvement in dorsiflexion range of motion. (Level I evidence).

Nelson AJ, Collins CL, Yard EE, et al: Ankle injuries among United States high school sports athletes, 2005–2006. *J Athl Train* 42:381–387, 2007.

A descriptive epidemiological study that investigated the incidence of ankle injury by sex, type of exposure and sport. Reviewed data collected from an injury database in Columbus, OH with specific sports studied: boys' football, boys' and girls' soccer, girls' volleyball, boys' and girls' basketball, boys' wrestling, boys' baseball, and girls' softball. Ankle injuries were significantly higher in competition versus practice and boys' sports compared to the same or similar girls' sports had higher incidence of ankle injuries. (Level III evidence).

Porter DA: Evaluation and treatment of ankle syndesmosis injuries. *Instr Course Lect* 58:575–581, 2009.

An evidence-based review of evaluation and treatment of syndesmosis injuries. Anatomy, injury classification, examination, imaging, treatment and rehabilitation were reviewed. (Level II evidence).

Porter DA, Berney T: Functional outcome after operative treatment of the ankle fractures in young athletes: A retrospective case series. *Foot Ankle Int* 29:887–893, 2008.

A retrospective case series of 27 patients investigating the functional and radiological outcomes after ORIF of distal fibula and tibia fractures with concomitant primary repair of involved ligaments ruptures in athletes. The authors compared points of interest for patients based on injury: how long crutches were used, how long the walking boot was used, how long the ankle brace was used and complications. Furthermore, return to activities of daily living, athletic practice and full competition were assessed. Athletes who undergo ORIF followed by early motion and early weightbearing were able to return to preinjury level of competition 2 to 4 months. (Level IV evidence).

Simanski CJ, Maegele MG, Lefering R, et al: Functional treatment and early weightbearing after an ankle fracture: a prospective study. *J Orthop Trauma* 20:108–114, 2006.

A prospective cohort of 43 patients investigating functional treatment with early weightbearing with matched comparison to an historical matched control (23 patients) treated with immobilization in a cast/orthoses for 6 weeks without weightbearing. Olerud (at least 12 months after surgery), Tegner (at least 12 months after surgery), time to full weightbearing, return to work, pain intensity, and hospital stay were compared. Patients with early weightbearing were full weightbearing at an average of 7 weeks (6 weeks earlier than controls) and returned to work an average of 7 weeks (3 weeks earlier than controls). Olerud scores for early weightbearing were an average of 90 out of 100 at greater than 1 year (no different than matched controls). (Level III evidence).

Stevens JE, Walter GA, Okereke E, et al: Muscle adaptations with immobilization and rehabilitation after ankle fractures. *Med Sci Sports Exerc* 36:1695–1701, 2004.

A prospective case control series of 20 subjects after ORIF of the ankle analyzing lower leg cross sectional area and torque production with 7 weeks of immobilization and subsequent 10 weeks of rehabilitation compared to matched healthy controls (six subjects). MRIs were acquired at baseline, 2 weeks and 7 weeks of immobilization to measure compartment cross-sectional area. Isometric plantar flexion strength was measured at 0, 5 and 10 weeks after immobilization. Cross-sectional area decreased the most over the first 2 weeks of immobilization and cross-sectional area increased the most over the first 5 weeks of rehabilitation. Torque output of plantar flexion increased mostly in the first 5 weeks of rehabilitation but at 10 weeks there was 20% less torque than matched controls. (Level III evidence).

Taylor DC, Tenuta JJ, Uhorchak JM, et al: Aggressive surgical treatment and early return to sports in athletes with grade III syndesmosis sprains. *Am J Sports Med* 35:1833–1838, 2007.

A prospective case series of six male collegiate athletes with grade III syndesmosis repairs. Each subject underwent internal fixation of a grade III syndesmosis injury with one 4.5 mm cortical screw. At 1 week after surgery, patients were allowed to begin range of motion exercises, progressive weightbearing, and gradually return to full activity as tolerated. Outcome measures included: return to full activity and Sports Ankle Rating System scores. Average time of return was 41 days with one screw breaking on removal and average Sports Ankle Rating System score at 34 months was 96/100. (Level IV evidence).

Vicenzino B, Branjerdporn M, Teys P, et al: Initial changes in posterior talar glide and dorsiflexion of the ankle after mobilization with movement in individuals with recurrent ankle sprain. *J Orthop Sports Phys Ther* 36:464–471, 2006.

A double-blind randomized crossover study with a control condition to evaluate the effect two mobilizations with movement (MWM) techniques in weightbearing and nonweightbearing. Sixteen subjects with recurrent ankle sprains, impaired talar posterior gliding and impaired weightbearing dorsiflexion were studied. A within-subjects study design was used to evaluate the effect of two independent variables: treatment conditions (weightbearing MWM, nonweightbearing MWM, and a no-treatment control group) and time (pretreatment and posttreatment) on the dependent variables of posterior talar glide and weightbearing dorsiflexion. Both weightbearing and nonweightbearing MWM improved talar glide over 50% versus 17% for controls and the weightbearing dorsiflexion by 26% percent versus 9% for control. MWM weightbearing and nonweightbearing help to improve talar glide and standing dorsiflexion. (Level I evidence).

Multiple-Choice Questions

QUESTION 1. The single most important factor leading to long term success for treatment of ankle fractures or instability is:

A. Anatomic reduction
B. Bone health
C. Functional rehabilitation
D. Strength

QUESTION 2. Factors that are positive predictors of return to sport after ankle fracture/instability surgery are:

A. Female gender, younger age, no systemic disease and ankle fracture only
B. Male gender, no systemic disease, ankle fracture only and surgery within 7 days
C. Female gender, no systemic disease, ankle fracture only and surgical intervention within 7 days
D. Male gender, younger age, no systemic disease and ankle fracture only

QUESTION 3. The guiding principles for safe progression of rehabilitation include all the following except:

A. Rate of healing
B. Based on the individual
C. The type of sport
D. Age

QUESTION 4. Your patient is a 19-year-old Lacrosse player status after 12 weeks an ORIF and syndesmosis stabilization to the left ankle. The fracture is well aligned and healing with the syndesmosis stabilized with a 4.5-mm cortical screw. The season is still ongoing and the player has rehabilitated well without pain or giving out during rehabilitation. What is the optimal criterion for return to sport? What additional precaution or device will you have the athlete use?

A. Y-Balance test anterior reach side to side difference <6 cm, Hop testing 80%, full ankle strength and ankle brace with no contact.
B. Y-Balance test posteromedial plus anteromedial reach side to side difference of less than 4 cm, hop testing 90%, no giving out with sports-specific activities and ankle brace.
C. Y-Balance test anterior reach side to side difference <4 cm, hop testing 80%, full ankle strength and ankle brace with no contact.
D. Y-balance test posteromedial plus posterolateral reach side to side difference <6 cm, hop testing 90%, no giving out with sports-specific activities and ankle brace.

Answer Key

QUESTION 1. Correct answer: **A**

QUESTION 2. Correct answer: **D**

QUESTION 3. Correct answer: **C**

QUESTION 4. Correct answer: **D**

POSTOPERATIVE REHABILITATION AFTER TREATMENT OF MICROFRACTURE OR CHONDRAL INJURIES OF THE ANKLE

Charles P. Hannon, BS, David Wickenden, DipPhty, MMT, FAAOMPT, Niall A. Smyth, MD, Christopher D. Murawski, BS, and John G. Kennedy, MD

Indications for Surgical Treatment

The decision to pursue surgical treatment for chondral injuries of the ankle is dependent upon multiple factors and must be individualized to each patient. After confirmation of the presence of an osteochondral lesion with magnetic resonance imaging, the general indications for surgical treatment for chondral injuries of the ankle are:

- Symptomatic patients with restriction of activities of daily living or sport activity
- Athletic patients or recreational athletes with a desire to return to sport
- Symptomatic patients with breach of the cartilaginous surface
- Symptomatic patients who fail conservative treatment after 3 to 6 months

Brief Summary of Surgical Treatment

- The most common chondral injury of the ankle joint is an osteochondral lesion of the talus. Current treatment strategies include stimulating tissue repair (i.e., bone marrow stimulation), tissue transplantation (i.e., autologous osteochondral transplantation), and cell-based techniques (i.e., autologous chondrocyte implantation, juvenile cartilage allograft).

- The most common surgical treatment for osteochondral lesions of the talus is microfracture. The major steps of this procedure are described below.

Major Surgical Steps

- Regional anesthesia with the patient placed in a supine position
- Physical exam and diagnostic arthroscopy to confirm all pathologies
- Arthroscopic debridement of frayed, soft, or fibrillated cartilage including the rim of the defect. Loose cartilage should be removed so that there is a stable edge of cartilage surrounding the defect
- Arthroscopic debridement and curettage of the osteochondral defect
- Microfracture of subchondral bone, with holes created at 3 to 4 mm intervals, ensuring there is subchondral bleeding at the defect site indicating the beginning of the formation of a fibrin clot
- Wound closure

Factors That May Affect Rehabilitation

Surgical

- Presence of other ankle pathology:
  - Osteochondral lesions of the talus are often found in conjunction with other pathologies, such as ligamentous injuries of the ankle. It is therefore important during surgery to determine if there are concomitant injuries present, as additional procedures performed may alter the postsurgical rehabilitation protocol.

Other Surgical Techniques and Options

- Major differences in other surgical techniques (if not covered in other sections)
  - While microfracture is the most common procedure for smaller, primary osteochondral lesions of the talus, other replacement strategies, such as autologous osteochondral transplantation (AOT) or autologous chondrocyte implantation, are more appropriate for larger lesions, cystic lesions and failed primary procedures. In tissue transplantation techniques, cylindrical osteochondral grafts are either harvested from the patient or from a cadaver donor, then transplanted into the prepared defect site. In cell-based strategies, a two-step procedure is required to first harvest chondrocytes, culture expand the cells *in vitro*, then surgically implant the cells.
- If these differences affect rehabilitation guidelines and, if so, how (if not covered in other sections)
  - One major difference between a microfracture procedure and AOT is that the latter requires two incisions, one at the ankle and one at the knee from where the graft is most commonly harvested. Therefore, knee rehabilitation must be added to the treatment of patients who have an AOT.

Before Surgery: Overview of Goals, Milestones, and Guidelines[2]

Patients with osteochondral lesions of the ankle commonly present with periarticular ankle pain that is exacerbated with activity and possibly associated with swelling and stiffness. The goals of preoperative rehabilitation are:

- Decrease swelling
  - Swelling is not typical with osteochondral lesions of the talus, but if present, should be managed preoperatively.
  - Cryo-compression devices are effective for managing swelling and pain.
  - Many other devices are commercially available that provide cooling and/or compression to the ankle. These devices are also commonly used in the postoperative period.
- Restoration of normal or near normal ankle range of motion.
  - Much of the exercise program preoperatively to restore normal or near normal ankle range of motion is similar to that of the postoperative period.
  - Full weightbearing and range of motion is encouraged.
  - Activities of daily living and sport activity should be conducted as tolerated.
  - Stationary cycling and elliptical machines are good exercise preoperatively to improve strength and endurance.

After Surgery-Postoperative Rehabilitation: Overview of Goals, Important Milestones and Guidelines

- Currently, there is no single standardized rehabilitation program after bone marrow stimulation for treatment of osteochondral lesions of the talus. Rehabilitation is challenging after cartilage repair procedures as there must be a balance between loading and unloading of the joint. Reduced loading of the joint with controlled motion stimulates cartilage repair, but prolonged immobilization and unloading of the joint may lead to deterioration of the cartilage. In addition, excessive loading may damage the repair tissue.
- Thus, the postsurgical rehabilitation after microfracture for treatment of chondral injuries of the ankle joint is a dynamic process that requires a team approach by the patient, orthopedic surgeon and the physical therapist. While goals and milestones are important for patients to reach towards, these are not strict guidelines that the patient must follow. Patients should allow their pain, mobility and range of motion to dictate their progression in rehabilitation. Patients should progress through their rehabilitation at a personalized and appropriate rate. Rehabilitation must be individualized

[2] *Prehabilitation, if appropriate, is described in the Nonoperative Rehabilitation section of this chapter.*

to each patient and must be adaptable to change based on the condition of the patient and his or her restrictions. The aim of rehabilitation should be to return the patient to their presymptomatic activity level, whether they are recreational activities or professional sport.

GUIDING PRINCIPLES OF POSTOPERATIVE REHABILITATION

- Reduction of postoperative pain and inflammation with various modalities including cryo-compression, electrotherapy and ultrasound
- Restoration of neuromuscular control with biofeedback modalities including, but not limited to, electrical muscle stimulation and proprioceptive training
- Restoration of full ankle range of motion
- Gradual progression to full weightbearing loads on the ankle
- Sport-specific training

Phase I: Immediate Postoperative Period (days 0 to 14)

Clinical Pearls

- One of the most important aspects of the immediate postoperative period is setting expectations with the patient so they have an understanding of the extent of their pathology and realistic rehabilitation timeframes.
- It is important to stress patient responsibility with home management. The patient needs to be able to protect the cartilage surfaces and allow undisturbed healing. It should be emphasized to the patient that of the 168 hours in a week, the patient will only be spending 3 hours a week with a therapist, which, represents only a fraction of the total time. Therefore, a major role of therapy in the initial stage is to help guide the patient and educate them regarding their home and work activities of daily living, commuting and to advise what symptoms should be acceptable and what are not.

Goals

- Educate patient regarding the postoperative plan, goals, and expectations
- Instruct patient in correct use of crutches and assistive devices
- Facilitate optimal healing by decreasing acute inflammation
- Restore joint motion and passive plantarflexion
- Regain adjacent neuromusculoskeletal function and symmetry

Protection

- In the immediate postoperative period, the patient is placed in a soft dressing, often with a compression bandage.
- Patient may also be placed in an immobilization boot for up to 4 to 6 weeks while ambulating.
- Patients will be nonweightbearing up to 6 weeks postoperatively and should be instructed in the use of crutches to ambulate

Management of Pain and Swelling

- Oral analgesic medications are effective for pain. However, nonsteroidal antiinflammatories such as aspirin should be avoided as they may interfere with the natural healing response.
- Cryotherapy assists in pain inhibition and allows early active ankle movement. Cryotherapy should be applied for periods of 20 minutes with intermittent bouts of active plantarflexion. Some commercially available devices can provide intermittent compression to facilitate circulation.
- Inflammation reduction is the primary goal of the immediate postoperative period. Inflammation of the joint inhibits muscle activation.
- Elevation, compression and cryotherapy are all important for swelling reduction. Ace bandage wraps, sleeves or cryo-compression devices are commonly used. Compression cryotherapy is recommended in 20-minute intervals as needed.
- Patient should also rest the foot with elevation as much as possible. During sleep, it is recommended that the foot of the bed is elevated.
- Electrical stimulation of the musculature also improves circulation to reduce swelling.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Manual therapy to release tension in the lower leg musculature including the gastrocnemius soleus complex, plantar fascia, and tibialis anterior and posterior
- Accessory joint mobilization to mid and forefoot articulations to avoid secondary joint stiffness due to immobilization
- Gentle anterior glides and traction

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Passive stretches of the hamstring, hip flexor and piriformis to 3+/5 (moderate stretch) two to three times/day.
- Passive plantarflexion

Other Therapeutic Exercises

Core Stability
- Leg raises in the seated position

Total Arm Strength (TAS)
- Upper body activities may be completed as tolerated. It is important that all total arm strength exercises are nonweightbearing during the initial postoperative period. These exercises may include:
  - Bench Press
  - Modified chin-ups
  - Seated pulleys and free weights

Total Leg Strength (TLS)
- Open chain kinetic activities

Open and Closed Kinetic Chain Exercises

Open Kinetic Chain Exercises
- Core Stability
  - These exercises are intended to strengthen the lumbar pelvic stabilizers through four different leg exercises including hip flexion, hip abduction, hip adduction, and hip extension.
- Pilates
- Straight leg raises (hip flexion, abduction, adduction)
- Total arm strength exercises with free weights

Closed Kinetic Chain Exercises

- Nonfree weight total arm strength exercises such as bench press, seat pulley and modified chin-ups.

Milestones for Progression to the Next Phase

- Removal of sutures with a clean and closed incision
- Minimal pain and swelling of the ankle joint
- Passive ROM (plantarflexion and dorsiflexion) improving to the level needed to perform active functional movements
- Good quadriceps strength and control as demonstrated by a strong quad set and straight leg raises with no extensor lag

Phase II (weeks 2 to 6)

Clinical Pearls

- After 2 weeks postoperatively there should be an improvement in the fluidity and mechanics of the exercises from the immediate postoperative period. As this phase progresses, the difficulty of exercises may increase.
- In addition, patients often become more active in their own ADLs and they need to be educated in the signs of irritability and determine how much mechanical stimulus their joints are tolerating, become aware of how much pain is acceptable and recognize the poststimulus pain they may experience after doing a particular activity.
- Irritability is very common with ankle injuries and patients must be aware of what is too much pain. For example, patients who have pain while walking are experiencing too much pain and must rest.
- Patients can use the therapist as sounding board as to whether symptoms they are experiencing are within reasonable limits or are just too much. Everyone needs to progress at their own rate and learn to listen to how they are responding to a particular mechanical activity.

Goals

- Gradually improve functional weightbearing tolerance to full weightbearing by week 6
- Swelling and pain modulation
- Introduce ankle proprioception and dynamic stability
- Normalize accessory motion of all foot and ankle articulations
- Patient education regarding appropriate progression of activities of daily living

Protection

- After 2 weeks, the sutures should be removed and the patient should be placed in a compression bandage or sleeve to reduce inflammation

TIMELINE 39-4 Postoperative Rehabilitation after Treatment of Microfracture or Chondral Injuries of the Ankle Joint

PHASE I (weeks 1 to 2)	PHASE II (weeks 3 to 6)	PHASE III (weeks 6 to 10)
• Educate patient regarding postoperative plan, goals and expectations • Immobilization boot and instruct in proper use of crutches • Rest, ice, compression, elevation, electrotherapy • Passive • CPM ROM as tolerated • Passive hamstring, hip flexor and piriformis stretches two to three times daily • Total arm strength exercises: seated pulley • Core stabilization: straight leg raises, Pilates • Gait training with support	• Progress to nonweightbearing by wk 6 • Rest, electrotherapy, and ice as needed • Maintain full passive ankle ROM • Continue stretching program • Gradual increase in ankle ROM by stretching Achilles and soleus • Continue and progress core stability as needed • Continue and progress total arm strength exercise as needed • May start stationary bike wk 3–4 • Start elastic band exercise (all four directions) as tolerance wk 4 • Restricted balance board standing or tai chi walking by wk 4 • Quadruped, kneeling chopping wk 4 • Normal gait training with/without support as tolerance wk 3–4	• Continue stretching program • Improve ankle ROM • Total leg strength exercises: ball squat, sumo squat • Standing and calf rises in pain free range wk 8 • Nonrestricted balance board standing or tai chi wk 6 • Stationary Bike • Ankle rocking motion with resistance wk 8–10 • Introduce certain motions related to sport as tolerance • Acceptable ankle strength and endurance in full ROM • Acceptable balance for performing functional exercise

- During the 2- to 4-week postoperative period patients should remain nonweightbearing using crutches for ambulation.
- Beginning at week 4, patients may begin partial weightbearing gradually increasing 10% per day until they are full weightbearing at week 6.

Management of Pain and Swelling

- Oral analgesic medications are most effective for pain as needed. However, nonsteroidal antiinflammatories such as aspirin should be avoided as they may interfere with the natural healing response.
- Cryotherapy may also assist in pain reduction. Some commercially available devices also have compression, which is also helpful in reducing inflammation.
- Elevation, compression and cryotherapy are all important for swelling reduction. Ace wraps, sleeves or cryocompression devices are commonly used to reduce swelling. Compression cryotherapy is recommended in 20-minute intervals as needed.
- Electrical stimulation of the musculature is not as critical for this stage, but may also improve circulation to reduce swelling.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Manual therapy should work on the lower leg musculature including the gastrocnemius soleus complex, plantar fascia, and tibialis anterior and posterior to release tension in the lower leg musculature.

Soft Tissue Techniques

- Massage balls may also be used at week four at the beginning of partial weightbearing to further stretch the plantar fascia.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Continued passive stretching of the hip flexors, piriforms and hamstrings to tolerance two to three times/day.
- Begin passive stretch of the Achilles to 2+ (median moderate stretch) on a 5-stretch scale two to three times/day. Care should be taken to avoid forced dorsiflexion and compression of articular surfaces. Reduced posterior talus motion can cause hinging on the anterior articular surface due to tight posterior musculotendinous structures.
- Stretching of the anterior and posterior tibialis, gastrocnemius soleus complex, and plantar fascia with proprioceptive neuromuscular facilitation techniques.
- Begin active ankle pumps by week four. It is important to avoid forced dorsiflexion that causes any anterior mortise or talus pain.
- Stationary bike cycling may also start toward the end of week four as the patient begins gentle weightbearing.

Other Therapeutic Exercises

Core stability
- Seated leg raises
- Triathlete core exercise
  - This consists of eight exercises including a twist crunch, sky reach, marching, quadruped, lunge and twist, clap overhead, double leg raises and side bridges.
- Lunges

Total arm strength
- Upper body activities as recommended and tolerated
- Bench press
- Modified chin-ups
- Seated pulley

Free weights

TIMELINE 39-4 **Postoperative Rehabilitation after Treatment of Microfracture or Chondral Injuries of the Ankle Joint** (Continued)

PHASE IV (weeks 10 to 14)	PHASE V (weeks 14 to 24)	PHASE VI (weeks 24 to 52)
• Maintain full ankle ROM • Progressed balance board standing • Elliptical trainer • Standing chopping motions on cable • FMS routine exercise against resistance • Introduce specific sports-related exercises • Weight training: squat, deadlift • Tai chi walking • Balance board standing • Standing calf raises in full ROM • Seating calf raises in full ROM	• Maintain full ankle ROM • Single leg balance standing • Ladder drills • Dynamic lunges with resistance • Jump rope exercises • Elliptical trainers • Continued weight training • Medicine ball exercises • Jogging beginning in wk 20 • Sport-specific exercises • Bilateral jumping	• Running • Ladder drills with weights or hurdles • Boxing or mixed martial arts • Dynamic lunges • Power lifting • Sport-specific exercises • Resume full activity

Sensorimotor Exercises

- Standing, sitting to stand and weight shifting exercises
- Seated Biodex Balance System
  - The Biodex Balance System SD is a balance training biofeedback device. The user stands on a platform while viewing real-time visual biofeedback on a high-resolution color touch-screen liquid crystal display (LCD). The platform tilts 20 degrees from horizontal in all directions, and comes with two adjustable support handles that lock in place for safety or swing away for an unobstructed, open environment for a variety of training activities. The biofeedback display prompts the user into proper postural and balance control.
- Stand supported on leg and then move to unsupported and finally to dynamic movement with arm motion.
- Begin use of wobble boards (Figure 39-36), slide boards
  - Wobble boards is a semisphere or smaller spherical cap (or a shape that is approximately such) whose flat side is attached to the center of the board's underside. This allows the board to pivot in all directions during the same ride.

Open and Closed Kinetic Chain Exercises

- Open Kinetic Chain Exercises
  - Core Stability
  - Straight leg raises
  - Triathlete core exercise
  - Total arm strength exercises with free weights
- Closed Kinetic Chain Exercises
  - Stationary bike
  - Nonfree weight total arm strength exercises

Techniques to Increase Muscle Strength, Power, and Endurance

- Elastic band (TheraBand) resisted ankle motion in all four planes for endurance and strength as tolerated

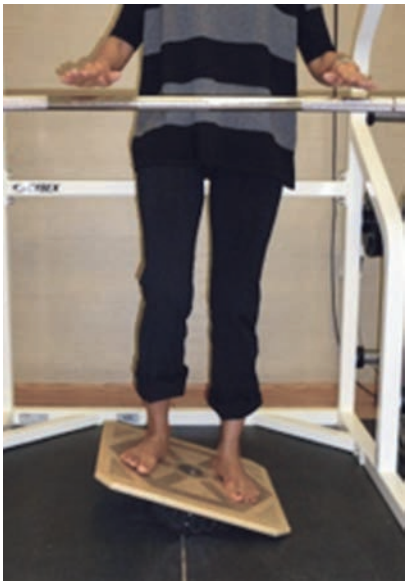

FIGURE 39-36 Wobble board balance.

- Knee extension and hamstring curl weight machines
- Pool therapy may begin with chest or shoulder-deep water walking
- Bent knee calf raises for soleus strengthening
- Calf raises with knee in extension
- Bicycling for endurance

Neuromuscular Dynamic Stability Exercises

- Kneeling chopping on cable
  - For multi-planar trunk stability. There are two ways to do it depending on ankle/knee condition: full kneeling chopping motion on cable or half kneeling chopping motion on cable.

Functional Exercises

- Walking with/without assistance to tolerance

Milestones for Progression to the Next Phase

- Full range of motion
- Acceptable ankle strength and endurance
- Acceptable balance for performing functional exercise.

Phase III (weeks 6 to 10)

Goals

- Improve static weightbearing tolerance under different loading conditions
- Improve dynamic ankle proprioception
- Improve entire lower body strength and endurance
- Enhance full pain free functional ankle and foot mobility range of motion
- Continue to monitor progression of activities of daily activities advise according to ankle irritability

Management of Pain and Swelling

- Rest, electrotherapy and ice as needed
- Ice, compression and elevation as needed

Techniques for Progressive Increase in Range of Motion

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Passive stretch soleus as well as the stretches as in Phase II

Other Therapeutic Exercises

- Core Stability
  - Straight leg raises
  - Triathlete core exercise
- Total Arm Strengthening
  - Bench press
  - Modified chin-ups
  - Seated pulley



FIGURE 39-37 Bilateral ball squat.

- Total Leg Strengthening
  - Bilateral ball squat in pain-free range of motion (Figure 39-37)
    - Squat performed on both feet when leaning on the ball for ankle isometric strength.
  - Ball squat
  - Elastic band resisted ankle motion for endurance and strength as tolerated

Sensorimotor Exercises

- Restricted balance board standing or tai chi as tolerance
- BOSU Ball Balance: Double Feet (Figure 39-38)
  - A BOSU Ball is an inflated rubber hemisphere attaching to a rigid platform. When the dome side faces up, the BOSU ball provides an unstable surface on which the patient stands
- A Biomechanical Ankle Platform System (BAPS) board is utilized to allow for anatomically appropriate motion for controlled closed chain rehab and conditioning of the lower limb. This may be utilized initially and then progressed to standing in all planes

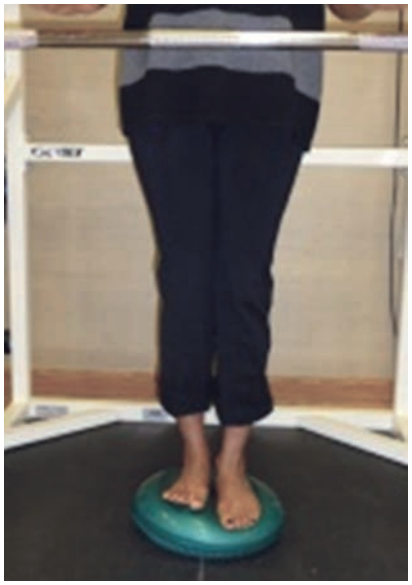

FIGURE 39-38 BOSU Ball balance: double foot.

- Progress from bilateral to unilateral and from stable ground to unstable surfaces such as foam and DynaDisc.

Open and Closed Kinetic Chain Exercises

- Open kinetic chain exercises
  - Elastic band exercises
  - Core stability
  - Straight leg raises
  - Triathlete core exercises
  - Total arm strengthening with free weights
- Closed kinetic chain exercises
  - Stationary bike
  - Ball squat
  - Seated calf raise
  - Nonfree weight total arm strengthening exercises

Techniques to Increase Muscle Strength, Power, and Endurance

- Elastic band resisted ankle motion for endurance and strength as tolerated
- Wall squats
- Standing heel raises
- Toe curls with towels
  - Rest foot on a towel and then slowly bunch up towel as the toes curl
- Step-ups

Neuromuscular Dynamic Stability Exercises

- Quadruped, kneeling chopping on cable
- Tai chi forms including walking (Figure 39-39)
- Medicine ball tossing standing on operated leg. Any shuffling and footwork drills can be used now with different catching techniques along with it to challenge the patient.

Functional Exercises

- Walking with resistance
- Ladder exercises as tolerated (Figure 39-40)

Sport-Specific Exercises

- Introduce certain motions related to sport as tolerated such as side to side jumping from one foot to the other.

Milestones for Progression to the Next Phase

- Acceptable ankle strength and endurance in full ROM
- Acceptable balance for performing functional exercise

Phase IV (weeks 10 to 14)

Goals

- Improve functional ankle stability
- Improve dynamic ankle proprioception with shared attention tasks
- Full and symmetrical lower body strength and endurance
- Optimize ankle and foot motion in all planes
- Restore confidence in performing daily activities



FIGURE 39-39 Tai chi walking.

Management of Pain and Swelling

- Rest, electrotherapy and ice as needed
- Ice, compression and elevation as needed

Techniques for Progressive Increase in Range of Motion

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Continue stretch as Phase III

Other Therapeutic Exercises

- Core stability
  - Triathlete core exercise

  Total arm strengthening
  - Bench press
  - Pushups
  - Chin ups
  - Seated pulleys
  - Free weights
- Total leg strengthening
  - Bilateral ball squat with and without weight, aiming for pain-free normal range of motion

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Elliptical trainer
- Ball squat
- Sumo squat (Figure 39-41)
  - One type of squat, which is different from front/back /deep squat in the weight loading mechanics. The overall weight loading is distributed more evenly, for example: the strength demand on back is less than back squat; the strength demands on legs are less than deep squat and front squat. Therefore, this is a



FIGURE 39-40 Ladder drills.



FIGURE 39-41 Sumo squat.

good squat for transition period from back squat to deep squat when working on leg/ankle stability.
- Standing and seated calf raises with and without weights

Sensorimotor Exercises

- Balance board standing or tai chi
- Continue to progress to unstable surfaces (BOSU ball, wobble board, Biodex Balance master) (Figure 39-42)
- Add additional challenges to exercises including writing the alphabet with the contralateral lower extremity and removing visual input

Open and Closed Kinetic Chain Exercises

- Open kinetic chain exercises
  - Core stability
  - Pilates
  - Straight leg raises
  - Triathlete core exercises
  - Upper body free weights
- Closed kinetic chain exercises
  - Elliptical trainer
  - Ball squat
  - Sumo squat
  - Seated calf raise
  - Ankle rocking against resistance (Figures 39-43)
    - There are many different ways to work ankle's dynamic stability: rocking ankle against resistance, see picture; single/double ankle rocking without resistance or even with support, see diagram.

Techniques to Increase Muscle Strength, Power, and Endurance

- Ball squat and sumo squat to tolerance
- Ankle rocking against resistance



FIGURE 39-42 BOSU Ball balance: single foot.



FIGURE 39-43 Ankle rock against resistance.



FIGURE 39-44 Standing chopping exercise on cable.

Neuromuscular Dynamic Stability Exercises

- Standing chopping on cable (Figure 39-44)
- Boxing/kickboxing or selected martial arts
- Ankle rocking against resistance

Functional Exercises

- Functional movement screening (FMS) routine exercise with/without resistance
  - Functional movement test consists of five different exercises including squat, single leg standing, in-line lunge, pushups, rotational stability.
- Begin unloaded jogging on Alter-G treadmill and progress to alternate jog/walk/jog on treadmill

Sport-Specific Exercises

- Introduce certain motions related to sport as tolerated

Milestones for Progression to the Next Phase

- Being able to perform normal daily activities
- Being able to walk at least 30 minutes without pain

Phase V (weeks 14 to 24)

Goals

- Improve ankle dynamic stability
- Improve ankle strength and endurance
- Improve ankle eccentric contraction strength
- Return to full unrestricted functional activities

Management of Pain and Swelling

- Rest, electrotherapy, and ice as needed
- Ice, compression, and elevation as needed

Techniques for Progressive Increase in Range of Motion

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Continue Stretch as per Phases III and IV

Other Therapeutic Exercises

- Core Stability
  - Triathlete core exercise

  Total arm strength
  - Bench press
  - Pushups
  - Chin-ups
  - Free weights
- Total leg strength
  - Weight lifting
  - Lunges
  - Leg press

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Elliptical trainer
- Jumping ropes
- Ball squat
- Sumo squat
- Lunge squat
- Standing and Seated calf rise with weight

Sensorimotor Exercises

- Single leg balance board standing
- Ladder drills
  - There is more ankle angles involved comparing with the normal running, one big difference is it demands more multiplanar ankle stability. The running speed, running with/without hurdles or resistance here is modified to match ankle condition.
- Tai chi



FIGURE 39-45 Jump rope: double feet.



FIGURE 39-47 Weightlifting squat.

- Continue to progress with single leg stability on unstable surfaces with exercises such as cone touches, single leg dips and lawn-mowers.

Open and Closed Kinetic Chain Exercises

- Open kinetic chain exercises
  - Core stability
  - Triathlete core exercise
  - Jumping ropes (Figures 39-45 and 39-46)
- Closed kinetic chain exercises
  - Elliptical trainer
  - Dynamic lunges and weight lifting including squats (Figure 39-47)
    - Different from static lunge. This exercise will demand more rear ankle push-off motion and more stability when the body stopped. This will be more challenging when performed with weight/resistance
  - Ankle rocking against resistance



FIGURE 39-46 Jump rope: single foot.

Techniques to Increase Muscle Strength, Power, and Endurance

- Dynamic lunge and weight lifting
- Ankle rocking against resistance

Neuromuscular Dynamic Stability Exercises

- Standing chopping on cable
- Boxing/kickboxing or mixed martial arts
- Ankle rocking against resistance

Plyometrics

- Jumping ropes
- Ladder drills

Functional Exercises

- FMS routine exercise with resistance

Sport-Specific Exercises

- Progress sport-specific exercise as tolerated

Milestones for Progression to the Next Phase

- Being able to perform bilaterally jump without pain

Phase VI (weeks 24 to 42)

Goals

- Improve ankle dynamic stability
- Improve ankle strength and endurance
- Improve ankle eccentric contractility
- Building confidence in sport-specific movement

Management of Pain and Swelling

- Rest, electrotherapy and ice as needed
- Ice, compression and elevation as needed

Techniques for Progressive Increase in Range of Motion

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Continue Stretch as in Phases III, IV and V

Other Therapeutic Exercises

- Core stability
  - Triathlete core exercise
- Total arm strength
  - Bench press
  - Pushups
  - Chin-ups
  - Free weights
- Total leg strength
  - Weight lifting
  - Leg presses
  - Lunges

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Elliptical training
- Jumping rope
- Ball squat
- Sumo squat
- Standing and seated calf raises with weights
- Lunge squat

Sensorimotor Exercises

- Single leg balance board standing
- Ladder drills
- Tai chi
- Progress with BAPS board level and add weights
- Continue progress on single leg stability with unstable surfaces (cone touches, single leg dips, lawn-mowers)

Open and Closed Kinetic Chain Exercises

- Open kinetic chain exercises
  - Core stability
  - Triathlete core exercise
  - Jumping ropes
- Closed kinetic chain exercises
  - Elliptical trainer
  - Dynamic lunges and powerlifting
  - Ankle rocking against resistance

Techniques to Increase Muscle Strength, Power, and Endurance

- Dynamic lunge and power weight lifting
- Ankle rocking against resistance
- Zig-zag cutting
- Diagonal patterns
- Figure of eights
- Back pedaling
- Carioca
  - Traditionally, carioca exercise is used for body mobility by twisting pelvis and shoulders during dynamic lateral running. Because it is carried by alternatively switching legs from anterior and posterior, the exercise will be highly dependent on the multiplanar ankle stability.
- Lateral shuffles
- Jumping progressing from bilateral to unilateral
- Trampoline Exercises (Figure 39-48)

Neuromuscular Dynamic Stability Exercises

- Standing chopping motion on cable
- Medicine ball routine for multi-plane exercise with resistance (Figure 39-49)
- Boxing/kickboxing or mixed martial arts
- Ankle rocking against resistance



FIGURE 39-48 Medicine ball exercises in multiple planes.

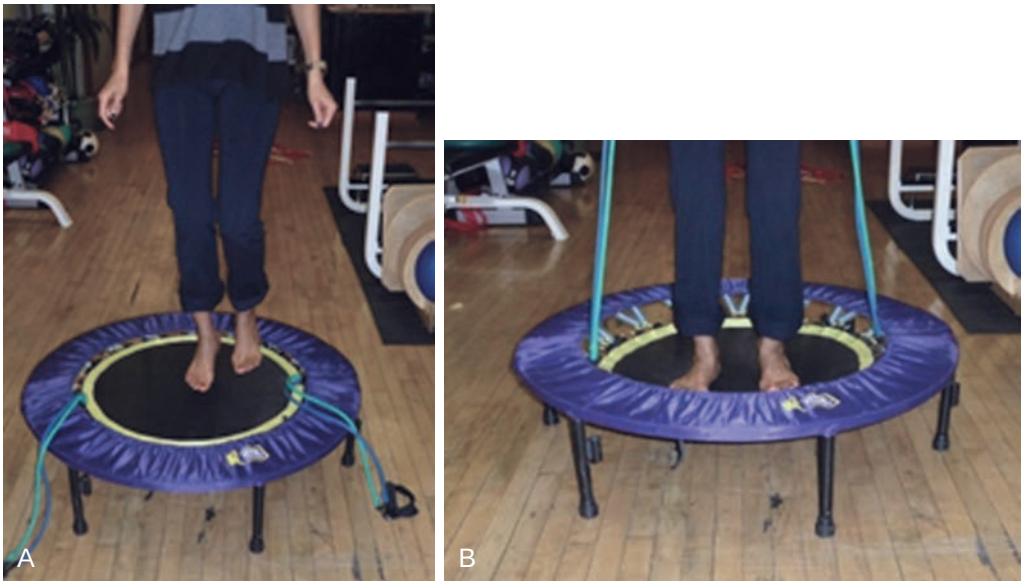

FIGURE 39-49 Trampoline exercises.

Plyometrics

- Jumping ropes
- Ladder drill with hurdles

Functional Exercises

- Progressed FMS routine

Sport-Specific Exercises

- Progressed sport-specific exercise as tolerated

Milestones for Progression to Advanced Sport-Specific Training and Conditioning

- Being able to perform single leg jump without pain

Criteria for Return to Sport

General

- Full pain-free active and passive ROM
- Able to perform any sport-specific activities without pain
- Pass FMS test
- Able to perform sport-specific movement freely
- No subjective sense of instability
- Single leg press at least 70% normal strength
- Single leg squat possible

Sport-Specific

- Long distance runner—no perceived difference between affected and unaffected ankles in endurance and stability over the appropriate distance.
- Hurdle jumper—no perceived difference between affected and unaffected ankle in strength, endurance and stability during/after hurdle race.
- Sprinter—no perceived difference between affected and unaffected ankle in perceived strength, endurance and stability during/after hurdle race during/after sprinting.

After Return to Sport

Continuing Fitness or Rehabilitation Exercises

- Athletes are encouraged to continue strength and agility exercises on their own to preserve strength, function and proprioceptive gains.

Exercises and Other Techniques for Prevention of Recurrent Injury

- Lateral box jumps
- Single leg hurdles
- Cutting, accelerating and decelerating exercises
- Leg press

Evidence

Becher C, Driessen A, Hess T, et al: Microfracture for chondral defects of the talus: maintenance of early results at midterm follow-up. *Knee Surg Sports Traumatol Arthrosc* 18:656–663, 2010.

This prospective study of 45 patients evaluated the results of microfracture for treatment of chondral defects of the talus at early and midterm follow-up. The study found the HSS functional outcome and visual analogue scale improved at each follow-up time point. The study also found that all 25 ankles available for MRI follow-up at 5 years displayed some surface damage including fibrillation, fissures or ulcerations. (Level II evidence)..

Choi WJ, Choi GW, Kim JS, et al: Prognostic significance of the containment and location of osteochondral lesions of the talus: independent adverse outcomes associated with uncontained lesions of the talar shoulder. *Am J Sports Med* 41:126–133, 2013.

This retrospective cohort study compared the clinical outcomes after microfracture for osteochondral lesions of the

talus by location. The study found that in 399 patients, those patients with lesions on the talar shoulder had substantially worse outcomes than those patients with nonshoulder lesions, even when adjusting for osteochondral lesion size. The study also found that there was no difference in clinical outcomes between patients with medial and lateral osteochondral lesions. (Level III evidence).

Ferkel RD, Zanotti RM, Komenda GA, et al: Arthroscopic treatment of chronic osteochondral lesions of the talus: long-term results. *Am J Sports Med* 36:1750–1762, 2008.

This retrospective case series evaluated the clinical outcomes of 50 patients with chronic osteochondral lesions of the talus who underwent arthroscopic microdrilling. The study found that at a mean follow-up of 71 months, there was significant improvement in the average AOFAS Hindfoot score and the modified Weber scale. All patients returned to their prior level of activity, but 12% of patients needed to modify their activities. (Level IV evidence)..

Gobbi A, Francisco RA, Lubowitz JH, et al: Osteochondral lesions of the talus: randomized controlled trial comparing chondroplasty, microfracture and osteochondral autograft transplantation. *Arthroscopy* 22:1085–1092, 2006.

This prospective randomized controlled trial evaluated the clinical and radiographic outcomes after microfracture, chondroplasty and osteochondral autograft transplantation. The study found that at an average follow-up of 53 months, there was no difference in the AHS scores and SANE scores. MRI evaluation revealed incomplete fill and edema after chondroplasty and microfracture and chondral gaps evident after autologous osteochondral transplantation. (Level I evidence)..

Lee DH, Lee KB, Jung ST, et al: Comparison of early versus delayed weightbearing outcomes after microfracture for small to midsized osteochondrdal lesions of the talus. *Am J Sports Med* 40:2023–2028, 2012.

This prospective study evaluated 81 patients with single osteochondral lesion of the talus after treatment of arthroscopic microfracture treatment with half of patients placed in a delayed weightbearing group (6 weeks) and the other half in an early weightbearing group (2 weeks). The study found no differences in terms of AOFAS score, VAS score, and AAS score. (Level II evidence).

Lee KB, Bai LB, Yoon TR, et al: Second look arthroscopic findings and clinical outcomes after microfracture for osteochondral lesions of the talus. *Am J Sports Med* 37:63S, 2009.

This retrospective study evaluated second-look arthroscopies in 20 ankles at 12 months postoperative follow after microfracture for treatment of osteochondral lesions of the talus. The study found that 40% of the osteochondral lesions were incompletely healed, but 90% of ankles had excellent or good AOFAS scores greater than 80 points. (Level IV evidence).

Multiple-Choice Questions

QUESTION 1. At what time period should plyometrics begin in the rehabilitation process?

A. 1 to 2 weeks
B. 2 to 6 weeks
C. 6 to 14 weeks
D. 14 to 24 week period

QUESTION 2. Which of the following is one of the greatest differences between microfracture and autologous osteochondral transplantation?

A. The rehabilitation program for microfracture is significantly longer
B. Autologous osteochondral transplantation patients have worse outcomes after rehabilitation
C. Autologous osteochondral transplantation patients have two incisions and procedures completed and require rehabilitation of both the knee and ankle.
D. There are no differences in the rehabilitation of the two procedures.

QUESTION 3. Which of the following is not a goal of the immediate postoperative period (week one to two)?

A. Educate patient regarding postoperative plan, goals and expectations
B. Instruct patient in correct use of crutches and assistive devices
C. Restore accessory joint motion and passive range of motion
D. Restore full strength of the surrounding musculature

QUESTION 4. By what time period should the patient be able to fully weight bear?

A. Week 2
B. Week 3
C. Week 4
D. Week 6

QUESTION 5. Which of the following is not a good exercise to prevent further injury after the rehabilitation program is complete?

A. Lateral box jumps
B. Sitting leg raises
C. Leg press
D. Cutting, accelerating and decelerating exercises

Answer Key

QUESTION 1. Correct answer: **D** (see Phase V)

QUESTION 2. Correct answer: **C** (see Other Surgical Techniques and Options)

QUESTION 3. Correct answer: **D** (see Goals for immediate Postoperative Period)

QUESTION 4. Correct answer: **D** (see Phase II)

QUESTION 5. Correct answer: **B** (see Exercises and Other Techniques for Prevention of Recurrent Injury)

Chapter 40



Ankle Impingement

INTRODUCTION

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Epidemiology

- Ankle impingement is one of the more common challenges faced by the orthopedic foot and ankle surgeon.
- Ankle impingement is a pathology defined as the entrapment of osseous and/or soft tissue overgrowth that leads to pain and decreased range of motion.
- Although the exact incidence of ankle impingement syndromes is unknown, it is commonly associated with overuse injuries and can also present with chronic ankle sprains.
- Current literature on ankle impingement is described by its location in three anatomically distinct regions: anterolateral, anteromedial, and posterior. This chapter introduces each of the three ankle impingement syndromes.

Anterior Ankle Impingement: Anteromedial and Anterolateral

- Anterior ankle impingement is a common condition seen in many athletes, particularly soccer players, dancers, gymnasts, and cross-country runners.
- Ballet dancers are prone to anterior ankle impingement with repetitive microtrauma in the forced dorsiflexion position while in the plié or demi-plié positions.
- It is also commonly found in patients who suffer recurring trauma to the anterolateral aspect of the ankle either as a result of inversion injuries or repetitive dorsiflexion.
- Anterior ankle impingement is further discussed in the literature by its location: anteromedial and anterolateral.

Posterior Ankle Impingement

- Posterior ankle impingement is a relatively common syndrome found in many athletes, particularly dancers, downhill runners, and soccer players.
- It is typically identified as a chronic injury owing to forced plantarflexion that can result in one of several pathologies.
- It may be described as os trigonum syndrome, posterior block, or talar compression syndrome.

Pathophysiology

Intrinsic Factors

- In general, any intrinsic factors that are associated with ankle sprains may predispose to ankle impingement. These include:
  - Increased body weight
  - Preexisting ankle ligament laxity
  - Ankle flexion strength asymmetry
  - Poor proprioception
  - Decreased physical conditioning
  - Younger age
  - Previous ankle sprain
- The most common form of posterior impingement is related to the os trigonum.
- The os trigonum is a congenital anomaly that forms where the talar body and lateral tubercle (Stieda process) does not fuse, and is found in 2.3% of the population.
- The presence of an os trigonum predisposes a patient to posterior ankle impingement.

Extrinsic Factors

- In general, any extrinsic factors that are associated with ankle sprains may contribute to ankle impingement. These include:
  - Increase in shoe heel height.
  - Participation in athletic activity.
  - Regarding athletic activity, participation in competitive play leads to increased risk versus noncompetitive training.

- Participation in contact sports versus non-contact sports
- Use of nonbreakaway bases in baseball and softball

Traumatic Factors

Anteromedial Ankle Impingement

- The exact cause of anteromedial ankle impingement is currently undefined, but several theories have been proposed including:
  - Repetitive capsular traction during hyperplantarflexion movements.
  - Inversion ankle sprain, including the entrapment and/or tearing of the anteromedial joint capsule and impaction between the medial malleolus and medial facet of the talus.
  - Repetitive dorsiflexion.

Anterolateral Ankle Impingement

- Commonly associated with an ankle inversion injury with concurrent damage to the lateral ligament complex.
- Recurrent instability and associated microtrauma may cause soft tissue and intra-articular hemorrhage, reactive hyperplasia, and scarring.
- Symptoms of anterolateral ankle impingement may be reproduced with compression of the abnormal anterolateral soft tissue during eversion or dorsiflexion.
- In severe cases, the soft tissue may be molded within the anterolateral recess to form a reactive hyalinized connective tissue mass termed the meniscoid lesion.

Posterior Ankle Impingement

- Posterior ankle impingement is commonly associated with repetitive traumatic injuries to the ankle.
- During plantarflexion pain is caused by either the compression of bony anomalies and/or soft tissue such as scar tissue, posterior ankle ligaments or posterior joint capsule between the posterior aspect of the distal tibia and calcaneal bone or a microenvironment of the os trigonum or an avulsion fracture fragment.
- Loose bodies or avulsion fractures of the posterior tibiotalar ligament (Cedell fracture) have been described as a cause of posterior impingement syndrome.

Classic Pathological Findings

Anteromedial Ankle Impingement

- Arthroscopic evaluation may reveal soft tissue synovial hyperplasia at the anteromedial aspect of the ankle (Figure 40-1).
- A majority of patients also have anteromedial tibial osteophytes and/or anteromedial talar osteophytes.
- In some cases, superficial fibers of the deltoid ligament may also be impinged during arthroscopic examination.

Anterolateral Ankle Impingement

- Arthroscopic evaluation demonstrates that patients may have hypertrophied, inflamed synovium that is hemorrhagic with a firm elastic consistency.

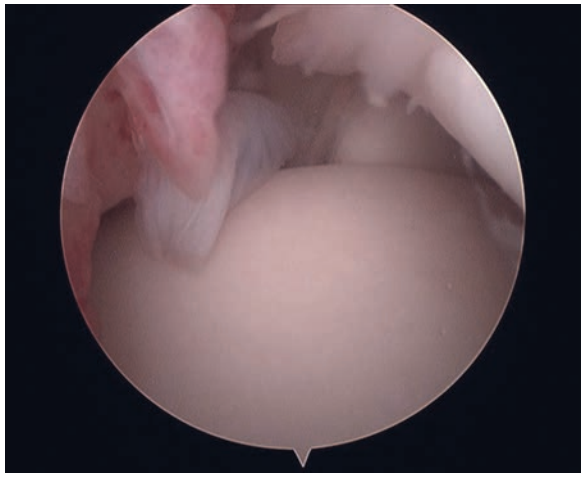

FIGURE 40-1. Soft tissue synovial hyperplasia at the anteromedial aspect of the ankle.

- Anterior tibial and/or talar osteophytes may also be evident.
- Evaluation of the cartilage may note degenerative and fibrotic changes.
- Patients may also present with adhesive bands of scar tissue similar to meniscoid lesions in the lateral gutter.

Posterior Ankle Impingement

- During arthroscopic evaluation, the patient should be placed in plantarflexion to view the impingement.
- In plantarflexion the patient may have compression of bony anomalies and/or soft tissue such as scar tissue, posterior ankle ligaments or posterior joint capsule between the posterior aspect of the distal tibia and calcaneal bone.
- An os trigonum or avulsion fractures may also be evident on arthroscopic evaluation.

Clinical Presentation

History

Anteromedial Ankle Impingement

- Patients with anteromedial ankle impingement often present with chronic ankle pain localized to the anteromedial aspect of the joint that is often exacerbated by activity or dorsiflexion motions such as running, jumping, or kicking a ball.
- Pain can typically be replicated with forced dorsiflexion of the ankle and pressing in the soft spot just medial to the anterior tibial tendon.
- Patients may also present with a history of ankle inversion injuries or ankle trauma.

Anterolateral Ankle Impingement

- Patients typically present with a history of anterolateral ankle pain and swelling exacerbated by activity.
- Patients may describe a history of ankle inversion injuries or ankle trauma.
- Patients may complain of a popping or snapping sensation in the joint during activity.

- Symptoms are often exacerbated by activity, such as running, jumping, or kicking a ball.

Posterior Ankle Impingement

- Patients with posterior ankle impingement often present with chronic ankle pain in the posterior aspect of their ankle that is exacerbated by activity, such as running or jumping, and plantarflexing the ankle.
- Patients often describe a history of a hyperplantarflexion ankle injury.

Physical Examination

Abnormal Findings: Anteromedial Ankle Impingement

- Patients often present with restricted dorsiflexion and inversion associated with soft tissue thickening of the anteromedial compartment.
- Palpation over the anteromedial ankle joint and dorsiflexing the ankle may reproduce symptoms.
- Anteromedial bony spurs may be palpable.

Abnormal Findings: Anterolateral Ankle Impingement

- Patients are typically tender upon palpation along the anterolateral aspect of the ankle.
- This pain is often reproduced at extreme passive dorsiflexion.
- A painful mass may be palpable in the region of the anterolateral gutter.
- Exacerbation of symptoms may be caused by single leg squatting and ankle eversion or dorsiflexion.

Abnormal Findings: Posterior Ankle Impingement

- Patients are typically tender upon palpation along the posterior aspect of the ankle, classically medial to the Achilles tendon.
- Patients' pain is worsened when placed in forced plantarflexion.

Pertinent Normal Findings

- When evaluating ankle impingement it is important to assess for functional and mechanical ankle stability by evaluating the integrity of the ligamentous structures of the ankle such as the anterior talofibular ligament, calcaneofibular ligament, and deltoid ligament for pathology.
- It is also important to rule out fractures of the ankle as well as any cartilage defects such as osteochondral lesions of the talus or tibia.

Imaging

- For ankle impingement both osseous and soft tissue pathology should be suspected.
- AP and lateral weight-bearing radiographs are useful images for assessing bony abnormalities such as os trigonum in posterior ankle impingement.
- Computed tomography allows for further delineation of osseous abnormalities with greater detail.
- However, to view soft tissue pathologies, magnetic resonance imaging is the most appropriate modality and should be used in all patients with suspected soft tissue impingement.
- Studies have suggested that MR arthrography has the greatest sensitivity and specificity for evaluating ankle impingement, but this is less preferred because of its invasive nature.
- Clinical association with imaging findings is essential because imaging features may also be seen without symptoms of ankle impingent.

Anteromedial Ankle Impingement

- The use of standard lateral and AP radiographs are often unremarkable when assessing anteromedial ankle impingement.
- An oblique anteromedial impingement view described by van Dijk et al. allows visualization of medial osteophytes at the talotibial articulation.
- The AMI view is an oblique 45° craniocaudal radiograph with 30° of external rotation of the leg (Figure 40-2).
- MRI should also be used to evaluate the extent of soft tissue hyperplasia, swelling, and impingement.
- It is important to obtain a MRI to also rule out any other potential medial ankle pathologies (discussed in the following).
- A diagnostic injection of local anesthetic may also be given into the anteromedial joint capsule and soft tissue. If symptoms are resolved with the injection, this is considered a positive test for anteromedial impingement.

Anterolateral Ankle Impingement

- AP and lateral weight-bearing radiographs are nonspecific for anterolateral ankle impingement, but should be obtained to rule out potential osseous causes of the patients symptoms (e.g., fracture).
- Axial T1-weighted or proton density–weighted images combined with sagittal T1-weighted images are the



FIGURE 40-2. Oblique anteromedial impingement view.



FIGURE 40-3. Prominent talar process.

most accurate for identifying soft tissue anterolateral impingement.
- MRI findings associated with anterolateral impingement include a focal mass within the gutter or hypertrophy of soft tissue and/or synovium in the lateral gutter.
- Abnormalities of the lateral ligament complex may also be visualized.

Posterior Ankle Impingement

- In patients with posterior impingement, an anteroposterior radiograph is unlikely to show abnormalities.
- Lateral radiographs may show a prominent talar process or an os trigonum (Figures 40-3). However, an os trigonum may be superimposed on the medial talar tubercle on lateral radiographs and therefore difficult to identify.
- Lateral radiographs with the foot in 25° of external rotation in relation to the standard lateral radiographs may assist in viewing an os trigonum.
- CT imaging may be useful to determine the dimension, exact location, and anatomical relationship of the os trigonum or other osseous structures present.
- MRI is also important for assessing the position of the os trigonum and the presence of any other soft tissue structures that may be causing pain.
- MRI with the foot in plantarflexion may yield additional information regarding the mobility of the os trigonum and the site of impingement.
- MRI may also show whether the os trigonum has a fibrous, fibrocartilaginous or cartilaginous attachment to the talus.

Differential Diagnosis

- There are several conditions that may cause similar symptoms to anterior and posterior ankle impingement.
- Listed in the following are several pathologies that should be included in the differential diagnosis when suspecting ankle impingement.
- A thorough history, a complete physical examination, and imaging are all important modalities to confirm the diagnosis of ankle impingement.

Anteromedial Ankle Impingement

- Osteochondral lesion of the ankle
- Stress fractures
- Injuries to deltoid ligament, spring ligament, or posterior tibial tendon
- Equinus contracture

Anterolateral Ankle Impingement

- Peroneal tendon pathology
- Sinus tarsi syndrome
- Stress fractures
- Chronic ankle instability
- ATFL, CFL pathology
- Intra-articular loose bodies
- Equinus contracture

Posterior Ankle Impingement

- Achilles tendinosis
- Flexor hallucis longus tendinosis
- Tibialis posterior tendonitis
- Deltoid ligament, posterior tibial tendon pathology
- Haglund's deformity

Treatment

Nonoperative Management

- Nonsurgical treatment for ankle impingement includes rest, cryocompression, and elevation.
- Analgesics such as nonsteroidal anti-inflammatories may also be used to reduce pain. Activities that exacerbate pain should be avoided.
- Physical therapy is also an additional nonsurgical treatment option available, to improve range of motion, proprioception, and strength.
- Physical therapy may also work to correct any motions that may contribute to the pathogenesis of the ankle impingement, such as overpronation in ballet dancers with anterior ankle impingement.
- Injections of steroids and/or local anesthetic may also be appropriate for some patients to reduce inflammation and pain.

Guidelines for Choosing Among Nonoperative Treatments

- Rest, cryocompression and elevation should be advised for all patients with ankle impingement.
- For athletes, both recreational and professional, physical therapy may be appropriate to help assist in the recovery phase and quicken the recovery time period.
- Local anesthetic and steroidal injections are intended for those patients who are limited in their activities of daily living or athletes who are unable to return to sport.

Surgical Indications

- The surgical treatment options for ankle impingement include open surgery, arthroscopy using the standard

anteromedial and anterolateral portals or hindfoot arthroscopy using posterolateral and posteromedial portals.
- The indication for surgical treatment is continued pain following 4 to 6 weeks of conservative management.

Aspects of History, Demographics, or Exam Findings that Affect Choice of Treatment

- The choice to pursue surgical treatment of ankle impingement is complex and must be individualized to each patient.
- Patients who are most appropriate for surgical treatment are those who have failed conservative management, and athletes who require a rapid return to sport.

Aspects of Clinical Decision Making When Surgery Is Indicated

- When surgery is indicated, the surgeon must decide between open surgery and arthroscopy.
- It is recommended that anterior or posterior arthroscopy be utilized for treatment of ankle impingement as it has comparative outcomes to open surgical treatment with fewer complications (e.g., infection and nerve damage).
- Of note, if a particularly large osteophyte or os trigonum needs to be removed, the arthroscopic portal may need to be enlarged or converted to open.

Evidence

Calder JD, Sexton SA, Pearce CJ: Return to training and playing after posterior ankle arthroscopy for posterior impingement in elite professional soccer. *Am J Sports Med* 38(1):120–124, 2010.

This retrospective study evaluated hindfoot arthroscopy for the treatment of posterior impingement in professional soccer players who failed nonoperative treatment. The study found that in 27 players, the average return to playing was 41 days and found that no patients had any complications at 23 months follow-up. (Level IV evidence)

Ferkel RD, Tyorkin M, Applegate GR, et al: MRI evaluation of anterolateral soft tissue impingement of the ankle. *Foot Ankle Int* 31(8):655–661, 2010.

This retrospective review evaluated the effectiveness and reliability of conventional MRI for diagnosing anterolateral soft tissue impingement of the ankle. In an evaluation of 24 patients, the study found that MRI was accurate in 78.9% of cases, with a sensitivity of 83.3% and a specificity of 78.6%. The study demonstrates that while MR arthrography has a higher specificity and sensitivity, conventional MRI is more preferred because of its less invasive nature and comparable effectiveness and reliability of diagnosing anterolateral soft tissue impingement. (Level II evidence)

Hassan AH: Treatment of anterolateral impingements of the ankle joint by arthroscopy. *Knee Surg Sports Traumatol Athrosc* 15(9):1150–1154, 2007.

This prospective study evaluated arthroscopic debridement of anterolateral soft tissue impingement in 23 patients. At an average follow-up of 25 months, the study reported an improvement in the American Orthopedic Foot And Ankle Society (AOFAS) foot and hindfoot score of 55 points with 21 patients reporting good or excellent outcomes. (Level IV evidence)

Murawski CD, Kennedy JG: Anteromedial impingement in the ankle joint: outcomes following arthroscopy. *Am J Sports Med* 38(10):2017–2124, 2010.

This retrospective study evaluated the use of arthroscopic resection for anteromedial impingement in 41 patients. The study found that at a minimum follow-up of 2 years, significant improvements in the American Orthopaedic Foot and Ankle Society (AOFAS) hindfoot and Short Form 36 outcome scores The study found that all patients, but one, returned to their prior level of athletic activity. (Level IV evidence)

van Dijk CN, de Leeuw PA, Scholten PE: Hindfoot endoscopy for posterior ankle impingement. Surgical technique. *J Bone Joint Surg Am* 91(suppl 2):287–298, 2009.

This prospective study evaluated the effectiveness, morbidity and recovery with the use of hindfoot arthroscopy for the treatment of posterior ankle impingement. The study evaluated 55 patients at a median follow-up of 36 months. The study found an improvement in the American Orthopedic Foot and Ankle Society (AOFAS) hindfoot score from 75 to 90 postoperatively as well as only one complication. (Level IV evidence)

Multiple Choice Questions

QUESTION 1. What approach should be taken remove a pathological os trigonum?

A. Open surgery
B. Ankle arthroscopy using anteromedial and anterolateral portals
C. Ankle arthroscopy using posterolateral and anterolateral portals
D. Ankle arthroscopy using posterolateral and posteromedial portals.

QUESTION 2. Which of the following imaging modalities is most sensitive and specific for diagnosing ankle impingement, but not commonly used because of its invasiveness?

A. Radiographs
B. Computed tomography
C. Magnetic resonance imaging
D. Magnetic resonance arthrography

QUESTION 3. What imaging modality provides the best view for osseous causes of anteromedial ankle impingement?

A. Anteroposterior radiograph
B. Lateral radiograph
C. 45° craniocaudal radiograph with 30° external rotation of the leg
D. None of the above

QUESTION 4. Anterior ankle impingement is most commonly found in which of these sports?

A. Soccer
B. Skiing
C. Hockey
D. Basketball

QUESTION 5. Which of the following should not be included in a differential diagnosis of posterior ankle impingement?

A. Achilles tendinosis
B. Flexor hallices longus tendinosis
C. Tibialis posterior tendinosis
D. Anterior tibialis tendinosis pathology

Answer Key

QUESTION 1. Correct answer: **D** (See Treatment)

QUESTION 2. Correct answer: **D** (see Imaging)

QUESTION 3. Correct answer: **C** (see anteromedial imaging)

QUESTION 4. Correct answer: **A** (see Anterior Ankle Impingement Etiology)

QUESTION 5. Correct answer: **D** (see Posterior Ankle Impingement Differential Diagnosis)

BEYOND BASIC REHABILITATION: RETURN TO SOCCER AFTER SURGICAL TREATMENT OF POSTERIOR ANKLE IMPINGEMENT

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ASPECTS OF SOCCER THAT REQUIRE SPECIAL ATTENTION IN REHABILITATION

- The ability to sprint and jump
- Kicking the ball with the medial, dorsal, and lateral surface of the foot
- Changing sprinting direction suddenly (e.g., cutting maneuver, ability to backpedal and pivot)

Introduction

- Athletic participation in soccer subjects the ankle to a variety of acute and chronic biomechanical forces. The posterior ankle is particularly stressed because of the ankle being naturally plantar flexed in activities such as jumping, kicking, and tackling.[1] An accumulation of these biomechanical stresses or a sudden hyper-plantar flexion injury can lead to posterior ankle impingement syndrome (PAIS), a condition that has been described frequently in soccer players.[2-4]
- Treatment of PAIS is traditionally tailored around the player's season, with conservative treatment (e.g., local anesthetic and/or steroid injection) pursued initially to manage symptoms during the season.
- Definitive surgical treatment (e.g., hindfoot arthroscopy) may then be carried out in the off season.
- Unfortunately there is a direct correlation between the duration of symptoms before surgery and the postoperative time required to return to athletic participation. Therefore, a tailored rehabilitation program is important in allowing a player a quick and effective return to playing soccer.

TIMELINE 40-1: **Postsurgical Rehabilitation after Surgical Treatment of Posterior Ankle Impingement**

PHASE I (Postoperative Weeks 1 to 3)

- Communicate with MD regarding individualized postop rehab precautions specific to each case
- Ankle splint/CAM walker
- Progressive WBAT (wean from crutches)
- PT modalities for pain reduction (electrical stimulation) and edema control (cryotherapy, cold whirlpool, vasopneumatic device)
- Range of Motion:
  - AROM [plantar-flexion (pain-free to avoid compression on posterior ankle) dorsiflexion, inversion, eversion, foot circles, alphabets]
  - PROM gastrocnemius/soleus stretching in NWB position, joint mobilizations (grades 1 to 2) for dorsiflexion, inversion, eversion
- Proprioception: Biomechanical Ankle Platform System (BAPS) board seated
- Strength: ankle isometrics in pain-free range, proximal lower extremity and core musculature
- Precautions: Limit FHL activation owing to its proximity to os trigonum. Do not force plantar flexion as it will cause increased pressure on posterior ankle.

PHASE II (Postoperative Weeks 4 to 6)

- Wean from ankle splint/CAM walker, D/C crutches
- Continue PT modalities for pain reduction and edema control
- Minimize scar formation
- Range of motion:
  - AROM: Continue in all planes
  - PROM gastrocnemius/soleus stretching with increased intensity, joint mobilizations (grades 1, 2, 3) for dorsiflexion, inversion, eversion
- Proprioception: BAPS board, progress to standing in all planes
- Strength: ankle Thera-Band in all four planes (pain-free plantar flexion), standing heel raises (pain-free to avoid posterior ankle compression), toe curls with towel (avoiding FHL pain), step-ups, wall-squats,
- Balance: Progress from bilateral to unilateral and from stable (ground) to unstable (foam, Dyna-disc) surfaces

Literature

- The mean time to return to soccer following hindfoot arthroscopy for posterior ankle impingement has been described previously. In a study analyzing outcomes in 27 professional soccer players, the mean time to return to training following surgery was 34 days (range, 24 to 54 days). Mean time to return to playing was 41 days (range, 29 to 72 days).[4]

Phase I: Advanced Strength and Conditioning Programs

Periodization

- Linear

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- Flexibility/joint mobility for joint stability
  - Ankle range of motion should be fully restored upon start of an advanced strength and conditioning program. The mean postoperative range of motion of the ankle joint after arthroscopic excision of posterior ankle bony impingement has been previously described and improved from 59.2° to 68.4°.[5]
  - If range of motion (ROM) is not within normal limits (WNL), the patient should perform gastrocnemius/soleus flexibility exercises and the physical therapist should perform talocrural mobilization techniques to restore ankle ROM. Early range of motion to improve integrity of soft tissue structures has been well documented in research.[6-8]
  - It is important for soccer athletes to have full ankle ROM to perform running, cutting, and stability exercises as described later in this rehabilitation program.
  - Following surgery, it is important to avoid excessive pronation as this will put increased pressure on the posterior ankle; thus it is important to teach the patient subtalar neutral position for improved foot stability.
  - Gastrocnemius and soleus stretching exercises should start in a non–weight-bearing position and should progress to a weight bearing position with increased intensity as tolerated by the athlete.
- Training with optimum posture
  - Training with optimum posture is important for patient athletes as they perform all therapeutic and functional exercises. This includes deep core muscle activation and maintaining appropriate posture throughout the entire kinetic chain.
  - As patient athletes progress in the rehab, it is important that they be taught to utilize core musculature in functional positions (i.e., activating transverse abdominis while accelerating into a sprint during soccer, this will be further expanded upon in later rehabilitation phases) (Figure 40-4).
  - Athletes are first taught to engage their core musculature in a non–weight-bearing position (i.e., performing a pelvic tilt, which is done by starting the athlete in a supine hook lying position and having him or her flatter out the back by tightening his or her abdominal muscles and pushing the pelvic bone posterior).
  - Once they have mastered this in a static, non–weight-bearing position they are progressed to a dynamic exercise in which they maintain core activation while moving their arms or legs (i.e., dead bug exercise in which the arms and legs are moving while the posterior pelvic tilt is maintained).
  - After athletes show the ability to complete this exercise without disengaging the pelvic tilt (and activation of the transverse abdominis), they are ready to perform the exercise in a functional, standing position.
  - Athletes are taught to do a squat with their back against a wall while maintaining a posterior pelvic tilt, and this concept should be translated into all therapeutic exercises that the athlete is performing (making sure to activate the core before any exercise).
  - Wall drills are also an important sport specific exercise for soccer athletes teaching them how to establish core activation in a functional position (i.e., when starting to accelerate into a sprint). They are

TIMELINE 40-1 **Postsurgical Rehabilitation after Surgical Treatment of Posterior Ankle Impingement** (Continued)

PHASE III (Postoperative Weeks 7 to 10)	PHASE IV (Postoperative Weeks 11 to 14)
• DC ankle splint/CAM walker • PT modalities as needed • ROM: full. Mobilizations as needed to maintain full ankle/foot ROM • Proprioception: Progress BAPS board level and add weight • Strength: Continue ankle Thera-Band in all four planes (pain-free plantar flexion) • Balance: Continue to progress unstable surfaces (BOSU ball, wobble board) • Biodex Balance Master if available for proprioceptive exercises. • Add perturbations, including alphabets with contralateral lower extremity, kicking/heading a soccer ball, remove visual input • Running: Begin unloaded jogging on Alter-G treadmill, progress to alternating jog/walk/jog on treadmill (no incline)	• PT modalities as needed • ROM: full. Mobilizations as needed to maintain full ankle/foot ROM • Proprioception: Progress BAPS board level and add weights • Strength: Continue ankle Thera-Band in all four planes (pain-free plantar flexion), continue proximal lower extremity strengthening • Balance Continue to progress single leg stability on unstable surfaces (lawnmowers, cone touches, single leg dips) • Running: Progress from straight jogging on treadmill to sprint/jog/sprint on flat, straight surface. Progress from running on treadmill to track to pavement to turf. • Agility drills: ladders, zig-zag cutting, diagonal patterns, figure-eights, back pedaling, carioca, lateral shuffles, jumping (progress bilateral to unilateral), plyometrics • Return to sport: Athletes return to functional return to sport with soccer-specific drills during this phase.



FIGURE 40-4. Acceleration wall drills. Place hands on a wall or soccer goal post so that the head, neck, shoulders, and hips are aligned. Start by lifting the left leg as shown. Quickly drive the left leg into the ground while lifting the right leg into position. Maintain proper posture and core stability throughout the exercise.



FIGURE 40-5. Tandem stance on a half foam roller. Athletes perform the single leg stance on a half foam roller while heading a soccer ball.

performed by having the athlete place both of his or her hands on wall or soccer goal post so that head, neck, shoulders, and hips are aligned and the core is activated. The athlete starts by lifting one leg (as shown in Figure 40-4) and then quickly drives the left leg into the ground while lifting the right leg into position. The main focus of this exercise is to maintain proper posture and core stability throughout exercise.

- Sensorimotor and balance training
  - Sensorimotor and balance exercises are progressed from bilateral to unilateral and from a stable surface to an unstable surface (i.e., foam, Dyna-discs, BOSU ball, rocker board, wobble board, dynamic Biodex balance master).
  - Figure 40-5 shows an athlete heading a soccer ball while performing tandem stance on a half foam roller.
- Core training
  - Core strengthening exercises are of upmost importance to improve stability upon return to sport and to minimize the risk of additional injury on the field.[9] Exercises should focus on activating the transverse abdominis musculature through specific training.
  - Exercises at this stage are initiated in a non–weight-bearing position (pelvic tilts, bridges with transverse abdominis activation, front planks, side planks).
  - Proximal lower extremity musculature strength should also be maintained and improved upon during rehabilitation and closed chain exercises will functionally develop strength throughout surrounding joints (i.e., progress calf press to heel raises and progress leg press to wall squats).
- Cardiorespiratory training
  - Cardio training is important to avoid deconditioning and maintain endurance with bike, arc/elliptical and Alter-G treadmill. This principle can be applied by aerobic endurance training of both fast and slow twitch muscle fibers (both of which are needed for soccer athletes).
- Multiplanar training
  - Multiplanar training activities are important because soccer athletes are constantly changing directions on the field and need to be able to quickly plant their feet and cut. Multiplanar training activities include progressions on BAPS board (non–weight-bearing to weight-bearing position) and plantar/dorsiflexion, inversion/eversion, and clockwise/counterclockwise movements.
  - Strengthening exercises should challenge musculature both concentrically and eccentrically. Isotonic strengthening includes Thera-Band exercises (all planes throughout full ROM) and manual, progressive resistance exercises.
- Training for optimum muscle balance
  - Balance exercises are progressed from bilateral to unilateral and from firm surfaces to unstable surfaces. Additional perturbations are added (soccer kicks while performing single leg stance on opposite leg for soccer players) and taking away visual input are appropriate advancements.
  - Athletes should be able to display appropriate single leg stability before advancing to functional soccer drills. This is determined by having the athlete stand on one leg. He or she should be able to balance on an uneven surface (foam, Dyna-disc, BOSU ball) for at least 30 seconds without loss of balance before starting any sports specific single leg balance exercises.

Training Principles Used in the Design of the Program

- Principle of progression
- Principle of variation

- Principle of individualization
- Principles of specificity: specific adaptation to imposed demands (SAID)

Application of Acute Training Variables

- Acute training variables vary based on the athlete's preoperative condition, training background, and exercise history. These variables, listed in the following, affect how the body adapts to resistance exercise.[10]
  - Repetitions: 8 to 10 repetitions of each exercise
  - Sets: two to three sets of each exercise
  - Rest interval: 60 seconds between sets
  - Intensity: Dependent upon the specific goals of the athlete; however should be low intensity at this point in the rehabilitation. Athletes should begin with a low weight and progress to a heavier weight once proper form is established. The exercise should be challenging by the third set of 8 to 10 repetitions.
  - Repetition tempo is dependent upon the goal of the athlete. At this point in the rehabilitation, patient athletes are most likely looking to gain maximal strength, so a slow, eccentric contraction is best.
  - Training frequency two to three times per week
  - Training duration should be about 30 to 60 minutes for each workout and is dependent upon the athlete and his or her specific glycogen stores.
  - Training volume is dependent upon the other acute training variables as described in the preceding.

Phase II: Performance Enhancement Training Techniques

Periodization

- Mesocycles

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- Flexibility/joint mobility for joint stability
  - Patients should have full ankle ROM before performance enhancement training techniques. It is important to maintain a stretching routine for gastrocnemius and soleus musculature along with hamstring, psoas, piriformis, and TFL for soccer athletes because they need to be agile on the field and to decrease risk of further injury.[11]
- Training with optimum posture
  - As in previous stages of rehabilitation, it is important to continue to maintain optimum posture throughout rehabilitation and when transitioning to soccer specific drills because it is essential to have a sturdy base of support from which to accelerate off.
- Sensorimotor and balance training/training for optimum muscle balance
  - Sensorimotor and balance exercises should focus on unilateral stance on an unstable surfaces (i.e., foam, Dyna-discs, BOSU ball, rocker board, wobble board, dynamic Biodex balance master) at this point in the rehabilitation.



FIGURE 40-6. Single leg stance on BOSU with a soccer kick. Athletes perform a single leg stance while kicking a soccer ball with the opposite leg.

  - Further progressions in proprioception include removing visual support, adding perturbations, kicking a soccer ball with the opposite lower extremity (Figure 40-6), or heading a soccer ball while maintaining balance.
- Core training
  - Core training exercises should progress from non–weight-bearing positions to functional weight-bearing positions. Wall drills (see Figure 40-4) teach core musculature activation in soccer specific positions.
  - Athletes should also focus on core activation during sudden changes of position and landing from a jump.
- Cardiorespiratory training
  - Patient athletes should maintain an appropriate cardiovascular endurance level on the bicycle so that when they are ready to return to sport specific drills they are not deconditioned and do not become easily fatigued; thus mitigating the risk of further injury.
  - Patient athletes progress to a running program once cleared by treating physician. This determination is specific to each treating medical doctor; however usually it is determined based on the patient's subjective reports, results of objective tests/measures by the MD (full ROM, 5/5 strength, single leg stability without loss of balance, single hop test), and the level of play of the athlete.
  - The running program starts on an Alter-G treadmill with a percentage of body weight unloaded, progressing to alternating jog/walk/jog on treadmill and then to straight running.
- Multiplanar training activities
  - Multiplanar training activities should be progressed at this point in the rehabilitation from non–weight-bearing exercises (ankle four-way progressive resistive exercises) to weight-bearing exercises (multidirectional lunges and multidirectional heel raises), which further improve strength and endurance of ankle musculature.

- Training for optimum muscle functional strength
  - At the beginning of this phase patient athletes should demonstrate the ability to perform bilateral heel raises without pain or apprehension, especially with going into plantarflexion because this may exacerbate the surgical site.
  - The patients then progress into the ability to perform unilateral heel raises before advancement to sport-specific soccer drills.
- Training for optimum muscle functional power
  - To train for optimum muscle function power, patients should vary acute training variables. Once patients are able to perform the exercise with proper form at low intensity, they may be progressed to short bouts of higher intensity work.

Phase III: Sport-Specific Training

Periodization

- Macrocycles
- Mesocycles

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- Flexibility/joint mobility for joint stability
  - Athletes should have full ROM and flexibility at this stage in sport specific training. It is important to maintain flexibility for appropriate muscle balance.
- Training with optimum posture/sensorimotor and balance training/core training
  - It is important to maintain training with optimum posture including core stability training and balance training as previously described.
- Cardiorespiratory training
  - Athletes should continue to maintain a base level of endurance through a running program. The running program for each athlete is specific to their cardiovascular endurance and the position they play/level of endurance they need to maintain. There is no one specific running program for every athlete, it should be a tailored program developed by the medical professional treating that particular athlete.
  - Soccer-specific field conditioning should be implemented at this phase which can include ball touches and dribbling within a 10 × 10 yard box starting at 30-second intervals and progressing to 20 × 20 yard box at 60-second intervals as endurance and conditioning goals are met.
- Multiplanar training activities
  - Athletes should continue to progress their multiplanar training activities as it relates to soccer specific movements. Resistance via sport cord with multidirectional lunges and adding intensity to lateral drills are both functional exercises for the soccer athlete.
- Training for optimum muscle balance/neuromuscular dynamic stability exercises
  - Balance exercises should focus on unilateral stability on unstable surfaces. Additional perturbations should be added in order to continuously challenge the athlete (e.g., soccer kicks while performing single leg stance on opposite leg) and taking away visual input are appropriate advancements.
- Training for speed, agility, quickness (SAQ)
  - Speed, agility, and quickness training involves sprints, speed ladder drills, and acceleration drills. Ladder drills are performed in various challenging patterns (Figure 40-7) that simulate movements an athlete performs on the soccer field.
  - Adding in a quick soccer kick or dribbling at the end of each set of the ladder drill adds an additional functional component for the athlete. Speed, agility, and quickness circuits should be progressed from forward drills to lateral (Figure 40-8), backward, and randomized movements.
- Plyometric training
  - Plyometric drills utilizing explosive, fast-twitch movements are important for soccer players to develop power and speed as needed on the field to be faster and stronger than their opponents.
  - Plyometric drills should begin bilateral, are progressed to unilateral, and include: hopping over a soccer ball on one foot, bounding, box/depth jumps (Figure 40-9), lateral jumps (Figure 40-10), hurdle hoping.
  - Athletes rehabbing from ankle surgery should take into consideration the rigidity of surface on which they are performing plyometric drills. Performing such drills on softer surfaces such as a track or a grass field will reduce unnecessary stress on joints.
- Functional/sport-specific training
  - Many of the drills described in the preceding entail a significant amount of soccer specific training. Adding soccer kicks and heading a soccer ball into



FIGURE 40-7. Agility ladders. Athletes can perform ladder exercises various ways (both vertical and horizontal to challenge the ankle musculature). Types of ladder drills include quick-step, three forward/one back, high knees, in-in-out-out, and dance step. Athletes should kick a soccer ball at the end of the ladder as a progression into sport-specific training.

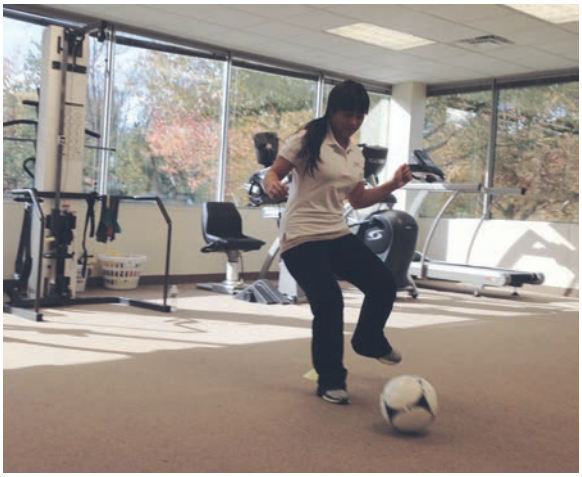

FIGURE 40-8. Lateral shuffles with a soccer kick. Two cones are set up about 40 feet apart. Athletes start in an athletic stance and perform a lateral shuffle to the left, a soccer ball is tossed to them, and they must kick the ball while quickly changing directions. Repeat, going in the other direction.



FIGURE 40-9. Box jump. Start with the feet shoulder width apart. Bend the hips and knees and jump with both feet landing on the box. (The knees should be bent on landing.) This movement should be explosive.



FIGURE 40-10. Bilateral lateral jump. Start in an athletic stance, jump with both feet laterally over a line and back for one repetition. Be sure to land with the knees bent.

the balance and plyometric exercises add an additional sport-specific component for the athlete.

Training Principles Used in the Design of the Program

- Principle of progression
- Principle of overload
- Principle of variation
- Principle of individualization
- Principles of specificity: specific adaptation to imposed demands (SAID)

Application of Acute Training Variables

- Repetitions: 8 to 10 repetitions of each exercise (should be challenging to complete the third set; however the athlete should maintain proper form with each exercise)
- Sets: three sets of each exercise
- Rest interval: 30 to 60 seconds between sets
- Intensity: Dependent upon the specific goals of the athlete; however, intensity should be high at this point in the rehabilitation. The exercise should be challenging by the third set of 8 to 10 repetitions.
- Repetition tempo is dependent upon the goal of the athlete. For those who are looking to gain maximal strength, a slow, eccentric contraction is best. Faster tempos are better for soccer athletes looking to improve power and explosive strength. This is also dependent upon sport season.
- Training frequency three to five times per week (for specific return to soccer drills)
- Training duration should be about 30 to 60 minutes for each workout and is dependent upon the athlete and his or her specific glycogen stores.
- Training volume is dependent upon the other acute training variables as described above.

Application of Chronic Training Variables

- Chronic training variables are dependent upon the sport season for the specific athlete. Soccer athletes in the off-season will perform high level resistance training to improve muscle endurance, strength, and power.
- During the preseason, equal priority is given to sport specific training and strength training.
- Athletes that are in season focus on maintenance of strength, whereas practice time focuses on sport-specific movements and functional drills.
- During the post-season, athletes focus on maintaining muscle endurance and sport-specific skills while actively resting.

Sports Performance Testing

General Information

- General history
- Subjective questionnaires
- Medical history
- Sports injury history
- Surgical history
- Chronic conditions/medication
- Pain level

Objective Tests

- Physiological assessments: pulse measurement (resting and post workout), respiration measurement, body temperature, blood pressure, pulse oximetry, peak flow, weight, height, VO_2max
- Orthopedic assessments: ROM, strength
- Body composition tests
  - Body fat composition
  - Flexibility: sit and reach test
- Static/dynamic postural assessments
  - Static: plumb line
  - Dynamic: Assess athletes gait pattern while running, jumping, kicking, sprinting, and cutting. Gait analysis can be performed by a trained healthcare professional who looks at step length, stride length, cadence, speed, hip/foot/knee angle, pelvic rotation, amount of foot pronation, arm swing, and base of support at various angles. Gait labs can give a more objective measure of a patient's gait by placing markers on various bony landmarks on the body and then having the athlete walk on the treadmill and/or perform sport-specific activities while taking video. Computer-software and force-plates then give a breakdown of the movement of each joint.
- Movement performance testing
- Functional movement screen (deep squat, hurdle step, in-line lunge, active straight leg raise, trunk stability pushup).
- Minimal research is documented on elite soccer players and the Functional Movement Screen to determine injury risk. Chorba et al.[12] looked at 38 NCAA Division II female athletes (soccer, volleyball, and basketball) ad found a score of 14 or less on the FMS tool resulted in a fourfold increase in the risk of low extremity injury.
- Sport-specific testing
  - 40 yard dash
  - Vertical jump
  - Broad jump
  - Sprint repeats
  - Shuttle run

Specific Criteria for Progression to the Next Stage to Determine Readiness for Soccer

- Progression of an athlete from one stage to the next is a multidimensional decision involving a team of healthcare providers.
- An athlete should be able to complete all treatment goals in the previous phase before progression to the next phase (i.e., patient athletes in an early strengthening phase should display normal ROM/flexibility, sufficient strength base, and equal balance of affected vs. unaffected lower extremity before advancement to sport-specific training).
- Patient athletes need to be able to run pain-free and have 5/5 manual muscle testing (MMT) strength throughout their lower extremity (including the ankle) to begin the sport specific training.
- The Foot and Ankle Ability Measure (FAAM) is a reliable measure of performance during ADLs and

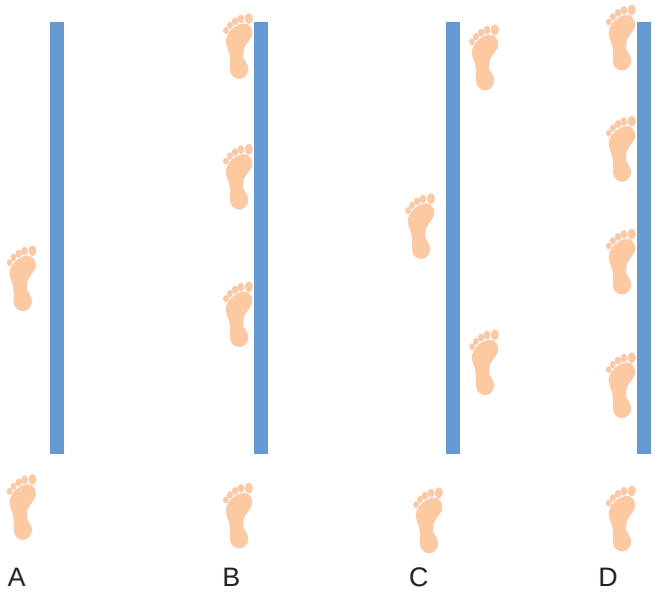

FIGURE 40-11. The single leg hop test. The athlete performs (1) a single leg hop for distance, (2) a triple straight hop for distance, (3) a triple cross-over hop for distance, and (4) a 6-meter timed hop. The athlete should be able to perform the test at 85% of the unaffected extremity before returning to sport.

sport-specific activities for individuals affected by an ankle injury. Physical performance of function can be measured with the four-part single leg hop test (also referred to as the Limb Symmetry Index when compared with the unaffected side, athletes should be able to perform the hop test at greater than 85% on affected limb vs. unaffected limb, as long as no other injury has been sustained on the opposite limb). The athlete performs: (1) a single leg hop for distance; (2) a triple straight hop for distance; (3) a triple crossover hop for distance; and (4) a 6-meter timed hop. The athlete should be able to perform the test at 85% of the unaffected extremity before returning to sport (Figure 40-11).

- The Single Leg Hop Test has been proved to be a convenient, reliable, and valid outcome measure during rehabilitation.[13] It is important to look at functional movements and perform a biomechanical video analysis of sport specific activities.

Specific Criteria for Release to Unsupervised Complete Participation in Soccer

- The length of time for a patient to return to full sport is dependent on many factors, including physical fitness and level of sport play.
- It is recommended that a patient demonstrate 85% strength in affected versus unaffected lower extremity. This is measured by the single leg hop test (as in the preceding).
- Patients should demonstrate ability to carry out functional sport specific testing (running, cutting, jumping, sprinting, kicking a ball) before clearance.
- The Drop Vertical Jump Test has been repeatedly shown in the literature to identify lower extremity biomechanics during plyometric activity.[14] The test is performed by having the athlete do a double-leg jump landing from a 31-cm step and then immediately perform a maximum effort double-leg jump. The athlete is evaluated by visually (or by video analysis) observation: symmetry of both feet leaving the box, feet landing simultaneously, and symmetry of weight bearing. This tests for mechanical faults or neuromuscular control deficits that can be worked on with therapeutic exercises if found.
- The Tuck Jump assessment (Figure 40-12) also has been found reliable in identifying landing techniques in plyometric athletic activity.[15] The athlete performs repeated tuck jumps for 10 seconds while the clinician visually assesses form. (Video analysis may be used for accuracy.) If a patient demonstrates six or more flawed techniques, further therapeutic exercises to address deficits before clearance for sport would be beneficial.[16]
- Athletes should be progressed into sport by returning first to practice at 50% intensity and then progressing by 25% intensity each week.
- Practice situations should start as noncontact, progress into three versus three small-sided games, then to five versus five games, and finally, progress to full contact.
- Lack of apprehension with sport-specific drills is also imperative before return to sport. This is tested by using the FAAM (as in the preceding) along with the Single Leg Hop Test, Drop Vertical Jump Test, and Tuck Jump Assessment (all as in the preceding).
- Patients must have clearance from referring/surgical physician before returning to soccer.

Recommended Ongoing Exercises

- Athletes often target large muscle groups while participating in a sport (especially while in season); however atrophy may occur in smaller muscle groups when training focuses on sport-specific drills and not on strength training.
- It is recommended that athletes continue to focus on balance and proprioceptive exercises throughout their participation in soccer along with stability muscle exercises targeting the peroneals and intrinsic muscles of the foot.
- Maintenance of core muscle strength is imperative in soccer players as well.

Evidence

Calder JD, Sexton SA, Pearce CJ: Return to training and playing after posterior ankle arthroscopy for posterior impingement in elite professional soccer. *Am J Sports Med* 38(1):120–124, 2010.

Case series of 28 professional soccer players who underwent arthroscopy for posterior ankle impingement. The mean length of time to return to training was 34 days (range, 24 to 54 days), and mean length of time to return to playing was 41 days (range, 29 to 72 days). All players were competing symptom free at an average follow-up of 23 months. (Level IV evidence)

Willson J, Dougherty C, Ireland M, et al: Core stability and its relationship to lower extremity function and injury. *J Am Acad Orthop Surg* 13:316–325, 2005.

Core stability is predominantly maintained through dynamic function of muscular elements. Current evidence indicates

Tuck Jump Assessment	Pre	Mid	Post	Comments
Knee and Thigh Motion				
1 Lower extremity valgus at landing	❑	❑	❑	
2 Thighs do not reach parallel (peak or jump)	❑	❑	❑	
3 Thighs not equal side-to-side (during flight)	❑	❑	❑	
Foot Position During Landing				
4 Foot placement not shoulder width apart	❑	❑	❑	
5 Foot placement not parallel (front to back)	❑	❑	❑	
6 Foot contact timing not equal	❑	❑	❑	
7. Excessive landing contact noise	❑	❑	❑	
Plyometric Technique				
8. Pause between jumps	❑	❑	❑	
9. Technique declines prior to 10 seconds	❑	❑	❑	
10. Does not land in same footprint (excessive in-flight motion)	❑	❑	❑	
	Total _____	Total _____	Total _____	

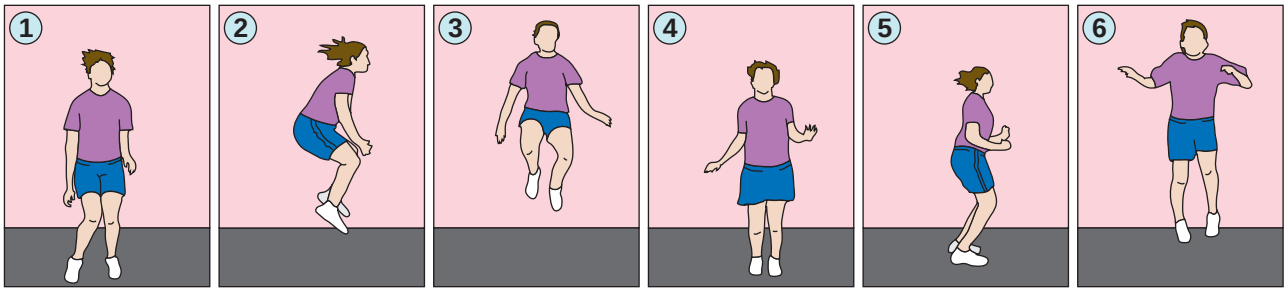

FIGURE 40-12. The tuck jump assessment. The athlete performs repeated tuck jumps for 10 seconds while the clinician visually assesses his or her form. If six or more flawed techniques are observed, further therapeutic exercises to address deficits before clearance for sport would be beneficial: (1) unwanted medial knee collapse; (2) knees not parallel at the top of flight; (3) lower limb positions not synchronized during flight; (4) landing with feet too close together; (5) landing in a staggered position; and (6) not landing with both feet at the same time. *(Redrawn from Myer GD, Ford KR, Hewett TE: Tuck jump assessment for reducing anterior cruciate ligament risk. Athl Ther Today September:39–44, 2008.)*

that decreased core stability predisposes to injury, particularly lower extremity injury. Core stability is tested and improved through isokinetic, isometric, and isoinertial exercises.

Witvrouw E, Danneels L, Asselman P, et al: Muscle flexibility as a risk factor for developing muscle injuries in male professional soccer players. *Am J Sports Med* 31(1):41–46, 2003.

One hundred forty-six professional soccer players with no previous history of injury had the flexibility of their hamstring, quadriceps, adductor, and calf muscles measured goniometrically, and injuries to these muscle groups were recorded. The authors concluded that over the course of a full soccer season, players with increased tightness of the hamstring or quadriceps muscles have a statistically significant increase in risk of developing an injury. (Level II evidence)

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Multiple Choice Questions

QUESTION 1. If postoperative range of motion of the ankle is not within normal limits, which muscle group should be worked on with flexibility exercises?

A. Tibialis anterior, extensor digitorum
B. Peroneus longus, peroneus brevis
C. Tibialis posterior, flexor hallucis, flexor digitorum
D. Gastrocnemius, soleus

QUESTION 2. When training for optimum muscle balance, what are appropriate progressions that may be added to the exercises for the athlete to advance?

A. Removing auditory signals
B. Removing visual input
C. Progressing from unilateral stance to bilateral stance
D. Progressing from unstable surface to stable surface

QUESTION 3. Following surgery, which ankle motion should be most cautiously advanced because it may irritate the surgical site?

A. Dorsiflexion
B. Plantarflexion
C. Inversion
D. Eversion

QUESTION 4. Once the patient athlete has started sport-specific training, how should his cardiorespiratory training progress?

A. Ball touches and dribbling exercises within a 10 × 10 yard box
B. Full soccer pitch sprints
C. Stair climbs
D. Long distance track running

QUESTION 5. What criteria should be used in order to release the athlete into athletic activity without supervision?

A. Strength at 50% of contralateral leg
B. Able to single heel raise on the postsurgical side
C. Strength at 85% of contralateral leg
D. Patient is able to plantarflex on the postsurgical side without pain

Answer Key

QUESTION 1. Correct answer: **D** (see Phase I)

QUESTION 2. Correct answer: **B** (see Phase I)

QUESTION 3. Correct answer: **B** (see Phase II)

QUESTION 4. Correct answer: **A** (see Phase III)

QUESTION 5. Correct answer: **C** (see Specific Criteria for Release to Unsupervised Complete Participation in Soccer)

Chapter 41



Flexor Hallucis Longus Tendinopathy

INTRODUCTION

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Epidemiology

Flexor hallucis longus (FHL) tendinopathy (dancer's tendinitis) is common in female ballet dancers who perform in toe shoes. It is rare in athletes.

- Age: early teens to early 40s
- Sex: females (male dancers rarely dance in toe shoes)
- Sport/Art: usually ballet, but occasionally in other dancers and athletes
- Position: maximum plantarflexion

Pathophysiology

Intrinsic Factors

- The FHL tendon is the "Achilles tendon of the foot" for the ballet dancer working on pointe.
- The tendon has its origin on the posterior fibula, crosses behind the ankle and passes through a fibroosseous tunnel on the medial side os calcis then exits into the arch of the foot.
- It can become strained and swollen within this tunnel, setting up a repetitive cycle: because it is swollen, it binds as it moves and the binding, in turn, causes swelling and irritation, etc.
- If the condition is chronic, the tendon can develop a fibrous knot that causes triggering of the great toe ("hallux saltans") (Figure 41-1).
- Splits and partial tears can develop in the tendon but these are infrequent (Figure 41-2).
- FHL tendinitis can be associated with *posterior impingement* on an os trigonum or trigonal process ("Stieda's process") (Figure 41-3).
- At times, the differentiation between these two syndromes can be difficult, because they can exist separately or together.
- Posterior impingement does not cause FHL tendinitis. They are two separate syndromes that may coexist.



FIGURE 41-1. A nodule on the FHL tendon causing triggering of the hallux.

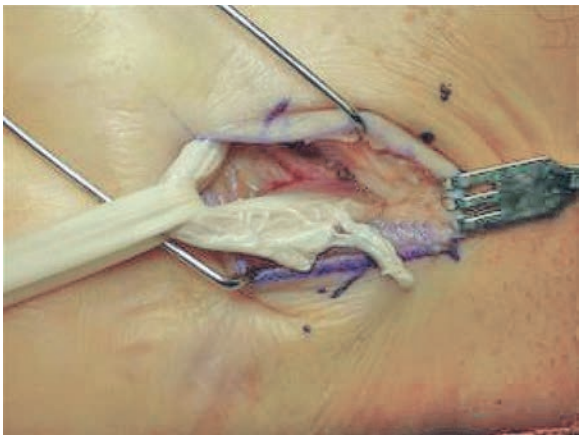

FIGURE 41-2. A serious tear of the FHL with shredding of the tendon.



FIGURE 41-3. Posterior impingement on an os trigonum.

Extrinsic Factors

- Toe shoes and pointe work contribute to the injury, although it can be found in male ballet dancers and even modern dancers who usually dance barefooted.
- It is a common "overuse" injury in this group of performers.
- It is rare in athletes but can occasionally be seen in pronated runners along with the "jogger's foot" (tendonitis at Henry's knot).
- It can occur in athletes such as place kickers in American football.
- The author has removed the os trigonum of a place kicker of an NFL professional football team.
- Hard floors, fatigue, and poor technique ("rolling in," or pronating) can contribute to this injury.
- It is frequently misdiagnosed as posterior tibial tendinitis, which is relatively common in athletes but rare in dancers.

Traumatic Factors

- This is rarely an acute injury. It is almost always caused by overuse.
- Forced plantarflexion in the presence of an *os trigonum* or *trigonal process* is usually the cause of posterior impingement.
- Posterior impingement can be associated with fractures of the posterior process ("Shepherd's fracture") (Figure 41-4).

Classic Pathological Findings

- FHL tendonosis results in chronic swelling and inflammation in the tendon as it enters or passes through the fibroosseous tunnel on the medial side of the os calcis.
- The swelling can cause ganglion-like cystic formation behind the ankle.



FIGURE 41-4. Fracture of the posterior process—"Shepherd's fracture."

- Posterior impingement causes inflammation, fractures, cystic changes, and occasionally displacement of the os trigonum (Figure 41-5).

Clinical Presentation

History

- The pain is usually activity related and relieved by rest.
- FHL tendonitis presents as posterior *medial* ankle pain without a history of trauma.
- Posterior impingement usually causes posterior *lateral* pain and may have a definite onset. It is exacerbated by plantarflexion such as pushoff in running and relevé in ballet (going up in a toe raise).
- The symptoms are frequently mistaken for strains of the Achilles or posterior tibial tendons.

Physical Examination

Abnormal Findings

- Localized pain and swelling behind the ankle over the FHL tunnel medially or over the os trigonum posterior laterally, or both
- Increased pain with plantarflexion, especially when forced—the positive "plantarflexion sign." It is only



FIGURE 41-5. Displacement of the os trigonum when the ankle is plantarflexed.



FIGURE 41-6. The "plantarflexion sign" for posterior impingement.

positive for posterior impingement, not for FHL tendonitis. This sign differentiates posterior impingement from all other causes of posterior ankle pain (Figure 41-6).
- Pain in FHL tunnel with active and passive motion of the first MP joint
- Triggering of the Hallux may be present.
- Tenderness over the FHL tunnel behind and below the medial malleolus
- Range of motion of the ankle may be reduced because of pain.

Pertinent Normal Findings

- No ecchymosis
- No effusion within the ankle joint
- No pain with dorsiflexion
- No loss of subtalar motion
- The "drawer sign" for ankle ligament will be negative.
- There is usually no peroneal tendon weakness.
- Examination of the posterior tibial tendon and Achilles tendon is normal.

Imaging

- Lateral radiographs taken in foot flat and in forced plantarflexion on in full toe raise will help diagnose posterior impingement but will not show FHL tendonitis.
- Sonography will reveal swelling of the FHL tendon.
- An MRI study will show the swollen FHL tendon and fluid within the sheath and tunnel surrounding it. This fluid may extend upward to the posterior ankle area and can be mistaken for joint fluid (Figure 41-7).
- Imaging studies do not always pick up tears, partial tear, and rents in the tendon.
- Often a sonogram will show these better than an MRI.
- A bone scan will be negative for FHL tendonitis but positive for posterior impingement.

Differential Diagnosis

- An osteochondritis dissecans lesion of the posterior talar dome
- Early arthritis or degeneration of the posterior facet of the subtalar joint
- A fibrous middle facet tarsal coalition
- Posterior tibial or Achilles tendinitis or strain

Treatment

Nonoperative Management

- Relative rest—"don't do what hurts" and antiinflammatory medications
- Physical therapy modalities such as phonophoresis, iontophoresis, and acupuncture
- Technique correction if this is a contributing factor
- If the symptoms warrant it, immobilization of the ankle and first metatarsophalangeal joint in a walking boot along with antiinflammatories
- If these fail, then a sonographic guided corticosteroid injection into the FHL sheath (but NOT into the tendon itself) or the os trigonum, if posterior impingement is present

Guidelines for Choosing Among Nonoperative Treatments

- It is important to know which of the three syndromes is present: FHL tendinitis, posterior impingement, or both. This can be difficult to determine.
- The diagnosis may require diagnostic injections of local anesthetics.
- Immobilization in a walking boot treats both conditions.

Surgical Indications

- Failure to respond to conservative therapy
- Symptoms severe enough to warrant surgical intervention
- Surgery should NOT be performed in the absence of discomfort simply to increase the plantarflexion in the ankle by removal of the os trigonum. The results will be disappointing in these cases.



FIGURE 41-7. An MRI study of acute FHL tendonitis showing fluid within the sheath extending upward behind the ankle.

- A diagnosed tear in, or rupture of, the FHL should be surgically decompressed and repaired.

Aspects of History, Demographics, or Exam Findings that Affect Choice of Treatment

- Posterior impingement can be treated by removal of the os trigonum or trigonal process either by a small posterolateral incision or by endoscopic excision.
- The open technique has a lower complication rate but a longer postop recovery.
- The author prefers the open technique for tenolysis and debridement or repair of the FHL because the posterior tibial nerve can be identified and protected with the medial approach and the os trigonum can also be removed at the same time.
- The author's results have been better in professional ballet dancers than in amateurs.

Aspects of Clinical Decision Making When Surgery Is Indicated

- Which of the two syndromes is present, or are both present?
- Are you going to do this endoscopically or open?
- In the open technique, posterior impingement alone can be corrected through a lateral incision, but FHL tendonitis or a combination of FHL tendonitis and posterior impingement should be approached through a medial incision so that the posterior tibial nerve can be protected.

Evidence

Hamilton WG: Stenosing tenosynovitis of the flexor hallucis longus tendon and posterior impingement upon the os trigonum in ballet dancers. *Foot Ankle* 3(2):74–80, 1982.

The earliest report of these syndromes in dancers.

Hamilton WG: Posterior ankle pain in dancers. *Clin Sports Med* 27(2):263–277, 2008.

Differential diagnosis and treatment of FHL tendonitis and posterior impingement in professional level dancers. (Level V evidence)

Hamilton WG, Geppert MJ, Thompson FM: Pain in the posterior aspect of the ankle in dancers. Differential diagnosis and operative treatment. *J Bone Joint Surg Am* 78(10):1491–1500, 1996.

A retrospective review was performed of the results of operative treatment of stenosing tenosynovitis of the flexor hallucis longus tendon or posterior impingement syndrome, or both, in 37 dancers (41 operations). The average duration of follow-up was 7 years. Twenty-six operations were performed for tendinitis and posterior impingement; nine, for isolated tendinitis; and six, for isolated posterior impingement syndrome. A medial incision was used in 33 procedures; a lateral incision, in six; an anterior and a medial incision, in one; and a lateral and a medial incision, in one. Thirty ankles had a good or excellent result; six, a fair result; and four, a poor result. The result was good or excellent for 28 of the 34 ankles in professional dancers, compared with only two of the six ankles in amateur dancers. This is still the definitive article on the subject. The results were better in the professional dancers than the amateurs. (Level IV evidence)

Kolettis GJ, Micheli L: Release of the flexor hallucis longus tendon in ballet dancers. *J Bone Joint Surg Am* 78(9):1386–1390, 1996.

Thirteen female ballet dancers had an operative release of the flexor hallucis longus tendon because of isolated stenosing tenosynovitis, and the results were reviewed after a mean duration of follow-up of 6 years. All of the patients danced at the advanced or professional level, and all had failed to respond to nonoperative management. Symptoms, which included pain and tenderness over the medial aspect of the subtalar joint, were exacerbated by jumping and by attempts to perform en pointe work. Crepitus was present in six patients, and triggering was present in three. No patient had evidence of a symptomatic os trigonum. Postoperatively, all patients participated in a formal physical-therapy program for a mean of nine weeks. All patients returned to dancing, within a mean of 5 months. Eight patients were professional ballet dancers, four were students at advanced ballet schools, and one had stopped performing ballet for reasons unrelated to the tenosynovitis of the flexor hallucis longus. No complications were noted in this series. We concluded that an operative release of the flexor hallucis longus is effective for the treatment of isolated stenosing tenosynovitis in female ballet dancers who place high demands on the foot and ankle and for whom non-operative treatment has failed. (Level IV evidence)

Niek van Dijk C: Anterior and posterior ankle impingement. *Foot Ankle Clin* 11(3):663–683, 2006.

Anterior ankle impingement is characterized by anterior ankle pain on activity. Recurrent (hyper) dorsiflexion is often the cause. Arthroscopic management with removal of the offending tissue provides good to excellent long-term results. In posterior ankle impingement, patients experience hindfoot pain when the ankle is forcedly plantarflexed. Trauma or overuse can be the cause. The trauma mechanism is hyperplantarflexion, Overuse injuries typically occur in ballet dancers and downhill runners, who report pain on palpation at the posterolateral aspect of the talus. On plain radiographs, an os trigonum or hypertrophic posterior or talar process can be detected. Surgical management involves removal of the os trigonum, scar tissue, or hypertrophic posterior talar process. In the case of combined posterior bony impingement and flexor hallucis longus tendinopathy, a release of the flexor hallucis longus is performed simultaneously. Endoscopic management is associated with a low morbidity, a short recovery time, and provides good/excellent results at 2 to 5 years follow-up in 80% of patient. This is a good paper discussing endoscopic treatment. (Level V evidence)

Sammarco GJ: Partial rupture of the flexor hallucis longus tendon in classical ballet dancers: two case reports. *J Bone Joint Surg Am* 61(1):149–150, 1979.

(Level IV evidence)

Sammarco GJ: Flexor hallucis longus injury in dancers and non-dancers. *Foot Ankle Int* 19(6):356–362, 1998.

Thirty-one cases of flexor hallucis longus injuries in 26 patients were treated over a 16-year period (1977-1993). Groups were divided into dance-related injuries (group I) and other causes (group II). The two groups were compared with regard to age, activity, duration of symptoms, operative findings, histopathology, and postoperative time to resumption of full activities. Twenty-seven cases required surgery for unsuccessful nonoperative treatment. In group I, 71% of patients had a partial longitudinal tear of the flexor hallucis longus compared with 30% in group II. Another common finding was isolated tenosynovitis (21% in group I and 53% in group II). Eight cases had magnetic resonance imaging

(MRI) evaluations before surgery. Clinical correlation was found to be an important factor in interpreting the MRI. Dancers tended to have symptoms for a longer period of time before seeking treatment than did non-dancers. Surgical correction of tenosynovitis, pseudocysts, and tendon tear yielded good or excellent results in 14 of 15 dancers and 9 of 11 nondancers. Surgical treatment of tendon tears and other pathologic tendon conditions gave consistently good results in patients with refractory flexor hallucis longus disease. This study noted a 71% incidence of longitudinal tears in the dancer group versus 30% in the nondancers. Good results were obtained in both groups. (Level IV evidence)

Multiple-Choice Questions

QUESTION 1. The "plantarflexion sign" will be positive for

A. FHL tendonitis only.
B. posterior impingement only.
C. Both conditions
D. Neither condition

QUESTION 2. Posterior impingement

A. is only seen in dancers.
B. is mostly seen in dancers.
C. is never seen in athletes.
D. usually accompanies FHL tendonitis.

QUESTION 3. Posterior impingement can lead to FHL tendonitis.

A. True
B. False

QUESTION 4. A documented partial tear in the FHL is best approached

A. through a lateral incision.
B. through a medial incision.
C. endoscopically.
D. Any of the above

Answer Key

QUESTION 1. Correct answer: **B** (see Abnormal Findings)

QUESTION 2. Correct answer: **B** (see Pathophysiology)

QUESTION 3. Correct answer: **B** (see Pathophysiology)

QUESTION 4. Correct answer: **B** (see Aspects of Clinical Decision Making)

BEYOND BASIC REHABILITATION: RETURN TO BALLET AFTER TREATMENT FOR FLEXOR HALLUCIS LONGUS TENDINOPATHY AND POSTERIOR IMPINGEMENT

William G. Hamilton, BSE, MD, AAOS, AOA, FACS, Marika Molnar, PT, LAc, and Nadia Sefcovic, DPT, COMT

ASPECTS OF BALLET THAT REQUIRE SPECIAL ATTENTION IN REHABILITATION

Unlike any other sport, the rules of the game are never the same in dance.

- Dancers are required to perform their art at the extremes of range, making return to activity challenging. Extreme plantar flexion (PF) of the ankle/foot complex is necessary so that the dancer can balance on the tips of the toes as well as be able to fully dorsiflex the hallux while in plantar flexion at the ankle in order to balance or push off from there.[1,2] Ankle dorsiflexion (DF) is essential for landing from big jumps, lunging, preparation for all turns, etc.
- The dancer must also regain strength and proprioception of the ankle/foot complex in these extreme ranges of motion. Acceleration, deceleration, and isometric holds are required.
- The dancer must be able to maintain strength, stability, and flexibility at the lumbopelvic and hip joints and the entire lower extremity in order to meet the demands of the choreography. For example ballet dancers must have adequate neuromuscular control in hip external rotation (i.e., turnout).
- Dynamic strength and alignment control will be important as the dancer returns to the studio. The dancer must be able to move with varying speeds, in various body positions, in all planes of movement and in all directions.
- Special attention must be paid to the type of shoe the dancer must wear in order to return to dance (i,e., pointe shoes, ballet slippers, jazz/character shoes, barefoot, etc.). Dancing barefoot or in ballet slippers usually requires more hallux dorsiflexion than other forms of footwear.

Introduction

- Posterior ankle impingement (PAI) is caused by compression of the tissues between the posterior tibia, talus, and calcaneus, which occurs in extreme ranges of ankle plantar flexion that dancers require to achieve en pointe and demi-pointe positions.[2,3,4]
- Osseous or soft-tissue can be impinged in PAI. Causes of osseous impingement include an os trigum, Stieda's process, or anatomical variations in the posterior aspects of the tibia or calcaneous.[2,5] Soft tissue impingement causes can include various structures including: the capsule or synovium of the subtalar or talocrural joints; ligaments such as the posterior talofibular ligament, the posterior intermalleolar ligament, or the posterior tibiotalar ligament; or tendons such as the flexor hallucis longus (FHL) as it passes from the fibula, crossing the posterior talus, and running through the fibroosseous tunnel.[2,3,5]
- Repetitive plantar flexion required of dancers can also cause FHL tendinopathy. Dancers can develop irritation and swelling of the tendon or the tendon's sheath.[5] This irritation to the tendon and sheath causes pain and limited motion as the musculotendinous unit hypertrophies.[6] The dancer will have resultant tendon and muscular weakness secondary to pain and disuse of the muscle. As this becomes a chronic condition the tendon can develop adhesions, calcifications, and nodules at the musculotendinous junction as part of the degenerative process.[7]
- Flexor hallucis longus injury is very common in dancers, both male and female. Most dance movements require the use of the FHL as the foot and ankle go through plantar and dorsiflexion thousands of times per day. When the foot is in plantarflexion, the FHL functions as a stabilizer[8] and eccentrically it restrains dorsiflexion at the first metatarsophalangeal joint as well as eccentrically controlling calcaneal eversion.[7] As the dancer is landing a jump or in grand plié, the FHL is stretched between the posterior talar tubercles and the sustentaculum tali.[7]
- Flexor halluces longus tendinopathy and posterior ankle impingement are separate injuries, but often they occur in combination.[6]
- Posterior impingement pain is usually posterolateral to the ankle joint;[3] pain, tenderness or swelling posterior to the medial malleolus is experienced with FHL tendinopathies. The dancer also can experience triggering of the toe or crepitus of the FHL tendon, which can be palpated at the tendon sheath when the dancer moves their hallux.[6,7]
- Although posterior impingement and FHL tendinosis are seen in both genders, these injuries seem to be more problematic for females and pointe dancers.[3] Female dancers who are on the professional track will usually have their os trigonum removed as it interferes with their ability to go up onto pointe. Once the surgical site is healed the rehabilitation follows the same course as outlined if it was a simple bony removal.
- A common precursor to posterior ankle impingement is ankle instability resulting from an ankle sprain.[2,9,10] If a lateral ankle sprain precedes these injuries it usually takes longer to rehabilitate owing to laxity in the ligaments, which then allows for excessive anterior displacement of the talus. This excessive motion will need to be controlled to provide more boney stability. Often when there is boney instability and ligamentous laxity, this will lead to muscle overactivity that can lead to tendinopathies.[11] Stability of the ankle as well as proprioception must be addressed in the dancer's rehabilitation in addition to addressing the stability role of the FHL in the medial longitudinal arch and great toe.[7,12,13]
- Generally if these injuries are treated appropriately with a conservative physical therapy program including sufficient relative rest and appropriate exercises, all usually return to dance.[4,5,6]
- If conservative therapy does not return the dancer to full function, surgical repair of tendon or removal of extra bone or scar tissue in the posterior ankle may be necessary;[6] the dancer can usually return to full participation once all rehabilitation criteria have been met.

Phase I (Weeks 1 to 2): Advanced Strength and Conditioning Programs

Periodization

- Linear

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- Appropriate alignment for dance technique is immediately integrated into phase I of the protocol, and done so in a limited weight-bearing position so the patient can focus on proprioception and neuromuscular reeducation during the exercises.
- During this phase the dancer is in a relative rest period. This means that the dancer will not participate in dance class, but will begin to focus on proper dance technique and alignment in physical therapy.
- FHL is eccentrically strengthened with dance-specific movements, but done so in a low-load situation to ensure proper dance technique and motor control training.

Training Continuum

See Box 41-1 for definitions of the dance-specific terminology used throughout this discussion. Additional definitions of ballet terminology may be found at http://www.abt.org/education/dictionary/index.html.

- Flexibility/joint mobility for joint stability
  - Active range of motion (AROM): non–weight-bearing wall program (Figure 41-8) including toe/ankle dissociation during PF and DF, doming, relevé
  - Soft tissue mobility: FHL release at proximal end, effleurage of posterior talocrural joint (TCJ) with dancer in prone, transverse friction massage to FHL if appropriate
  - Joint mobilization: posterior TCJ mobilization Gr II-IV, subtalar joint (STJ) inversion/eversion mobilization

  - Joint: If needed: first ray mobilization into PF, first metatarsophalangeal joint (MTPJ) into extension, distal and proximal tibia/fibula joint mobilization, tibia/femoral joint mobilizations
  - Taping to prevent all hallux joints from flexing during ankle PF (Figure 41-9)
  - Mobility of FLH tendon to slide in tunnel—gentle PROM of FHL in various ankle positions
  - If history of ankle sprain is present with posterior ankle impingement—ankle taping and ankle stabilization program and peroneal and tibialis posterior muscle strengthening
- Training with optimum posture
  - Alignment above and below site of injury
- Sensorimotor and balance training
  - Single limb stance (SLS) with eyes open and using port de bras, ensuring toes don't flex at interphalangeal joints (IPJs) (Figure 41-10)
  - SLS with eyes closed
- Core training
  - Supine: local and global muscle recruitment and strengthening progressing to standing abdominal stabilization (Figure 41-11)
- Cardiorespiratory/cross- training
  - Bike, swim, elliptical, Pilates, yoga
- Multiplanar training activities
- Training for optimum muscle balance
  - Pointing OKC: use of gastrocnemius/soleus as well as posterior tibialis and FHL/peroneus longus sling to PF ankle and flexor halluces brevis to flex first MTPJ, but not allowing the IPJ to flex
- Training for optimum muscle functional strength
  - OKC and CKC hip ER strengthening and gluteus medius strengthening
  - Eccentric FHL strengthening lower from full pointe rolling through demi-pointe to demi-plié. Initially done with feet on the wall, then progress to sitting (Figure 41-12).

TIMELINE 41-1: **Rehabilitation of Flexor Hallucis Longus Tendinopathy and Posterior Impingement**

PHASE I (Weeks 1 to 2)	PHASE II (Weeks 3 to 7)	PHASE III (Weeks 7 to 12)
• PT modalities to decrease inflammation and pain • AROM—wk 1: ankle and toe dissociation of DF & PF—on the wall • AROM—wk 1: foot intrinsic strengthening of DF & PF—on the wall • PROM FHL in various ankle positions • Mobilizations as needed • Single limb stance (SLS) eyes open and using port de bras • SLS eyes closed • Eccentric FHL strengthening—wk 1: on the wall • Eccentric FHL strengthening—wk 2: sitting • Neuromuscular reeducation exercises • OKC and CKC gluteus medius exercises • Gastroc & soleus flexibility • Gait training	• AROM: ankle and toe dissociation of DF & PF—wk 3—seated • AROM: CKC DF (pliés)—wk 3—on the reformer • Flexibility—FHL stretching—wk 3–7 • Eccentric FHL strengthening: Double leg elevé—wk 3– seated • Intrinsic foot strengthening: Doming—wk 3—seated • Eccentric FHL strengthening: Lowering from full pointe to demi-pointe—wk 3 standing • AROM: CKC DF (pliés)—wk 4—standing • Intrinsic foot strengthening: Doming—wk 4—standing • Eccentric FHL strengthening: Double leg relevé & elevé—wk 4—on reformer • Neuromuscular re-education: OCK ankle and toe dissociation of PF (tendus)—wk 4—standing • AROM: Single leg CKC DF (fondu)—wk 5—on the reformer • Eccentric FHL strengthening: Relevé & elevé, ascend on two legs, descend on affected leg in parallel—wk 5—on reformer • AROM: Single leg CKC DF (fondu)—wk 6—standing • Eccentric FHL strengthening: Single leg relevé & elevé—wk 6—on reformer • Eccentric FHL strengthening—wk 7: double leg relevé & elevé in standing in parallel and turn-out • Plyometrics: Simulate push-off and deceleration of landing a jump performed in a lunge position—wk 7—standing lunge • Proprioception & balance—progressing to uneven surfaces—wk 3–7 • Hip ER OCK & CKC PREs—wk 3–7 • Gait training—wk 3–7 • Mobilizations as needed—wk 3–7 • PT modalities as needed—wk 3–7	• PT modalities as needed • Mobilizations as needed • AROM—full weight-bearing ankle PF (90° for a ballet dancer) with hallux ext (90° for a ballet dancer) • Relevés & elevés—wk 7: double leg parallel & turn-out—standing • Relevés & elevés—wk 8: ascend on two legs, descend on affected leg parallel & turn-out—standing • Relevés & elevés—wk 9: single leg parallel and turn-out—standing • Dance specific—wk 10: turning technique • Plyometrics—wk 10: progressing from double leg to single leg—on reformer • Plyometrics—wk 11: progressing from double leg to one leg to the other—standing • Plyometrics—wk 12: progressing to single leg—standing • Proprioception & Balance—in CKC PF • Gait training

BOX 41-1 Glossary of Dance Terminology

TERM	DEFINITION
allegro	Rapid tempo movements, often includes jumping steps. Petit allegro includes smaller jumping steps. Grand allegro includes large expansive jumps such as grand jeté.
barre	The introductory/warmup portion of the ballet class, conducted while holding onto a ballet bar. The dancer always starts with the left hand at the bar, working the right gesture leg.
beats	To hit the legs together, moving in and out of fifth position in the air. See petite batterie.
center floor	The second portion of the ballet class, comprised of the adagio, turns, and small jumps (petit allegro)
dégagé	"To disengage." Sharp brushes of the pointed foot to develop speed and precision of the feet and legs.
demi	Half. As in demi-plié
dèveloppé	A large, relatively slow leg gesture. The gesture limb begins from first or fifth position, passes through passé, to extend at 90° or higher to the front (en avant), side (a la seconde), or back (en arrière—arabesque).
elevé	A rise upward onto the toes
frappé	Beginning from the cou-de-pied position, a rapid striking ricochet (off the floor) of the gesture foot, ending in a pointed position. Develops strength and precision of the gesture limb
grand	Large
grand battement	A large, swift leg "kick" with the knee extended and foot pointed. Performed to the front, side, or back and from first, fifth, or the point tondu.
penché	Inclined. Usually arabesque penché, in which the torso and gesture limb are tilted forward from the hip. This directs the torso and focus toward the floor.
petite	Small, little
plié	A bend of the knees while the torso is held upright. The action relies on varying degrees of hip and knee flexion, with ankle and MTP dorsiflexion, depending on whether the plié is demi- or grand.
pointe, en	On pointe. Position of the foot in a pointe (or toe) shoe, in which the dancer stands on the toes
port-de-bras	Carriage of the arms. The codified arm positions that provide strength and balance to the trunk, and may also serve as gesture or enhancement of focus.
relevé	A rise or spring onto the toes (demi- or full pointe) from plié.
ronde de jambe	A unilateral leg action in which the gesture leg is circled from front to back of the dancer's body, or vice versa. May be performed on the ground (a terre) or in the air (en l'aire).
tendu	A "stretched" action of the gesturing limb from a stance position with flat foot to a pointed foot, with the toes keeping contact with the floor

Compiled by the Practice Committee, Performing Arts Special Interest Group, Orthopaedic Section, APTA, January, 1998. (http://www.orthopt.org/downloads/PAglossary.pdf)

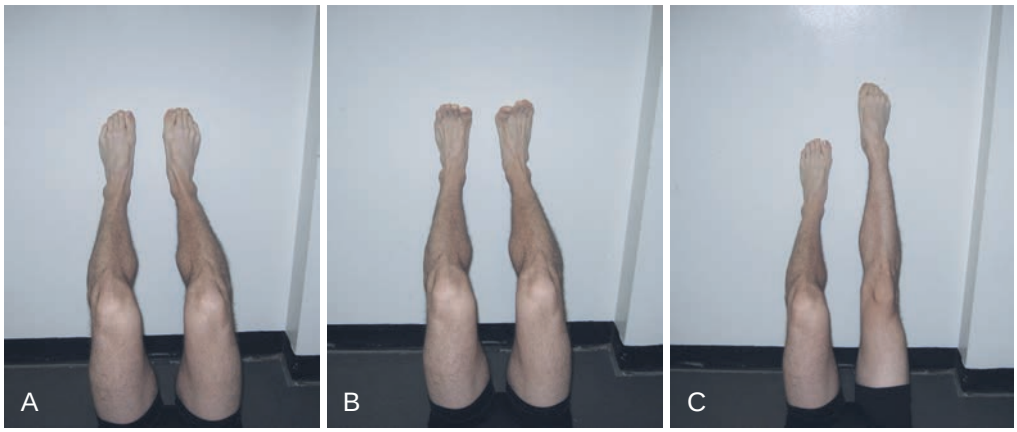

FIGURE 41-8. Non–weight-bearing wall program: doming. **A,** Right foot doming; ankle dorsiflexion, MTP joint plantar flexion. In the supine position he is able to keep correct alignment of his lower leg as he learns to use his intrinsic. **B,** Toe extension. **C,** Plantar flexion at ankle with MTP joint plantarflexing (doming).



.(**FIGURE 41-9.** Taping to prevent IP flexion (mainly proprioceptive feedback



FIGURE 41-10. Single-leg port de bras. **A,** Moving the arms through ballet arm positions. **B,** Single leg without gripping toes. **C,** Single leg gripping IP joints, a poor strategy.

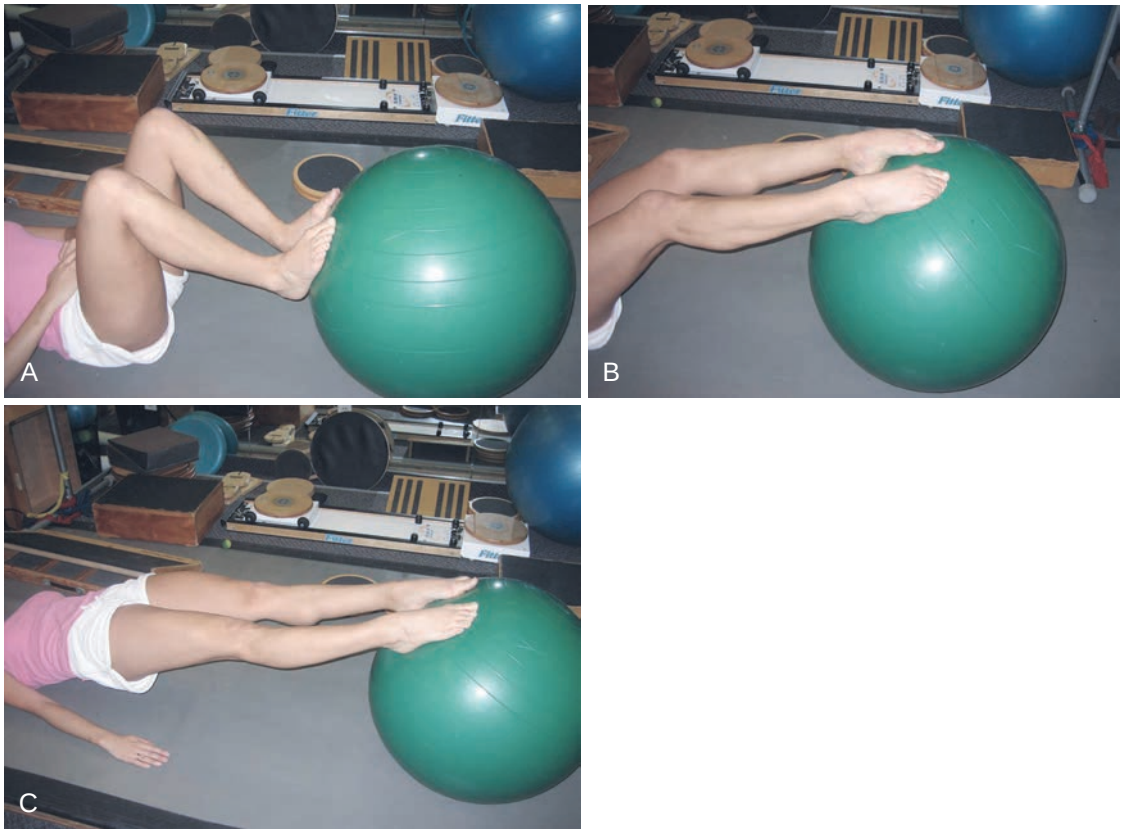

FIGURE 41-11. Local and global muscle recruitment. **A,** Starting position in full dorsiflexion at ankle. **B,** Full plantar flexion at ankle and MTP joints. **C,** Strengthening local and global muscle groups.

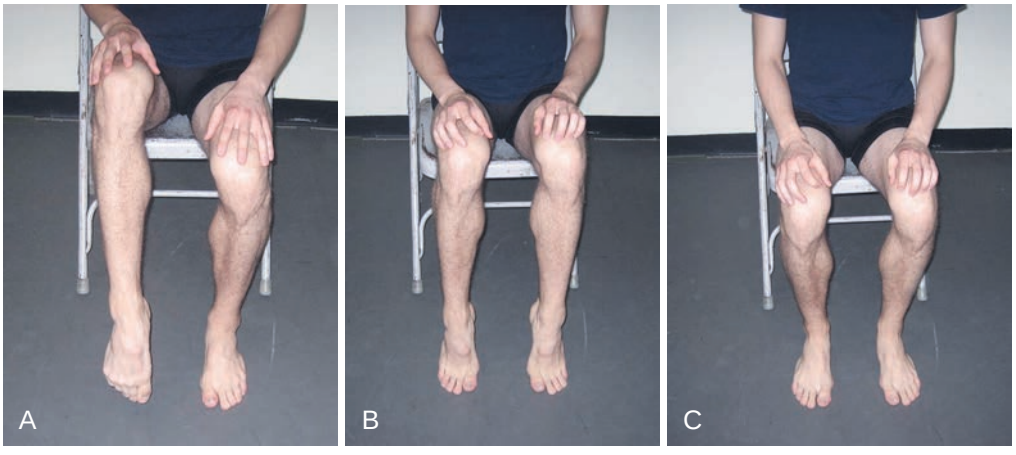

FIGURE 41-12. Eccentric FHL strengthening while sitting. **A,** Eccentric rolling through FHL from full plantar flexion. **B,** Full plantar flexion at

- Neuromuscular dynamic stability exercises
  - Main focus is reeducation for PF without gripping toes (flexing the MTPJs and IPJs) and implementing foot intrinsic strengthening program initiating on the wall and progressing to sitting by end of second week
    - Isolating PF at the TCJ joint (tendu on the wall) (see Figure 41-8C)
    - PF at the ankle, MTPJ flexion, not allowing IPJ to flex
    - Dome foot and slide into tendu
    - Tendu to ball of foot then dome
    - Pointe, roll through to ball of the foot, roll through to demi-plié (not allowing IPJs to flex)
- Functional training
  - Gait reeducation

Training Principles Used in the Design of the Program

- Principle of progression

Application of Acute Training Variables

- Repetitions: 10 to 15
- Sets: 3
- Rest interval: 10 seconds between each set
- Intensity: low to moderate intensity
- Repetition tempo: slow; this phase focuses on motor control and neuromuscular reeducation; often when dancers increase their tempo they return to poor technique habits that contribute to FHL tendinosis and irritation of posterior ankle joint.
- Training frequency: daily, alternating cross-training with cardio; and other exercises specific to injury rehab daily × 3
- Training duration: 10 min per set
- Specific exercises used in the training: as above

Phase II (Weeks 3 to 7): Performance Enhancement Training Techniques

Periodization

- Linear

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- Appropriate alignment for dance technique, especially ballet barre, is integrated into phase II of the protocol, and done so initially in a limited weight-bearing position (a flat ballet barre can be integrated initially, meaning NO relevé activities); then progressing to relevés on a Pilates reformer and finally standing (Figure 41-13).

This is done so the patient can focus on proprioception and neuromuscular reeducation during the exercises while functionally strengthening FHL eccentrically.

Training Continuum

- Flexibility/joint mobility for joint stability
  - ROM: OKC and CKC PF to DF (without flexing IPJs) starting in seated position PWB before moving into WB: on ball or reformer
  - Joint: posterior TCJ mobilization Gr IV-V, STJ inversion/eversion mobilization (Figure 41-14)
    - Joint: If needed, first ray mobilization into PF, first MTPJ into extension, proximal fibula/tibia, tibia/femoral

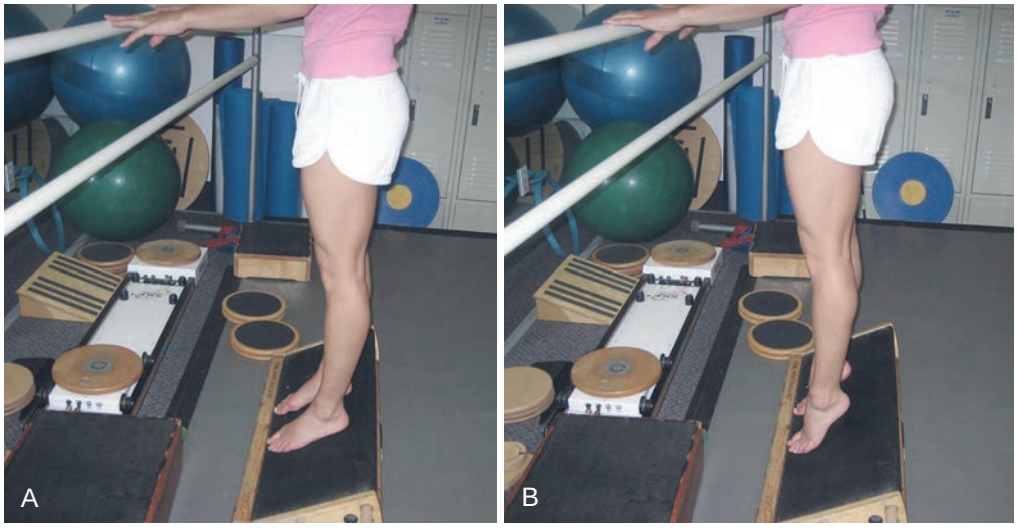

FIGURE 41-13. A, Strengthening at end range. **B,** Standing, end range strengthening.

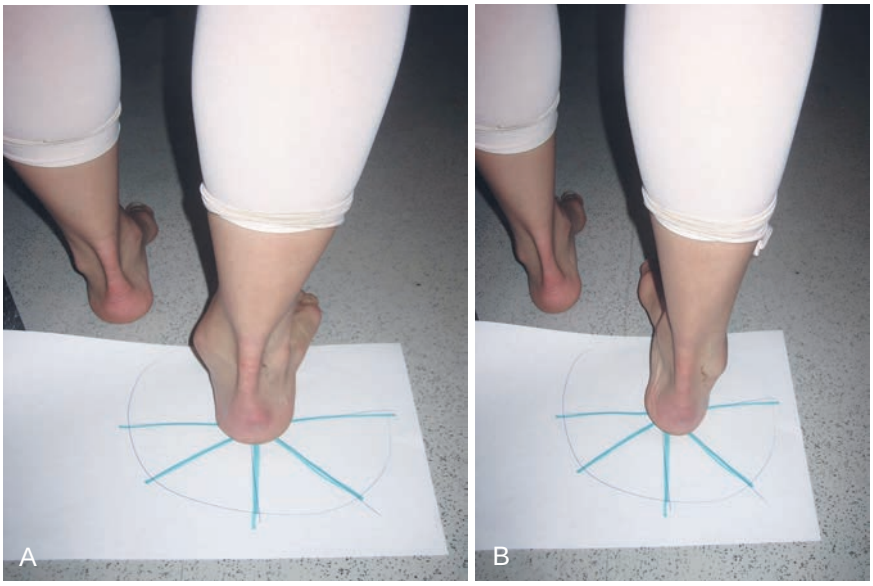

FIGURE 41-14. Heel clocks for mobilization of subtalar joint. **A,** Eversion. **B,** Inversion.

  - Soft tissue mobility: FHL, possibly gastrocnemius/soleus, transverse friction massage (if appropriate); dancer should contract/relax FHL during friction
  - Flexibility of FLH—stretch FHL: Stand with the hallux extended against a wall and the ball of the foot on the floor, dorsiflex the ankle. Hold stretch for 30 seconds (Figure 41-15).
  - If history of ankle sprain is present with posterior ankle impingement—ankle taping and ankle stabilization program and peroneal and tibialis posterior muscle strengthening
- Training with optimum posture
  - Dynamic posture of lumbopelvic girdle during movements of hip and lower extremity
- Sensorimotor and balance training
  - On uneven surfaces with opposite lower extremity performing dance specific movement (e.g., frappe)
  - On double leg relevé by end of phase (Figure 41-16)
- Core training
  - Weight bearing Pilates, etc.
  - Plank
- Cardiorespiratory training
  - Bike, swim, elliptical
  - Step-up at quicker pace, increase by adding port de bras
- Multiplanar training activities
  - Initiate plié, elevé, relevé activities on reformer in turn-out
  - Initiate tendu and OKC PF in turn-out
- Training for optimum muscle balance
  - Standing dome
  - Dome and DF ankle (in sitting and progress to standing and plié)
- Training for optimum muscle functional strength
  - Reformer
    - Relevé progression (double leg, then progress to up on two-down on one, then progress to single leg) (Figure 41-17)
      - Note: It is easier to work in pointe shoes than in flat ballet slippers because it lessens rolling through the foot.
    - Elevé progression (double leg, then progress to up on two-down on one, then progress to single leg)

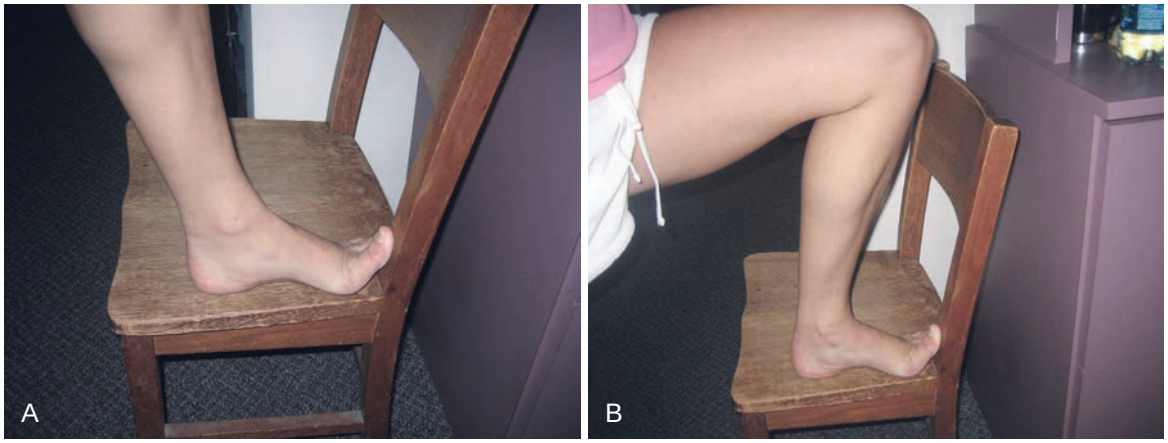

FIGURE 41-15. Improving FHL flexibility. **A,** Stand with the hallux extended against a wall or firm surface and the ball of the foot on the floor. **B,** Dorsiflex the ankle. Hold stretch for 30 seconds.

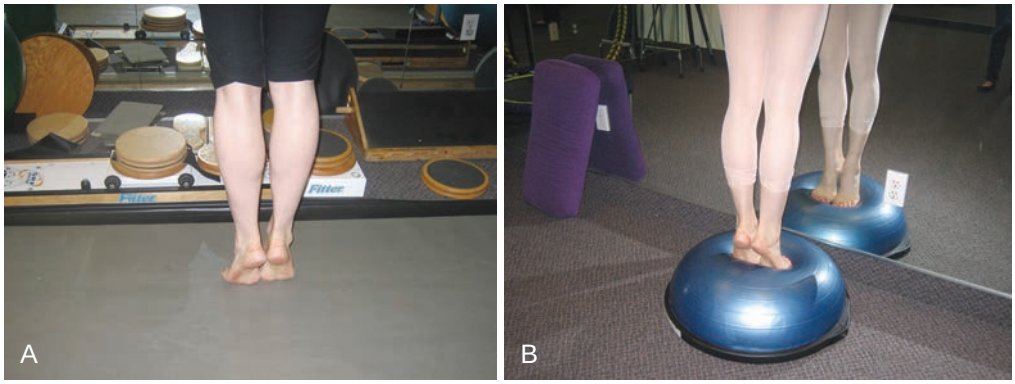

FIGURE 41-16. Reformer training. **A,** Double leg in pointe shoes. **B,** Single leg in pointe shoes.

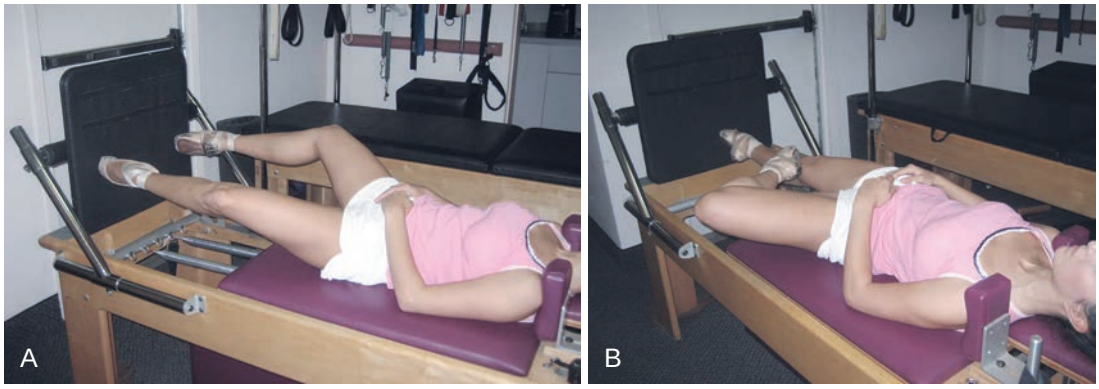

FIGURE 41-17. Double-leg relevé. **A,** Parallel. **B,** On uneven surface.

- FHL: Eccentric FHL strengthening lower from full pointe rolling through demi-pointe to demi-plié. Standing on right leg, go to full pointe on the left foot, rolling through demi-pointe to demi-plié. Repeat on other side in parallel and turned out (Figure 41-18).
- Training for optimum muscle functional power
- Neuromuscular dynamic stability exercises
  - Lunge exercise training push-off and deceleration control
  - Single leg pliés with correct alignment
- OKC and CKC hip ER strengthening and gluteus medius strengthening
- Training for speed, agility, quickness: vary the speed and timing of exercises
- Plyometric training
  - Lunge exercise training push-off and deceleration control
- Functional training: Begin basic barre in parallel and turn-out (Figure 41-19).
  - Initially this will include a flat ballet barre, (see activities in sport-specific training) the dancer will not perform grand pliés, relevés, or elevés. Gradually add in double leg demi-pointe activities (grand plié, relevé, and elevé) into barre. By the end of this phase, the dancer can progress to a ballet barre including leg demi-pointe activities as long as relevé and elevé activities are pain free.
- Sport-specific training
  - Flat barre—no relevé or elevé: slow tempo to start progressing to moderate
  - Demi-plié
  - Tendu (Figure 41-20)
  - Dégagé
  - Frappé
  - Rond de jambe
  - Dèveloppé (Figure 41-21)
  - Battement
- Additional types
  - Gait

Training Principles Used in the Design of the Program

- Principle of progression

Application of Acute TraIning Variables

- Repetitions: 8 to 10
- Sets: 3
- Rest interval: 10 seconds
- Intensity: moderate
- Repetition tempo
- Training frequency: daily
- Training duration: 30 to 45 minutes per set
- Training volume
- Specific exercises used in the training

Phase III (Weeks 7 to 12): Sport-Specific Training

Periodization

- Linear

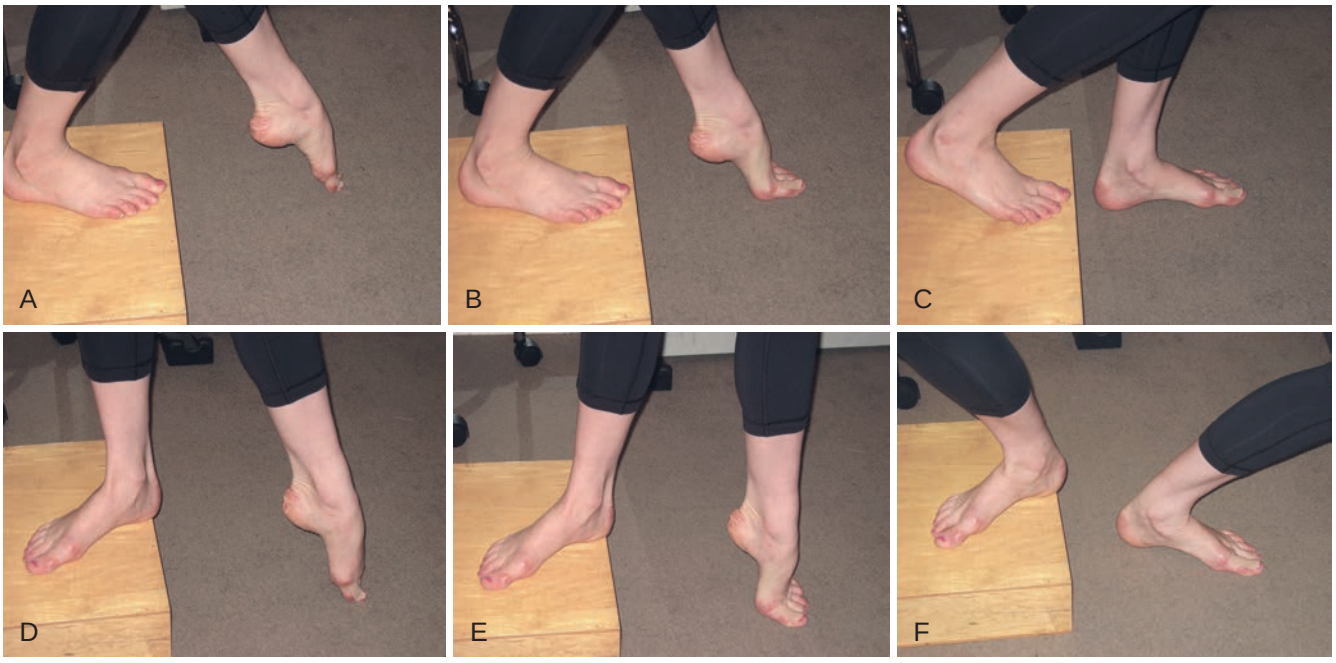

FIGURE 41-18. Eccentric FHL strengthening lower from full pointe rolling through demi-pointe to demi-plié. **A,** Standing, full weight bearing load: Eccentric FHL to retrain deceleration in parallel. **B,** Standing Eccentric FHL strengthening. **C,** Eccentric FHL strengthening. **D,** Eccentric load FHL—Turned out deceleration sequence. **E,** Eccentric load FHL-turned out deceleration sequence. **F,** Eccentric load FHL—turned out deceleration sequence.

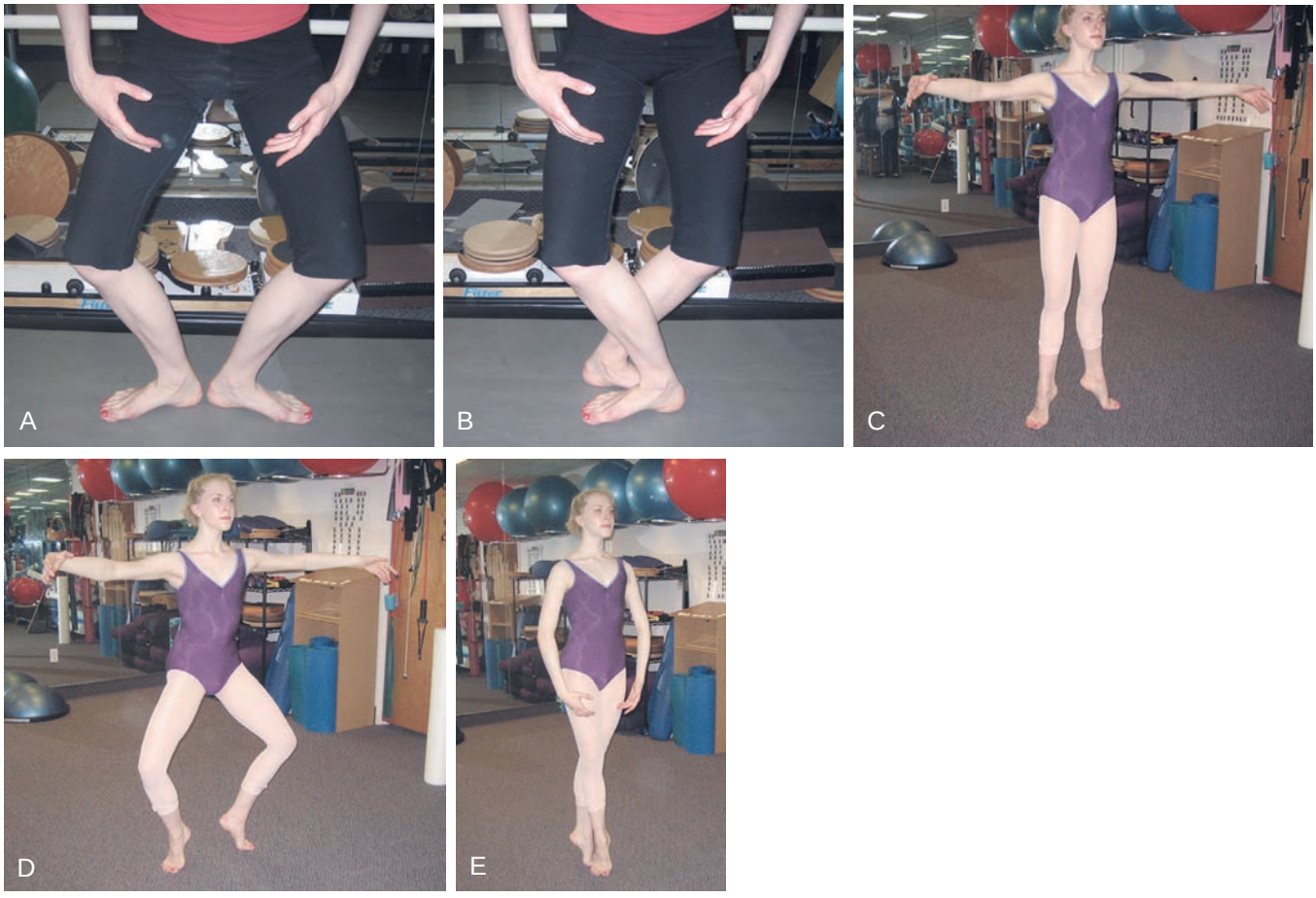

FIGURE 41-19. Functional training. Initially, flat barre. **A,** First position plié. **B,** Fifth position plié. **C,** Progress to relevé work on two feet: first position. **D,** First position with bent knees (more challenging). **E.** Fifth position relevé.



FIGURE 41-20. Flat barre tendu. **A,** Front. **B,** Side. **C,** Back.

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- Dance technique is integrated during phase III by progressing from ballet barre into center. The continued focus is on proprioception and neuromuscular reeducation during more dynamic exercises to ensure appropriate functional use of the foot and ankle musculature while in full weight bearing.

Training Continuum

- Flexibility/joint mobility for joint stability
  - ROM—Full weight bearing ankle PF with hallux extension
  - Joint: Posterior TCJ mobilization Gr IV-V, STJ inversion mobilization
    - Joint: If needed, first ray mobilization into PF, first MTPJ into extension, proximal fibula/tibia, tibia/femoral
  - Soft tissue mobility: FHL, possibly gastrocnemius/soleus
    - If history of ankle sprain is present with posterior ankle impingement—ankle taping and ankle stabilization program and peroneal and tibialis posterior muscle strengthening
- Training with optimum posture
- Sensorimotor and balance training[6]
  - On uneven surfaces with gross movement such as penché (Figure 41-22)
  - Medial/lateral ankle stability on half foam roller
  - On single leg elevé by end of phase
- Core training
  - Weight bearing
  - Plank
- Cardiorespiratory training
  - Bike, swim, elliptical
  - Step-up at quicker pace increase by adding port de bras
- Multiplanar training activities
  - Initiate center dance activities moving in and out of different planes
- Training for optimum muscle balance
- Training for optimum muscle functional strength



FIGURE 41-21. Dèveloppé in center.

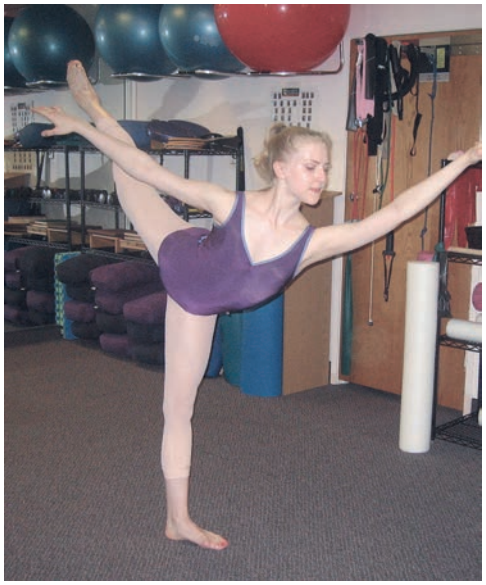

FIGURE 41-22. Penche arabesque.

  - Standing
    - Elevé progression without the support of the ballet barre (double leg, then progress to up on two-down on one, then progress to single leg)
    - Relevé progression without the support of the ballet barre (double leg, then progress to up on two-down on one, then progress to single leg)
- Training for optimum muscle functional power
  - Concentric and eccentric use of FHL while performing jumps on the Pilates reformer. Initiate with double leg jumps, then progress to jumping off one foot and landing on two feet, next progress to jumping off one foot and landing on the other, then jumping off and landing on the same foot, finally progressing to jumping off two feet and landing on one foot. Jumps should be practiced in parallel as well as turn-out.
- Neuromuscular dynamic stability exercises
  - CKC PF with hallux extension
  - FHL eccentric control landing jumps on reformer
  - Pointe work at ballet barre
- Training for speed, agility, quickness
  - Initiate faster PF activities.
  - Add petite allegro.
- Plyometric training
  - Initiate on reformer or in a pool.
    - Initiate with double leg jumps, then progress to jumping off one foot and landing on two feet; next progress to jumping off one foot and landing on the other, then jumping off and landing on the same foot, finally progressing to jumping off two feet and landing on one foot. Jumps should be practiced in parallel as well as turn-out.
  - Progress the above to full weight bearing
  - Add speed component
  - Add height and complexity—beats, revolutions, etc.
- Functional training
  - Focus on foot pushing off and landing, especially to control deceleration.
  - Focus on eccentric control of FHL in a pointe shoe.
- Sport-specific training
  - Progress from barre in flat shoes to barre en pointe.
  - Add class through adagio.
  - Then progress to add turns in class.
  - Then progress to add jumps in class.
- Additional types
  - Gait

Training Principles Used in the Design of the Program

- Principle of progression
- Principle of overload
- Principles of specificity—specific adaptation to imposed demands

Application of Acute Training Variables

- Repetitions—increased reps for endurance
- Sets 3 to 5
- Rest interval none
- Intensity low to high
- Repetition tempo—faster paced
- Training frequency daily
- Training duration 1 to 2 hours/day
- Training volume
- Specific exercises used in the training: ballet technique

Sports Performance Testing

General Information

- General history
  - What are your symptoms?
    - Location of pain
    - Type of pain
    - How does your pain react to rest?
  - Onset of symptoms?
    - When? Is it a chronic or acute problem?
    - Cause? Insidious, or increase in dance load?
  - What increases symptoms?
  - What decreases symptoms?
  - How do your symptoms change throughout the course of the day?
  - How do your symptoms change throughout the course of a dance class?
  - What are the dancer's goals?
- Subjective questionnaires (Figure 41-23)
  - Visual analog pain scale
  - Menstruation history
- Medical history
  - History injuries
  - Medications, vitamins, supplements, drug use
  - Have you ever been hospitalized?
  - Are you seeking treatment for an ongoing medical condition?
  - Benign joint hypermobility syndrome
  - Anomalies
- Sports injury history
  - Is there a history of ankle sprains?
  - History of tendinitis and/or tendinosis
  - Have you had an x-ray on pointe or demi-pointe that reveals an os trigonum or a form of osseous posterior ankle impingement?
- Surgical history
  - Have you had an os trigonum removed in your other ankle?
- Chronic conditions/medication
  - Asthma
  - Diabetes
  - Any conditions requiring chronic use of steroids

Objective Tests

- Physiological assessments
  - AROM
    - DF, PF, open kinetic chain & closed kinetic chain
    - Hallux extension—open kinetic chain and functional hallux ROM in weight bearing
    - Thomasen test[14]
      - A positive Thomasen sign occurs when extension of the first MTPJ is normal when the ankle is plantarflexed, but disappears when the ankle is dorsiflexed (as in a grande plié in first position). It is caused by muscle fibers on the FHL

Age you began dancing: _____ Type of dance you do: _____

Age you began pointe work: _____

Formal dance training: School: _____ Number of years: _____

School: _____ Number of years: _____

Present dance training and number of classes/week: _____

_____

Are you performing now? _____ Name of company: _____

Type of shoes worn: _____ Type of floor surface you dance on: _____

Number of years you have been dancing as a professional: _____

Major injuries or illnesses throughout your career:

DATE	TYPE OF INJURY	WHOM SEEN	COURSE OF TREATMENT	RECOVERY

Special Questions for Women

1. At what age did you start menstruating? _____

2. Are your cycles regular? _____ Explain: _____

3. Are the symptoms of your *current injury* associated with your menstrual cycle either around the 14th day (ovulation) or at the onset of menses? _____

4. Do you notice a change in flexibility at either of these times? _____

5. Circle any premenstrual symptoms: Water retention Mood swings Headaches Food cravings Tender breasts Other _____

6. What type of birth control do you use? _____

7. Number of pregnancies: _____ Vaginal births: _____ Ceasarean births: _____

Episeotomy: _____ Numbness in pelvic area: _____

Problems related to pregnancy: _____

8. Do you currently experience leakage of urine? _____ If yes, circle when it occurs: Jumping coughing Sneezing Laughing During intercourse When putting key in door

9. Do you have any pelvic pain? ____ If yes, what activity brings it on? _____

10. Have you had any of the following (circle)? Retroverted uterus Fibroids/tumors Endometriosis Overian cyst Pelvic inflammatory disease Osteopenia Osteoporosis Diabetes

11. Have you gone through menopause (Y/N) or perimenopause (Y/N)?

12. Are you taking any medications, herbs or supplements for hormone replacement? _____ If yes, list them: _____

FIGURE 41-23. Subjective questionnaire for dancers and those with dance injuries.

tendon that attach abnormally far down and impinge on the entrance of the FHL tunnel. It is often found in dancers who are asymptomatic, so it is NOT a pathological sign, but more of an anatomical anomaly. It may be found in association with FHL tendinopathy.

- Special Tests
  - Tinnel's test at tarsal tunnel
  - Hyper plantar flexion test[15]
  - Palpation: Tenderness: posterior-lateral ankle with an os trigonum or posteromedial ankle (tarsal tunnel area) with FHL tendinopathy[15]
  - Swelling: posterior TCJ
  - Thickness: lateral tubercle of the posterior talar process
  - Crepitis: FHL at tarsal tunnel
  - Trigger toe
  - Warmth: posterior TCJ

- Strength
  - Manual muscle test foot intrinsics and extrinsics
- Cyriax selective tissue tension test, especially to rule out posterior tibialis tendinopathy. This assesses AROM, PROM, resistive tests, and palpation. The ROM tests the patient's willingness to move, the available AROM, and the muscular power available. Resistive movements can assess the status of the contractile structures around the joint. PROM test noncontractile structures. Palpation is performed to detect any deformity or inflammatory signs, including warmth or swelling.
- Anterior and posterior draw
  - If positive perform specific ligament tests
- Talar swing test (Pettman course notes).
- Joint glides
  - Foot and ankle as well as proximal fibula/tibia and tibia/femur

- Body composition tests
- Static/dynamic postural assessments
  - Qualitative standing postural assessment
    - Examples:
      - Does the dancer have genu recurvatum?
      - Is the dancer able to stand and walk in parallel or does she/he have excess toe out while walking and in a static stance?
      - Is there noticeable intrinsic foot muscle atrophy?
      - Is the muscle bulk in the gastrocnemius and soleus equal side to side?
      - What foot type does the dancer have (Grecian, pheasant, etc.)?
      - Is the dancer's foot pes planus or pes cavus?
- Dynamic muscle performance testing
  - Resist FHL in full ankle PF with hallux fully extended (relevé position) lowering to CKC DF (demi-plié)
- Movement performance testing
  - Double leg relevé/plié
  - Single leg relevé
  - Single leg plié
  - Jumps
- Sport-specific testing
  - Technique assessment of
    - Relevé
    - Plié
    - Tendu
    - Jumps
- Others
  - Pointe shoe assessment

Specific Criteria for Progression to the Next Stage to Determine Readiness for Ballet

- Phase I
  - Pain is decreased
  - Full open kinetic chain ankle AROM DF & PF pain free
  - FHL manual muscle test is pain free
  - Able to ambulate and roll through foot without pain
- Phase II
  - Manual muscle test of FHL is 5/5 without pain
  - Able to tolerate 20 single leg relevés on reformer without pain
  - Able to tolerate full ballet barre without pain
- Phase III
  - Full weight-bearing PF—25 repetitions without pain
  - 50 repetitions of tendu without pain
  - 25 single leg jumps without pain

Specific Criteria for Release to Unsupervised Complete Participation in Ballet

- Return to full class, and if no exacerbation then dancer is able to return to rehearsal or performance

Recommended Ongoing Exercises

- Intrinsic foot exercise progression
  - Doming for the lumbricals: Initiate in sitting or with feet on the wall (note that if the dancer cannot perform toe flexion at the MTPJs while keeping the IPJs in neutral, a towel roll can be placed under the heel to help facilitate the exercise). This should be progressed to standing on two feet. Then finally to standing on one leg.
  - Abductor hallucis: Initiate with place/hold isometric contractions in sitting by passively moving the hallux into abduction and have the dancer isometrically hold the contraction for 3 to 5 seconds. Progress to AROM of great toe abduction in sitting; do not let the dancer substitute with the extensor hallucis longus. Next, the dancer can resist hallux abduction with the resistance of a small rubber band. Finally, the dancer will need to functionally progress AROM hallux abduction to a standing position.[16]
  - Dorsal & plantar interossei: Initiate in sitting or with feet on the wall. The dancer will squeeze and spread the toes without letting the toe IPJs flex. This can be progressed to standing on two feet, then standing on one foot.
  - Flexor hallucis brevis and flexor digitorum brevis: Initiate with seated doming, then progress to long sitting. Have the dancer long sit and the ankle in plantar flexion; extend the MTPJs while keeping the IPJs in neutral (no flexion). Next, progress to using the resistance of a Thera-Band while performing the aforementioned exercise.
  - Standing balance done barefoot. Initiate with single leg stance with eyes open, progress to eyes closed, then to uneven surfaces. To add more challenge, the dancer can do cervical rotation; upper extremity movement, such as port de bra; or lower extremity movement of the gesture leg, such as frappé or dèveloppé.

Evidence

Albisetti W, Ometti M, Pascale V, et al: Clinical evaluation and treatment of posterior impingement in dancers. *Am J Phys Med Rehabil* 88:349–354, 2009.

Nine out of twelve dancers with posterior ankle impingement in this study responded well to conservative PT to retrain the deep muscles of the foot to plantar flex the midfoot to decrease the amount of impingement occurring at the rear foot. (Level IV evidence)

Cook J, Purdam R: Is tendon pathology a continuum? A pathology model to explain the clinical presentation of load-induced tendinopathy. *Br J Sports Med* 43:409–416, 2009.

"Early tendon disrepair should be treated with load management and reduction in frequency and intensity of tendon loading. Degenerative tendinopathy treatments should stimulate cell activity, increase protein production (collagen or ground substance) and restructure the matrix are appropriate for this stage of tendinopathy." These treatments include: exercise with eccentric component, extracorporeal shock wave therapy, frictions, and ultrasound. (Level V evidence)

Cook J, Purdam R: Rehabilitation of lower limb tendinopathies. *Clin Sports Med* 22:777–789, 2003.

"Sporting participation does not guarantee intact function, as athletes are quick to develop strategies to unload painful structures. This can lead to specific unloading patterns within the kinetic chain, or can cause a general unloading pattern of the entire limb. They may consequently develop weakness in and around the symptomatic musculotendinous unit. Primary unloading is best identified by deficits in calf power and endurance, reduced capacity to squat, and loss of pelvic control."

"Biomechanical evaluation is an essential part of the clinical assessment and treatment of lower limb tendinopathies, even if there is little evidence to support this intervention. Management of this facet is designed to improve limb shock absorption or unload stressed structures."

"Improving shock absorption includes both increasing musculotendinous control of the antigravity units and increasing joint range. The ankle is the most important joint to treat, as range is easily compromised with injury and degeneration. The range of dorsiflexion is critical for Achilles [19] and patellar tendinopathy, as it allows greater range and lower rate of shock absorption in landing. Improving the range of motion of the stiff or cavus foot with mobilization or orthotics may also increase shock absorption."

"Complete tendon rehabilitation must be progressive and logical, with realistic time frames for each level. Each level will contain some eccentric contractions. The program should begin with a strength bias, progress to a power program, and finish with sport-specific load on the tendon." (Level V evidence)

Kulig K, Reischl SF, Pomrantz A, et al: Nonsurgical management of posterior tibial tendon dysfunction with orthoses and resistive exercise: A randomized controlled trial. *Phys Ther* 89(1):26–37, 2009.

In a randomized control trial examining treatment of posterior tibial tendon dysfunction, the group that used orthoses wear, stretching, and eccentric progressive resistive exercise demonstrated the most improvement in each subcategory (VAS, 5-minute walk test, and Foot Functional Index), when compared to other groups (orthoses wear, and concentric strengthening program along with orthoses wear). (Level II evidence)

Molnar M, Bornstein R, Hartog M, et al: Dance medicine: Strategies for the prevention and care of injuries to dancers. Foot and ankle injuries in the dancer: Examination and treatment strategies. Orthopaedic Section American Physical Therapy Association. *Independent Study Course* 18.3.5:18–19, 2008.

Expert clinical knowledge demonstrates that muscle imbalances can contribute to joint restrictions at the proximal fibula/tibia joint that warrant joint mobilizations. Clinical experts recommend taping to reduce excess load on the FHL tendon during pedestrian activities such as walking. (Level V evidence)

Pettman E: *North American Institute of Manual Therapy course manual 610—Intermediate Lower Quadrant*. Berrien Springs, MI, 2009, Lecture at Andrews University.

Talar swing test is used to determine if the talocrural joint is restricted in a posterior glide. If the joint glide is restricted, the test continues to help determine if the joint is restricted because of tight gastrocnemius, capsular tightness, or an intraarticular joint restriction, such as a loose body. (Level V Evidence)

Rees J, Wilson A, Wolman R: Current concepts in the management of tendon disorders. *Rheumatology* 45:508–521, 2006.

There are several manual therapies popular in the treatment of tendon disorders, the two most common being friction massage and soft tissue mobilization. These two are used often clinically, but there is not strong evidence in literature although it is cited that is can reduce pain. Except for eccentric training, physical therapies, strength deficits, inflexibility, and improper equipment had not been studied in a controlled and prospective manner with regard to tendon disorders. (Level III evidence)

Simpson M, Howard T: Tendinopathies of the foot and ankle. *Am Fam Physician* 80(10):1107–1114, 2009.

"A history of functional ankle instability may be present and directly related to the impingement syndrome initiation. Functional instability, as described by Maffulli and Ferran, consists of impaired proprioception, neuromuscular control deficits, postural control difficulty, and strength deficits." (Level III evidence)

Sussmilch-Leitch S, Collins N, Bialocerkowski A, et al: Physical therapies for Achilles tendinopathy: Systematic review and meta-analysis. *J Foot Ankle Res* 5:15, 2012.

"Systematic review of physical therapies for Achilles tendinopathy to perform meta-analyses and evaluate the methodological quality of included studies. Findings from individual randomized control trials support the use of eccentric exercise in the management of Achilles tendinopathy, with pooled data suggesting additional benefits using laser therapy as an adjunct intervention, and similar outcomes when shock wave therapy is utilized as an alternative to eccentric exercise."

"Sufficient evidence is lacking to enable recommendation of night splints and heel braces as a management option for Achilles tendinopathy." (Level II evidence)

Tan S, Chan O: Achilles and patellar tendinopathy: Current understanding of pathophysiology and management. *Disabil Rehabil* 30(20–22):1608–1615, 2008.

Twelve-week eccentric loading programs have shown favorable results in multiple studies both at the physiological level as well as the functional level of an athlete. (Level III evidence)

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16. Jung DY, Kim MH, Koh EK, et al: A comparison in the muscle activity of the abductor hallucis and the medial longitudinal arch angle during toe curl and short foot exercises. *Phys Ther Sport* 12: 30–35, 2011.

Multiple-Choice Questions

QUESTION 1. Where will a dancer have pain when presenting with FHL tendinosis?

A. Lateral ankle
B. Medial ankle
C. Anterior ankle
D. Lateral toes

QUESTION 2. In the first phase of rehabilitation of FHL tendinosis and ankle impingement what should the dancer be doing in dance class?

A. Full class including pointe work
B. Full class except pointe work
C. Flat ballet barre
D. No dancing

QUESTION 3. What ROM is most painful and limited when presenting with FHL tendinosis and ankle impingement?

A. Plantar flexion
B. Dorsiflexion
C. Forefoot abduction (winging)
D. Forefoot adduction (sickling)

QUESTION 4. What pathologies should be ruled out when diagnosing a patient with FHL tendinosis and ankle impingement?

A. Posterior tibialis tendinopathy
B. Achilles tendinopathy
C. Tarsal tunnel syndrome
D. All of the above

QUESTION 5. When is the dancer allowed to return to rehearsal?

A. Any time the artistic director says so
B. When a full class can be completed without exacerbation
C. When the dancer can jump on one leg 25 times
D. When the dancer has full strength and good alignment

Answer Key

QUESTION 1. Correct answer: **B**. (see Introduction)

QUESTION 2. Correct answer: **D** (see Program Design/ Performance Training Program of Phase I)

QUESTION 3. Correct answer: **A** (see Introduction)

QUESTION 4. Correct answer: **D** (see sports performance testing)

QUESTION 5. Correct answer: **B** (see criteria to release to full participation

Chapter 42



Plantar Fasciitis

INTRODUCTION

Charles Christopher Stroud, MD, Erick Fountain, MPT, OMPT, and Mike Pollzzie, PT, DPT, OMPT, CSCS

Epidemiology

- Ten percent of the US population presents with heel pain at some point in their lives.
- Age: 83% are between 25 and 65 years old. Peak incidence is between 40 and 60 years old. Older athletes are more susceptible.
- Sex: Studies differ on whether there is a male or female preponderance.
- Sport: Athletes who engage in running and sports with a significant amount of impact/jumping have an increased prevalence of this condition.

Pathophysiology

Intrinsic Factors

- Increased BMI (greater than 30 kg/m^2)
- Increasing age: for example, degenerative process of plantar fascia
- Reduced ankle dorsiflexion
- Pes planus or pes cavus foot posture (both foot types have been described as associated with plantar fasciitis)
- Seronegative spondyloarthropathies

Extrinsic Factors

- Increases in training program/intensity; for example, rapid increase in weight-bearing activities
- Training errors; for example, inappropriate running technique
- Prolonged walking on hard surfaces
- Inappropriate shoes; for example, stiff, thin heel and midsole
- Increased weight-bearing activities

Traumatic Factors

- Sudden forcible load on plantar fascia (forced ankle dorsiflexion while performing pushoff maneuver) may lead to plantar fascial/disruption or injury
- Repetitive impact

Classic Pathological Findings

- Myxoid degeneration/microtears in the fascia/collagen necrosis/angiofibroblastic hyperplasia
- Thickening of plantar fascia origin (Figure 42-1)

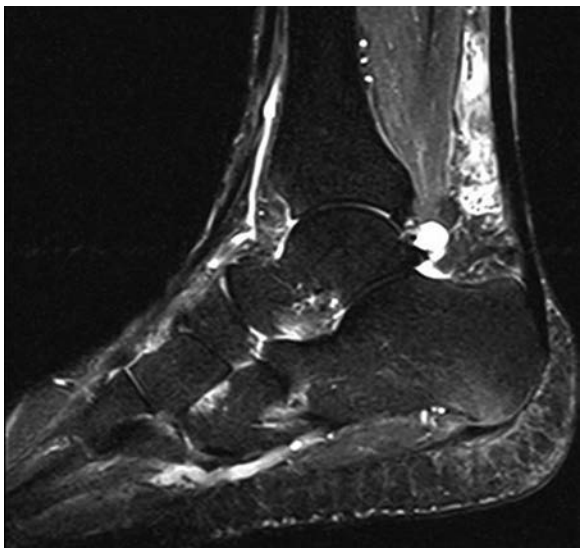

FIGURE 42-1. Sagittal T_2 MRI sequence showing the thickened insertion of the plantar fascia and mild bone marrow edema at the insertion.



FIGURE 42-2. Photograph showing the location of tenderness about the inferomedial aspect of the heel in a patient with plantar fasciitis.

Clinical Presentation

History

- Gradual onset of inferior heel pain described as a sharp stab/walking on a marble or hot poker
- Worse with first steps in morning/loosens up with walking/worse with prolonged standing/walking and toward the end of the day

Physical Examination

Abnormal Findings

- Tenderness at origin of plantar fascia (Figure 42-2)
- Contracted Achilles tendon (Figure 42-3)
- May have coexistent tenderness about the first branch of the lateral plantar nerve (Figure 42-4)
- Antalgic gait may be present.



FIGURE 42-3. Photograph demonstrating a contracted Achilles tendon. This photograph shows the Achilles tendon unable to be passively dorsiflexed to a neutral position with the knee bent.



FIGURE 42-4. Photograph showing a patient with tenderness about the first branch of the lateral plantar nerve (i.e., Baxter's nerve).

Pertinent Normal Findings

- Patient foot type may be either pes planus or pes cavus
- Lack of swelling/tenderness about the remainder of the foot

Imaging

- Imaging tests not needed in the initial workup of this condition
- If plain radiographs obtained, the presence of a calcaneal traction spur (heel spur) may or may not be present and is not the cause of this condition
- Radiographs are obtained for recalcitrant cases to rule out a calcaneal stress fracture or tumor
- Bone scan may reveal uptake at origin of plantar fascia (Figure 42-5)
- Ultrasound, if obtained, shows a thickened, hypoechoic area at the plantar fascia insertion (Figure 42-6)
- MRI, if obtained, can show thickening/increased signal about the origin of the plantar fascia (see Figure 42-1)

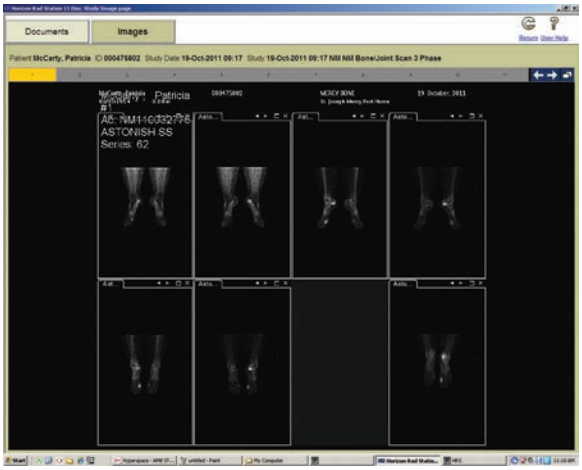

FIGURE 42-5. Bone scan showing uptake at the origin of the left plantar fascia in a patient with symptomatology.

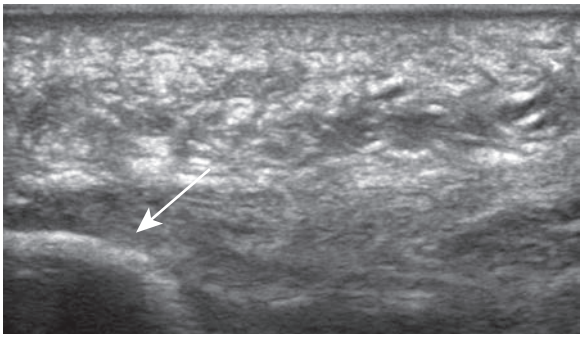

FIGURE 42-6. Ultrasound image showing a thickened hypoechoic area (*arrow*) at the origin of the plantar fascia in a patient with symptomology.

Differential Diagnosis

- Achilles tendinopathy: tenderness about the insertion of the Achilles tendon. The examiner may note the presence of thickening at the insertion and/or palpation of calcifications.
- Calcaneal apophysitis: tenderness medial and laterally in a skeletally immature patient
- Calcaneal stress fracture: pain with side-to-side compression of the heel; diffuse swelling of the heel
- Plantar fibromatosis: single or multiple nodules palpated within the central cord of the plantar fascia
- Entrapment of the first branch of the lateral plantar nerve: neuritic symptoms throughout the day, tenderness about the medial/inferior heel, positive Tinel's sign/radiating pain with percussion of the nerve
- Tarsal tunnel syndrome: neuritic symptoms, tenderness along the course of the posterior tibial nerve, positive compression/percussion sign with reproduction of symptoms
- S1 radiculopathy: subjective heel pain with no localizable symptoms; presence of radiating back pain
- Peripheral neuropathy: more global pain, history of diabetic neuropathy, decreased sensation to 5.07 monofilament testing, no localizable symptoms
- Central fat pad atrophy: tenderness about plantar central heel with attenuation of fat pad

Treatment

Nonoperative Management

- NSAIDs: not well studied as an effective modality
- Orthoses/heel cups/Inserts: no difference in custom versus off-the-shelf inserts
- Physiotherapy: Achilles/plantar fascia stretches
- Night splint: conflicting results in literature but generally accepted as effective
- Casting/walking boots: subjective improvement but not well studied
- Extracorporeal shockwave treatment: has been shown to improve symptoms in recalcitrant cases
- Corticosteroid injections: can provide short-term relief. Efficacy has not been well studied.

Guidelines for Choosing Among Nonoperative Treatments

- If severely antalgic gait: begin with short course of boot brace immobilization. If nonantalgic gait, begin with Achilles and focused plantar fascia stretches
- If no improvement after a 6-week course, consider night splint
- If no improvement after a 6-week course, consider formal physical therapy
- If no improvement after a 6-week course, consider orthotics
- If no improvement after a 6-week course, consider injection
- If no improvement after a 6-week course, consider shockwave treatment

Surgical Indications

- Recalcitrant, ongoing, unrelenting pain that has failed to improve with conservative treatment, usually 6 to 12 months

Aspects of History, Demographics, or Exam Findings That Affect Choice of Treatment

- All patients, whether athletes or not, are treated in a similar fashion
- Conservative treatment has been shown to be effective in approximately 90% of patients

Aspects of Clinical Decision Making When Surgery Is Indicated

- Failure of prolonged course of nonsurgical treatment, usually 6 to 12 months

Evidence

Berlet GC: A prospective trial of night splinting in the treatment of recalcitrant plantar fasciitis: The Ankle Dorsiflexion Dynasplint. *Orthopedics* 25:1273–1275, 2002.

The use of a night splint was noted to provide relief in patients with plantar fasciitis. (Level IV evidence)

Crawford F, Atkins D, Edwards J: Interventions for treating plantar heel pain. *Cochrane Database Syst Rev* (3):CD000416, 2000.

Differing interventions for patient with plantar fasciitis are discussed. (Level V evidence)

Davies PF: Painful heel syndrome; results of nonoperative treatment. *Foot Ankle Int* 15:531–535, 1994.

The successful results of nonoperative treatment are reviewed and discussed. (Level IV evidence)

DiGiovanni BF, et al: Plantar fascia-specific stretching exercise improves outcomes in patients with chronic plantar fasciitis: A prospective clinical trial with two-year follow-up. *J Bone Joint Surg A* 88:1775–1781, 2006.

This prospective, randomized trial showed that 52% of patients' heel pain was eliminated or improved with a plantar fascia specific program at 8 weeks versus 22% in the Achilles stretching program alone. Two-year follow-up showed no difference between the two groups. (Level I evidence)

Donley BG, et al: The efficacy of oral nonsteroidal anti-inflammatory medication (NSAID) in the treatment of plantar fasciitis: A randomized, prospective, placebo-controlled study. *Foot Ankle Int* 28:20–23, 2007.

Pain and disability scores were compared between a group treated with an NSAID vs placebo. Improved pain relief was seen in the NSAID group, but no statistical difference was noted. (Level I evidence)

Landorf KB, et al: Effectiveness of foot orthoses to treat plantar fasciitis: A randomized trial. *Arch Intern Med* 166:1305–1310, 2006.

One hundred thirty-five patients were divided into three groups (sham orthosis, off-the-shelf orthosis, and custom orthotics) and efficacy noted. No difference at 12 months was noted among the three groups. (Level I evidence)

Lemont H, Ammirati KM, Usen N: Plantar fasciitis: A degenerative process (fasciosis) without inflammation. *J Am Podiatr Med Assoc* 93:234–237, 2003.

The pathological findings in the surgical specimens of patients with plantar fasciitis are reviewed. (Level V evidence)

Odgen JA: Electrohydraulic high-energy shock-wave treatment for chronic plantar fasciitis. *J Bone Joint Surg Am* 86:2216–2228, 2004.

Seventy-seven percent of patients with chronic plantar fasciitis treated with one or more treatments of high energy shock wave had good/excellent results. (Level IV evidence)

Pfeffer G, et al: Comparison of custom and prefabricated orthoses in the initial treatment of proximal plantar fasciitis. *Foot Ankle Int* 20:214–221, 1999.

A randomized trial of 236 patients treated with various shoe inserts with a control group noted improvement in heel pain with the use of prefabricated inserts. (Level I evidence)

Powell M, et al: Effective treatment of chronic plantar fasciitis with dorsiflexion night splints: A crossover prospective randomized outcome study. *Foot Ankle Int* 19:10–18, 1998.

A randomized trial of 37 patients found that a night splint was effective in patients with chronic plantar fasciitis at 1 year follow-up. (Level I evidence)

Probe RA: Night splint treatment for plantar fasciitis. A prospective randomized study. *Clin Orthop Relat Res* 368:190–195, 1999.

The use of a night splint was noted to provide relief in patients with plantar fasciitis. (Level I evidence)

Riddle DL, Pulisic M, Pidcoe P, et al: Risk factors for plantar fasciitis: A matched case-control study. *J Bone Joint Surg Am* 85(5):872–877, 2003.

Reduced ankle dorsiflexion, obesity and work-related weight-bearing are risk factors for developing plantar fasciitis. (Level II evidence)

Multiple Choice Questions

QUESTION 1. Which of the following is one of the strategic historical features in patients with plantar fasciitis?

A. Pain at rest
B. Radiating numbness into the arch
C. Pain with the first steps in the morning
D. A contracted Achilles tendon

QUESTION 2. Which of the following is one of the strategic physical exam findings in patients with plantar fasciitis?

A. Tenderness at the inferomedial aspect of the heel
B. A positive Tinel's sign over the plantar fascia origin
C. Swelling about the medial heel
D. A unilateral pes planus foot deformity

QUESTION 3. What are the histological findings noted in the surgical specimens in patients with plantar fasciitis?

A. Edema
B. Microfibrillar tearing
C. Tendon thickening
D. Myxoid degeneration
E. All of the above

QUESTION 4. Which of the following is not in the differential diagnoses in the patients who presents with heel pain?

A. Calcaneal stress fracture
B. Radiculopathy
C. Posterior ankle impingement
D. Tarsal tunnel syndrome

QUESTION 5. Which of the following is not one of the conservative treatment options in a patient with plantar fasciitis?

A. Boot brace immobilization
B. Sclerosing alcohol injections
C. Formal course of physiotherapy
D. Specific plantar fascia stretching exercises

Answer Key

QUESTION 1. Correct answer: **C** (see Clinical Presentation)

QUESTION 2. Correct answer: **A** (see Clinical Presentation)

QUESTION 3. Correct answer: **E** (see Pathophysiology)

QUESTION 4. Correct answer: **C** (see Differential Diagnosis)

QUESTION 5. Correct answer: **B** (see Treatment)

NONOPERATIVE REHABILITATION OF PLANTAR FASCIITIS

Charles Christopher Stroud, MD, Erick Fountain, MPT, OMPT, and Mike Pollzzie, PT, DPT, OMPT, CSCS

GUIDING PRINCIPLES OF NONOPERATIVE REHABILITATION

- Protected weight bearing until normal gait
- Pain reduction and restoration of motion
- Progressive strengthening and functional assessment
- Return to specific functional demands or sport-specific activity level

Phase I (weeks 0 to 2)

Protection

- If the patient has a continuous antalgic gait, a boot brace with or without crutches, depending on the level of pain, is supplied. If the gait is nonantalgic, no boot brace is needed.

Management of Pain and Swelling

- Ice and/or heat, NSAIDs taken as needed, protected weight bearing if necessary.

Techniques for Progressive Increase in Range of Motion

Stretching and Flexibility Techniques for the Musculotendinous Unit

- If the patient is in a boot, then gentle, progressive active range of motion of the knee, ankle and foot (out of boot) is performed. If no boot, than begin Achilles and plantar fascia specific stretches (Figure 42-7).

Other Therapeutic Exercises

- Patient can continue with general upper body workouts.
- Patient can continue with general core strengthening.
- Patient can continue with general hip/thigh exercises.

Activation of Primary Muscles Involved

- Patients should perform the preceding to the point that they "feel" the stretch and not pain.

Milestones for Progression to the Next Phase

- Achieve nonantalgic gait with or without protective walking boot.
- Discontinue crutches if used.
- Wean out of walking boot if used.



FIGURE 42-7. A, Stretch of the gastroc-soleus complex with a towel. **B,** Stretch of gastroc-soleus complex against a wall with foot pointed forward and knee straight (affected leg back). **C,** Stretch of gastroc-soleus complex against the wall with foot pointed forward and knee bent (affected leg is forward). **D,** Stretch of gastroc-soleus complex using a stair for a more aggressive stretch. **E,** Stretch of the plantar fascia. Note that the knee is bent and one arm is used for the stretch and the other finger is used to palpate the plantar fascia. Each stretch should be performed to a count of 10, three sets and three times per day.

Phase II (weeks 2 to 4)

Management of Pain and Swelling

- As-needed usage of NSAIDs
- The use of IFC, TENS unit, iontophoresis, contrast baths can be used if enrolled in formal physical therapy.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- If a formal physical therapy program is used, than talocrural/subtalar glide maneuvers and subtalar joint distraction can be used. Efficacy not well documented

Soft Tissue Techniques

- Deep soft tissue massage techniques can be used by the therapist, although their efficacy not well documented.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Specific weight-bearing and non–weight-bearing stretches of the gastroc-soleus complex and of the plantar fascia as noted in the preceding section (see Figure 42-7).

Other Therapeutic Exercises

- Continue with patients regular conditioning exercises
- Add an aggressive and progressive program of hip/core/thigh strengthening exercises; for example, step-ups and step downs, box touches, toe touches, forward/backward/side monster walks, bridge exercises, assisted to full body split squats (Figure 42-8).

Activation of Primary Muscles Involved

- Progressive motion/stretching of the gastroc-soleus complex and great/lesser toe dorsiflexors and plantar flexors. Four-way resistance band exercises of the ankle are used (Figure 42-9).

Sensorimotor Exercises

- Single/double leg balance exercises, progressing from even to uneven surfaces. These exercises can be performed with the use of a DynaDisc, BAPS board, or BOSU (Figure 42-10; see also Figure 42-19 in the next section).

Open and Closed Kinetic Chain Exercises

- CKC exercises (single/double leg split squat) are performed in the PT facility (Figure 42-11), whereas OKC (band exercises) are performed via a home exercise program.

Techniques to Increase Muscle Strength, Power, and Endurance

- The preceding exercises are performed progressing from lower to high repetitions while increasing load/resistance over ensuing weeks.

Neuromuscular Dynamic Stability Exercises

- Core ball exercises, single leg balance exercises, rotational exercises (Figure 42-12).

Milestones for Progression to the Next Phase

- Normal gait, no limp
- Normal knee/ankle range of motion
- Minimal pain with regular daily activities

Phase III (weeks 4 to 8)

Protection

- Orthotic usage can be considered at this point.
- Low-dye taping can be applied by the therapist to control pain and provide stability to the foot.

TIMELINE 42-1: **Nonoperative Rehabilitation of Plantar Fasciitis**

PHASE I (weeks 0 to 2)	PHASE II (weeks 2 to 4)

• Boot if patient limping
• PT modalities
• Goal is to wean out of boot and achieve normal gait
	• PT modalities
	• Talocrural/subtalar glide, subtalar joint distraction
	• Deep soft tissue massage
	• Gastroc-soleus stretches
	• Progressive core strengthening, including:
	  • Step-ups/step-downs
	  • Box touches, toe touches
	  • Monster walks
	  • Bridge exercises
	• Assisted split squats progressing to full body split squats
	• Four-way resistance band exercises for the ankle
	• Single/double leg balance exercises progressing from even to uneven surfaces
	• Add DynaDisc/BAPS board or BOSU
	• Core ball/single leg balance/rotational exercises

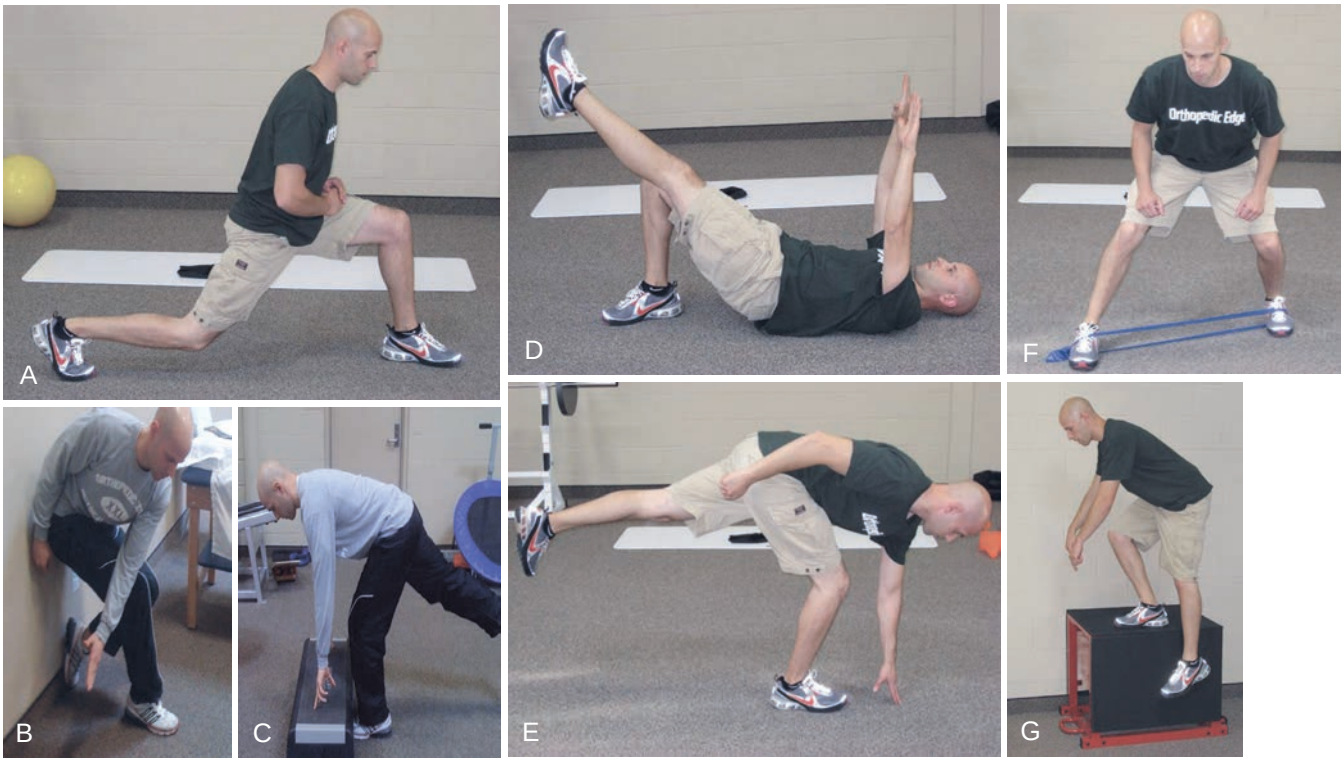

FIGURE 42-8. A, Split squat exercise. **B,** Assisted split squat crossover. **C,** Box touches. **D,** Bridge exercise. **E,** Toe touch. **F,** Monster walk with band. **G,** Step up/down.

Management of Pain and Swelling

- NSAIDs as needed

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- As in the preceding

Soft Tissue Techniques

- As in the preceding

Stretching and Flexibility Techniques for the Musculotendinous Unit

- As in the preceding
- Formal physical therapy, if not used previously, can be prescribed at this point.
- Also, the use of a night splint can also be considered at this point.

Other Therapeutic Exercises

- Progressively increasing the repetitions/load in the following exercises, as noted in previous section: step-ups/

TIMELINE 42-1: **Nonoperative Rehabilitation of Plantar Fasciitis** (Continued)

PHASE III (weeks 4 to 8)	PHASE IV (weeks 8 to 12)
• Orthotics/low dye taping • PT modalities as needed • Aggressive gastroc/plantar fascia stretches • Consider night splint • Triplanar foot/ankle proprioception exercises • Multidirectional slide board exercises • Slow hopping/gentle cutting • Agility ladder drills • Box jumps • Slow treadmill walking/jogging • Progress cardiovascular fitness • As above but increase repetitions/loading	• As above • Increase duration/frequency of impact/running time • By 3 months, should have athlete ready for regular routine



FIGURE 42-9. Four-way resistance exercises of the ankle using a band are demonstrated. Resisted eversion is noted here. Each exercise should be performed 10 times, three sets and two times per day.



FIGURE 42-10. Double leg balance exercise on the BOSU is shown.



FIGURE 42-11. Split squat exercise is shown.



FIGURE 42-12. Dynamic stability exercises (i.e., side reach with a weight).

step-downs, plank exercises, box touches, toe touches, forward/backward/side monster walks, bridge exercises

Activation of Primary Muscles Involved

- Continue stretches as noted in previous section. Single leg training continues: assisted split squats to full body weight.

Sensorimotor Exercises

- Single/double leg balance exercises continue as noted in previous section.
- Progress from an even to an uneven surface using a DynaDisc, BAPS board. and BOSU.
- Triplanar foot/ankle proprioceptive exercises, multidirectional slide board exercises used in both a static and dynamic way.

Open and Closed Kinetic Chain Exercises

- As in the preceding

Techniques to Increase Muscle Strength, Power, and Endurance

- Increased repetitions of strengthening exercises, calf raises

Plyometrics

- Begin slow hopping/gentle cutting/agility ladder drills/box jumps (Figure 42-13).

Functional Exercises

- Slow treadmill walking/jogging for limited time



FIGURE 42-13. Demonstrating double leg box jumps for plyometric exercises.

Sport-Specific Exercises

- Begin treadmill for runners/karaoke for team sports/elliptical for general cardiovascular fitness.

Milestones for Progression to the Next Phase

- Strength nearly equal to contralateral leg; for example, ability to perform
  - A single leg calf raise through at least 80% of ROM in weight bearing
  - A single leg squat on involved leg performed at 85% of total reps of uninvolved leg
  - A open chain manual muscle testing demonstrates 5/5 strength for quads, hams, and gastroc/soleus complex.
- The ROM for the calf raise is based on observation of the involved and uninvolved LE. The SL squat is performed first on the uninvolved LE, counting the max reps to failure and then reproduced on the involved LE.
- We are evaluating the patient's ability to perform selected movement tests compared with the healthy LE. There are several ways to measure and evaluate and these are just a few of most simple ways.
- Pain limited to end of workout.

Phase III (weeks 8 to 12)

Management of Pain and Swelling

- If the pain continues, the physician will consider the use of a one- or two-time corticosteroid injection around the origin of the plantar fascia.
- Approximately a 1-month interval should be allowed before a repeat injection is performed to allow for soft tissue healing.
- At the end of the 3-month period of treatment, if pain continues, the patient could consider shockwave treatment to the plantar fascia, if available.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- As in the preceding

Soft Tissue Techniques

- As in the preceding

Stretching and Flexibility Techniques for the Musculotendinous Unit

- As in the preceding and regular Achilles/plantar fascia stretches

Other Therapeutic Exercises

- As in the preceding

Activation of Primary Muscles Involved

- As in the preceding

Sensorimotor Exercises

- As in the preceding

Open and Closed Kinetic Chain Exercises

- As in the preceding

Techniques to Increase Muscle Strength, Power, and Endurance

- As in the preceding. The patient will perform single leg squats with rotational reach with subsequent hop; jumping activities; calf raises with maximal ankle dorsiflexion; step downs with opposite leg reach in all planes.

Neuromuscular Dynamic Stability Exercises

- As in the preceding

Plyometrics

- As in the preceding

Functional Exercises

- Begin increasing duration and/or frequency of impact/running time. Functional exercises when seen in the PT clinic depend on patient's symptomatology at presentation. If symptomatic, progress with lesser weight-bearing exercises such as multiplane balance training in double leg stance, such as step ups, partial WB full ROM calf raises, weight shifting in the frontal plane with band resistance, leg press, stationary bike and elliptical machine use. If minimal patient symptoms, then progress to single leg training with these exercises.

Sport-Specific Exercises

- Begin light workouts in the patients' specific activity of choice. During this phase of rehabilitation, we start submaximal sport specific training. We go through periods of training and re-assessment within a session to make sure the patient is tolerating the training. The patient performs the exercises at a slower speed to ensure correct movement patterns and tolerance to activity. In whichever sport the patient is involved, we often recommend a 50% reduction in the speed and 50% in the load of that specific sport.

Milestones for Progression to Advanced Sport-Specific Training and Conditioning

- All goals achieved, none to minimal pain about the heel noted.
- The patient demonstrates the ability to control motion through the sagittal, frontal, and transverse planes at slower speeds. The patient should demonstrate no pain with multijoint movement testing. Specifically the patient should be able to:
  - Perform a single leg calf raise from a full dorsiflexed ankle position in weight bearing.
  - Perform step lunges and hopping in different directions.
  - Perform or use the agility ladder for four to five cycles/back and forth at moderate speed.
- The therapist looks for full forefoot weight bearing during these exercises as a signal to progress.

Criteria for Abandoning Nonoperative Treatment and Proceeding to Surgery or More Intensive Intervention

- Failure to obtain patient activity goals by 3 months of intensive treatment or 6 to 9 months of symptoms
- Ongoing pain that limits desired activity

Tips and Guidelines for Transitioning to Performance Enhancement

- Begin progressive sport specific or running program. Progress every other day 10 minutes or 10% mileage increase per week.

Performance Enhancement and Beyond Rehabilitation: Training/Trainer and Optimization of Athletic Performance

- Regular stretching
- Counseled regarding appropriate footwear
- Counseled regarding appropriate training techniques

Specific Criteria for Return to Sports Participation: Tests and Measurements

- Able to sprint 40 yards without pain
- Able to perform cutting/twisting maneuvers. There are no specific guidelines driving these tests. However the tests that the therapist uses will try to closely replicate game situations; for example, cone drills, agility ladder drills, etc.
- Able to perform single leg hop 10 repetitions
- Quick stops/pivots/turning maneuvers
- Interval training: jog for 3 minutes, run/sprint for 30 seconds, walk for 1 minute

Evidence

Batt ME: Plantar fasciitis: A prospective randomized clinical trial of the tension night splint. *Clin J Sport Med* 6:158–162, 1996.

A good outcome was noted in patients treated with 9 to 12 weeks of night splint usage. (Level II evidence)

DiGiovanni BF: Tissue-specific plantar fascia-stretching exercise enhances outcomes in patient with chronic heel pain. A prospective, randomized study. *J Bone Joint Surg Am* 85-A:1270–1277, 2003.

The patient group that performed specific plantar fascia stretches was noted to have a significant reduction or elimination in pain compared with those with calf stretches alone. (Level I evidence)

Kudo P: Randomized, placebo-controlled, double-blind clinical trial evaluating the treatment of plantar fasciitis with an extracorporeal shockwave therapy (ESWT) device: A North American confirmatory study. *J Orthop Res* 24:115–123, 2006.

A statistically significant improvement in symptoms was noted at 3 months in the group that received one high-energy shock wave treatment. (Level I evidence)

Landorf KB: Effectiveness of foot orthoses to treat plantar fasciitis: A randomized trial. *Arch Intern Med* 166:1305–1310, 2006.

This blinded, randomized trial noted that of 136 patients who were treated with either a sham orthosis, a prefabricated orthosis or a custom orthosis, the groups treated with the prefabricated and custom orthoses produced short-term relief of symptoms that than was not significant after 1 year. (Level I evidence)

Pfeffer G: Comparison of custom and prefabricated orthoses in the initial treatment of proximal plantar fasciitis. *Foot Ankle Int* 20:214–221, 1999.

The groups treated with the prefabricated inserts and stretching had better outcomes than the custom orthotic group or stretching group along at short term follow-up. (Level III evidence)

Porter D: The effects of duration and frequency of Achilles tendon stretching on dorsiflexion and outcome in painful heel syndrome: A randomized, blinded, control study. *Foot Ankle Int* 23:619–624, 2002.

Patients randomized to either a sustained stretch or an intermittent stretch were noted to have an increase in ankle

dorsiflexion which correlated with a reduction in pain versus the control group. (Level II evidence)

Powell M: Effective treatment of chronic plantar fasciitis with dorsiflexion night splints: A crossover prospective randomized outcome study. *Foot Ankle Int* 19:10–18, 1998.

Eighty-eight percent of 37 patients were noted to have improvement in their chronic plantar fascial symptoms when worn for 1 month. (Level III evidence)

Rompe JD: Shock wave application for chronic plantar fasciitis in running athletes: A prospective, randomized, placebo-controlled trial. *Am J Sports Med* 31:268–275, 2003.

Morning pain was reduced in the treatment group at 6 and 12 months with 3 treatments of low energy shock wave. (Level I evidence)

Roos E: Foot orthoses for the treatment of plantar fasciitis. *Foot Ankle Int* 27:606–611, 2006.

Comparing the use of foot orthoses versus foot orthoses plus night splint or night splint only, the authors noted improvement in pain at 1 year follow-up in all groups. (Level II evidence)

Tisdel CL: Chronic plantar heel pain: Treatment with a short leg walking cast. *Foot Ankle Int* 17:41–42, 1996.

A short trial of a walking boot was noted to reduce symptoms of plantar fasciitis. (Level IV evidence)

Wang CJ: Long-term results of extracorporeal shockwave treatment for plantar fasciitis. *Am J Sports Med* 34:592–596, 2006.

Eighty-three percent of patients who received high-energy shockwave treatment noted good/excellent results at 72-month follow-up. (Level III evidence)

Multiple Choice Questions

QUESTION 1. Stretching exercises of which structure(s) typically resolves plantar heel pain?

A. Achilles tendon
B. Gastrocnemius/soleus
C. Plantar fascia
D. All of the above

QUESTION 2. Surgical treatment is generally considered after approximately ___ months of patient symptoms?

A. 1
B. 3
C. 6 to 9
D. 12

QUESTION 3. An aggressive core strengthening program is initiated in which phase of the nonoperative treatment of patient with plantar fasciitis?

A. Phase I
B. Phase II
C. Phase III
D. Phase IV

QUESTION 4. The use of a prefabricated, or off-the-shelf, insert has been shown to be as effective if not more effective than a custom orthotic.

A. True
B. False

QUESTION 5. Use of all of the following has been shown in the literature to be effective in the treatment of patient with plantar fasciitis, except one.

A. Night splint
B. Plantar fascia specific stretches
C. Prefabricated inserts
D. Distraction (manual) therapy

Answer Key

QUESTION 1. Correct answer: **D** (see Phase I)

QUESTION 2. Correct answer: **C** (see Phase IV)

QUESTION 3. Correct answer: **B** (see Phase II)

QUESTION 4. Correct answer: **A** (see Phase III)

QUESTION 5. Correct answer: **D** (see Phase II)

POSTOPERATIVE REHABILITATION AFTER PLANTAR FASCIITIS SURGERY

Charles Christopher Stroud, MD, Erick Fountain, MPT, OMPT, and Mike Pollzzie, PT, DPT, OMPT, CSCS

Indications for Surgical Treatment

- Persistent heel pain unresponsive to nonsurgical treatment over a 6- to 9-month period
- Pain that limits the desired athletic activity as well as activities of daily living
- Nonoperative treatment is generally successful in over 90% of patients and is recommended for a minimum of 6 months.
- A gastrocnemius release is considered in those patients with a demonstrable tight Gastrocnemius (i.e., a positive Silverskold test).

- These recommendations apply to both athletes and nonathletes

Brief Summary of Surgical Treatment

Major Surgical Steps

- Regional or local anesthesia; patient in semilateral position with bump/bean bag placed under the unaffected hip
- Calf tourniquet use is encouraged.
- Skin incision followed by dissection down to abductor hallucis fascia
- If just performing a plantar fascial release, dissect to confluence of plantar fascia and abductor hallucis (AH) fascia
- Palpate with a freer elevator the width/thickness of plantar fascia as it inserts on the calcaneus
- If performing a release of the first branch of the lateral plantar nerve, release AH fascia, retract muscle belly inferiorly and release deep fascia. Retract muscle belly superiorly and complete deep AH fascia release.
- Excise, medially to laterally, approximately 60% of the thickened plantar fascia.
- Gastrocnemius release is controversial but can be considered in individuals with a demonstrable gastroc equinus contracture and is performed now (see appropriate chapter for technique).
- Apply a padded compression dressing (if just plantar fascia release) or posterior splint in neutral position (if gastrocnemius release performed)

Factors That May Affect Rehabilitation

Anesthetic

- Modalities and limb elevation are crucial postoperatively to limit hematoma formation.

Surgical

- If gastrocnemius release performed, will need to aggressively address lower leg strengthening postoperatively

Other Surgical Techniques and Options

- The addition of a gastrocnemius release can be a useful adjunct in operative treatment.
- The patient will require more focused postoperative treatment of the lower leg in addition to the foot.

Before Surgery: Overview of Goals, Milestones, and Guidelines[1]

GUIDING PRINCIPLES OF POSTOPERATIVE REHABILITATION

- Understand the significant weight bearing forces that act on the foot while the tissues are healing
- Limit limb swelling and hematoma formation in the immediate postoperative period
- Protected weight bearing in a walking boot in the subacute postoperative period
- A progressive program of weight bearing, stretching and strengthening follows

Phase I (days 0 to 14): Immediate Postoperative Period

Clinical Pearl

Patient will perform his or her own application of ice and perform gentle range of motion exercises of the hip/knee and ankle during this phase.

Goals

- Limit activity related swelling/hematoma formation
- Progressive mobilization of the lower leg
- Transition into a boot brace
- Progressive weight bearing as tolerated (if not in a splint)

[1]*Prehabilitation, if appropriate, is described in the Nonoperative Rehabilitation section of this chapter.*

TIMELINE 42-2: **Postsurgical Rehabilitation after Plantar Fasciitis Surgery**

PHASE I (weeks 1 to 2)	PHASE II (weeks 2 to 6)
• In boot • Ice prn • AAROM/ AROM in all planes • Self-stretching for edema reduction and pain control	• WBAT in boot, progressing to OOB as symptoms allow. • PT modalities • Restore normal joint mobility at the TC and ST joints • Functional massage to normalize soft tissue mobility in the calf and posterior leg • Begin more aggressive calf stretching in WB • Progress AROM into RROM in OKC • Begin WB strength training program, progressing to higher level functional training in all planes of motion. • Maximize efficiency of gait pattern • Teach pt self-mobilizations for control of isolated PF pain • Advance with CKC strength, balance and proprioceptive training.

Protection

- Crutches are used until the first postoperative visit.
- Patient can be weight bearing as tolerated with crutches if just dressing used, non–weight bearing if a splint is applied.

Management of Pain and Swelling

For Pain

- Regional/local anesthesia reduces immediate postoperative pain
- Oral narcotic pain medication

For Swelling

- Limb elevation, gentle ankle range of motion, if not in a splint

Techniques for Progressive Increase in Range of Motion

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Stretching/flexibility techniques for the musculotendinous unit
- Gentle active range of motion of the knee, ankle, and subtalar joint

Other Therapeutic Exercises

- Begin upper body, core exercises, hip and thigh strengthening (i.e., straight leg raises)

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Gentle, progressive, active range of motion exercises of the knee, ankle, and subtalar joint, emphasizing full extension of the knee

Milestones for Progression to the Next Phase

- Patients should have at least 0° of ankle dorsiflexion and at least 30° of plantarflexion and a decreasing level of pain

Phase II (postoperative weeks 2 to 6)

Clinical Pearls

- This is the phase in which normal gait and range of motion is achieved.
- Patients can generally progress with their own home program or can be enrolled in formal physical therapy at this point.
- The overriding principle during this phase of treatment is to create and control load and force during weight bearing on the affected leg.
- Also, the patient will begin functional training as early as possible.
- Soft tissue mobilization is begun immediately.

Goals

- Further reduce pain/swelling
- Achieve a nonantalgic gait pattern
- Achieve full range of motion of ankle and hindfoot
- Initiate plantarflexion and calf strengthening

Protection

- Boot brace used until normal gait pattern

Management of Pain and Swelling

For Pain

- Oral narcotic/NSAID medication, IFC, TENS unit, iontophoresis, ice
- Begin warm water immersion or contrast baths depending on patient preference

TIMELINE 42-2: **Postsurgical Rehabilitation after Plantar Fasciitis Surgery** (Continued)

PHASE III (weeks 6 to 10)	PHASE IV (weeks 10 to 14)	PHASE V (weeks 14 to 24)
• Normal gait pattern with good push off noted at toe off phase of gait • Manual therapy prn: higher level joint stretches to resolve lingering jt ROM loss • Functional massage to control c/o pain and residual edema • Advance WB calf stretching to include full WB plantar fascia stretching • Progress exercises from above phase by advancing reps, then speed, then load • Functional training will include kettle bells, core and medicine balls • Focus moves from double leg to single leg stance training • Plyometric and hopping exercises can be initiated	• Normal gait pattern • Normal AROM/PROM of the involved foot and ankle • Edema should be resolved • Continue with calf and plantar fascia stretching/ self-mobs as needed • Modalities prn for management of any lingering ST soreness • High level core and balance training in WB • Emphasis on speed and performance recovery • Aggressive focus on gastroc strength recovery if gastroc release was performed • Initiate sport-specific training and jogging • Goal to achieve calf strength equal to 80–90% of uninvolved leg • Noticeable gastroc girth recovery	• Return to sport • Full function without residual pain or ROM loss • Ongoing lower extremity stretching, as needed, to maintain proper mechanics with functional training and exercise program



FIGURE 42-14. Photo demonstrating soft tissue mobilization technique to be administered by the patient at home.



FIGURE 42-16. Photo of assisted split squats using the TRX training system.

For Swelling

- Range of motion, ice, compression stockings. Patients will begin a home self-administered soft tissue mobilization/stretching program to the plantar fascia (Figure 42-14)

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Talocrural and subtalar joint mobilization
- There is limited evidence to support the use of manual therapy techniques in the treatment plan, but these techniques are often used.

Soft Tissue Techniques

- Functional massage of plantar fascia and gastroc-soleus complex in prone position; for example, soft tissue mobilization

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Patient or therapist aggressively begins calf stretches, and great and lesser toe stretches. This includes:
- PWB calf stretches (bilateral stance thus splitting body weight
- Active patient standing calf stretch with knee straight and bent (Figure 42-15*A*,*B*)
- Great and lesser toe dorsiflexion exercises
- Dynamic stretching while in boot (hamstring/hip rotators, including hip flexors/extensors/groin

Other Therapeutic Exercises

- Core/hip/leg strengthening continues: step-ups and step-downs, box touches, toe touches, forward/backward monster walks, side walks, bridge exercises, and single leg training to restore control of WB and hip stability
- Using TRX training system, progress from assisted split squats to full body weight over a 4-week period (Figure 42-16).
- For hip stability, use triplanar foot/ankle proprioceptive exercises on uninvolved leg; that is, multidirectional slide board exercises as well as static/dynamic slide board exercises (Figure 42-17*A*,*B*).
- Abdominal training for motion control during gait, all WB on involved limb (plank exercises) while in boot early and progress to out of boot (Figure 42-18).

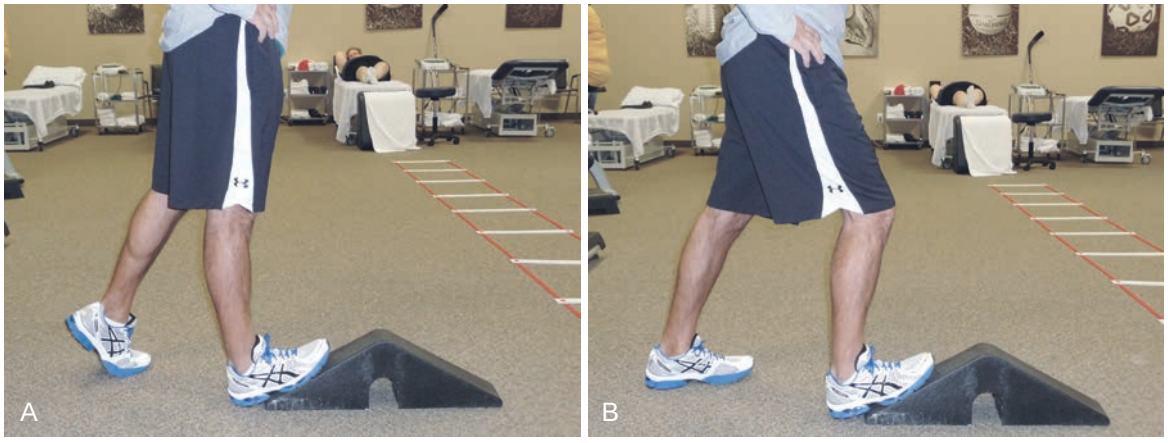

FIGURE 42-15. A,B, Photo demonstrating a partial weight-bearing calf stretch used while out of the boot, with knee extended and flexed.

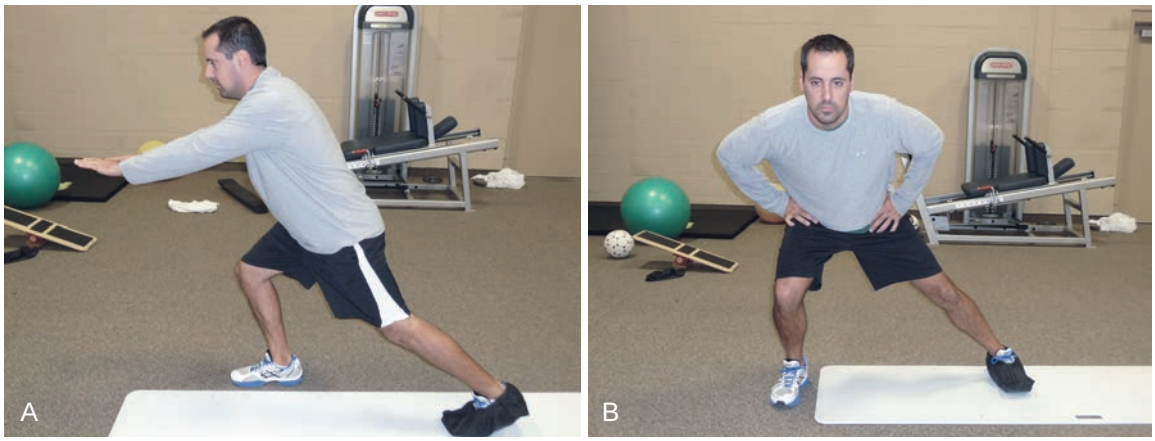

FIGURE 42-17. Photo demonstrating hip and core stabilization exercises using a multidirectional slide board, here both straight ahead (**A**) and lateral (**B**).

- Elliptical machine, both in/and out of boot, for general cardiovascular benefit.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Immediate and progressive motion of the gastrocnemius/soleus complex and great/lesser toe plantar flexors and dorsiflexors. Four-way resistance band exercises of ankle used.

Sensorimotor Exercises

- Single and double leg balance exercises (even progressing to uneven surfaces), DynaDisc, BAPS board, BOSU (Figure 42-19)

Open and Closed Kinetic Chain Exercises

- CKC exercises while in PT facility; that is, single/double leg, split stance
- Home exercises include open chain (band exercises) for hip, leg, and foot/ankle.



FIGURE 42-18. Photo demonstrating plank exercises (while patient is in or out of boot) used for abdominal training during this phase of recovery.

Techniques to Increase Muscle Strength, Power, and Endurance

- Check for proper muscle firing (normal gait mechanics), working on proper motion control of hip/knee/ankle during gait. Work on increasing from low load, low reps to higher load and repetitions.

Neuromuscular Dynamic Stability Exercises

- See Sensorimotor section.
- Weight-shifting evaluation: proper gait/pivoting mechanics, proper control of pronation/supination; that is, core ball exercises. Progress to single leg balance (i.e., therapeutic exercise section) and rotational exercises all with the goal of creating and controlling force (Figure 42-20*A*–*C*)



FIGURE 42-19. Photo demonstrating double leg balance exercises on BOSU, DynaDisc, or BAPS board.

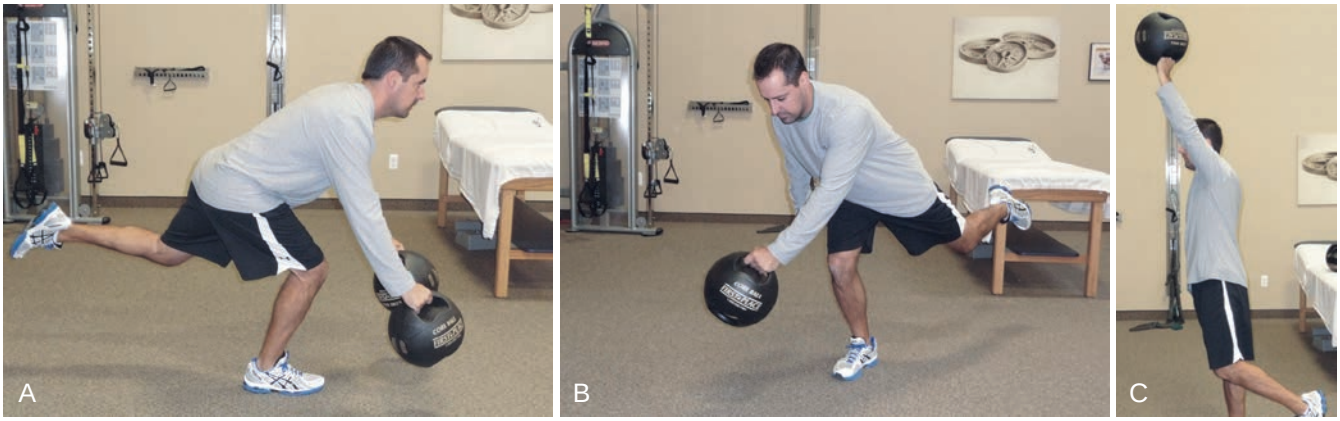

FIGURE 42-20. A-C, Photo of core ball exercises used to maximize proper control of lower extremity with forward, rotational, and upward reach.

Functional Exercises

- Lower extremity motion control exercises, progression and load, proper gait mechanics. Achieve normal gait, which requires 10° of ankle dorsiflexion.

Milestones for Progression to the Next Phase

- Pain controlled: no increase in pain with performance of above program, no lasting pain (greater than 24 to 48 hours post PT).
- Proper gait mechanics, restoration of motion

Phase III (postoperative weeks 6 to 10)

Clinical Pearls

- This is the phase in which strength gains are most noted.
- Progress load/speed of activity and repetitions of involved leg
- Constant testing/retesting of the soft tissues, joint mobility and function in order to advance treatment plan

Goals

- Demonstrate isometric control of ankle muscle in plantarflexion (i.e., adequate push off during toe-off portion of gait)
- Greater than 50% strength/power production of uninvolved leg as measured by number of maximum repetitions compared with contralateral leg

Protection

- Supportive taping (PT or patient) as needed. Calcaneal or low-dye taping may provide short-term relief of symptoms.

Management of Pain and Swelling

For Pain

- Switch to anti-inflammatory pain medication taken as needed.

For Swelling

- Edema reducing soft tissue massage as needed

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- ROM should be normal; however more aggressive talocrural ROM, emphasizing the posterior ankle and subtalar joint.
- Long axis talocalcaneal traction, all performed to resolve residual joint limitations

Soft Tissue Techniques

- Functional massage continued

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Full WB and full range stretch (single leg calf stretch, knee bent/flexed), elevate great toe MTP joint for additional stretch with and w/o WB

Other Therapeutic Exercises

- Same as in the preceding section but without boot

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- If gastrocnemius release performed, aggressive plantarflexion exercises with Thera-Bands, isometric plantar flexion exercises in weight-bearing position. Same as in the preceding phase but emphasizing increased speed/repetitions.



FIGURE 42-21. Photo demonstrating single leg balance with the use of kettle bells or medicine balls.



FIGURE 42-23. Photo demonstrating Plyo-box jump exercises.

Sensorimotor Exercises

- Emphasis on single leg balance, such as kettle bells and weighted medicine balls.
- Single leg dead lifts, single leg squats, slide board, lunges, split squat lunging (Figure 42-21)
- Triplanar lunges

Open and Closed Kinetic Chain Exercises

- Same as previous section

Techniques to Increase Muscle Strength, Power, and Endurance

- Increasing repetitions, maximizing ROM of hip/knee/ankle, increasing load
- If 15 to 20 repetitions can be achieved w/o fatiguing, then progress and increase load

Neuromuscular Dynamic Stability Exercises

- Teach patterns of movement using agility drills (use agility ladder): double leg lateral hopping (Figure 42-22).
- Progress from walking to trotting to quick movements.

Plyometrics

- Begin plyometric exercises: Bounding exercises, agility ladder, Plyo-box jumps (Figure 42-23)
- Teach proper landing techniques.
- Teach to control lower extremity pronation/supination

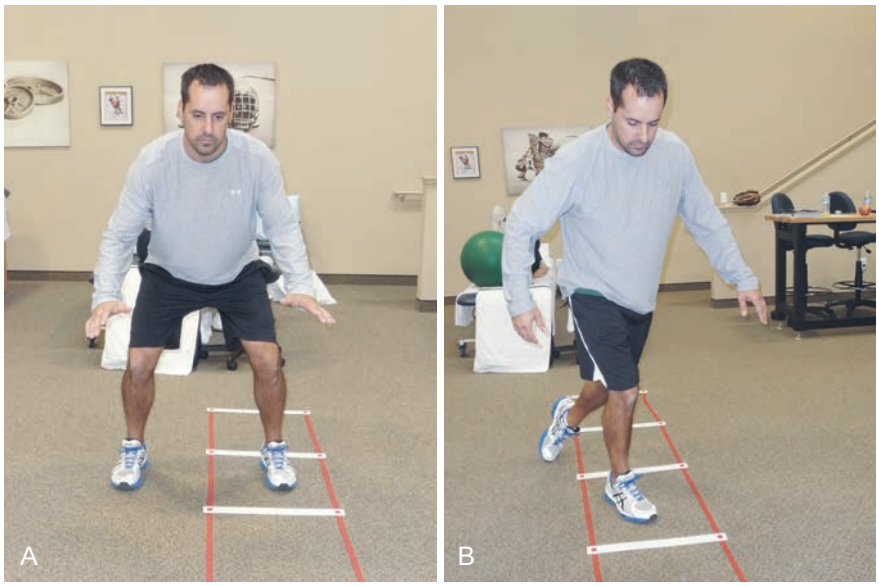

FIGURE 42-22. Photo demonstrating using agility ladder. Patient hops on both legs from one box to the next (**A**). Patient demonstrates a crossover step technique from in and out of the ladder (**B**).

Functional Exercises

- See therapeutic exercise section

Sport-Specific Exercises

- Light jogging, biking, plyometrics, agility ladder, shuffling, hopping, change of direction

Milestones for Progression to the Next Phase

- All exercises as in the preceding performed but particularly hopping exercises, higher-level agility ladder exercises, hop side to side, step-ups with hop, sets of 15 to 20 without pain.
- Jogging without gait compensation or residual pain. Cutting/twisting, higher load resistive training accomplished.
- Some soft tissue soreness can be noted, but is not limiting.

Phase IV (postoperative weeks 10 to 14)

Clinical Pearls

The patient or therapist works on dramatically increasing repetition and load. Constant testing and retesting are performed to make sure patient is progressing. Return to practicing specific sport and ready for return during this phase. Do everything as in the preceding but harder, faster, stronger and longer. It should take the patient 4 to 6 weeks at this time to return to his or her activity of choice. The patient will increase the intensity of exercise roughly 25% per week.

Goals

- Achieve significant strength gains in affected leg including:
  - Ability to perform a single leg calf raise through at least 80% of ROM during weight bearing
  - Single leg squat performed at 85% of total reps of uninvolved leg
  - Open chain manual muscle testing that is 5/5 for quads, hamstring, and gastroc/soleus complex
- Begin to see calf muscle girth increase.
- All exercises should be pain free.
- Progress to DC to HEP.

Management of Pain and Swelling

- NSAIDs only for pain
- Swelling should not be present.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Manual self-stretches for normal pelvic and extremity movement

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Self-stretching ankle and plantar fascia techniques to maintain normal flexibility

Other Therapeutic Exercises

- Aggressive total body strengthening, as noted in preceding section

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- See previous section

Sensorimotor Exercises

- See previous section

Open and Closed Kinetic Chain Exercises

- Both types of exercises as tolerated and as noted in previous section

Techniques to Increase Muscle Strength, Power, and Endurance

- Same as previous section but progress total time of repetitions as tolerated.

Neuromuscular Dynamic Stability Exercises

- Same as previous section

Plyometrics

- Same as previous section

Functional Exercises

- Fast feet, lateral fast feet, scissor exercises, karaoke, lateral hopping, side-to-side hops, jump squats, step squats with weighted ball or kettle bells, lunges in all directions, box jumps (Figure 42-24)

Sport-Specific Exercises

- Progress as tolerated

Milestones for Progression to the Next Phase

- Athlete or patient should be ready to engage in sporting activity

Phase V (postoperative weeks 14 to 24)

Goals

- Athlete has returned to sport of choice
- Able to work through pain, if any
- Should have no limitation in function



FIGURE 42-24. Photo demonstrating Fast feet exercises.

Sensorimotor Exercises

- At this point, the athlete has returned to his or her specific sport of choice. Progressions at this point are focused on sport-specific movement patterns and performance enhancement.

Open and Closed Kinetic Chain Exercises

- Same as in the preceding

Techniques to Increase Muscle Strength, Power, and Endurance

- Same as in the preceding

Neuromuscular Dynamic Stability Exercises

- Same as in the preceding

Plyometrics

- Same as in the preceding

Functional Exercises

- Same as in the preceding

Sport-Specific Exercises

- Same as in the preceding

Milestones for Progression to the Next Phase

- Same as in the preceding

Criteria for Return to Sport

General

- Pain is present only during start-up activities and resolves quickly
- Equivalent ankle dorsiflexion and subtalar joint motion compared with contralateral side.
- Calf circumference is 85% of contralateral side and muscle definition present
- Able to perform 85% to 90% of repetitions of contralateral leg during single leg squat, calf raises, single leg balance, and proprioceptive exercises

Sport-Specific

- Able to perform 10 repetitions of a single heel rise
- Able to perform cutting, twisting and karaoke maneuvers
- Able to sprint 10 yards without pain
- For runners, ability to run normal course or circuit

After Return to Sport

Continuing Fitness or Rehabilitation Exercises

- Daily calf/plantar fascial stretches

Exercises and Other Techniques for Prevention of Recurrent Injury

- Consider usage of accommodative orthotics for impact activities, such as running
- Patient education regarding his or her specific foot type and appropriate shoe wear, such as patients with pes planus, require "motion-control" footwear, and patients with a pes cavus foot type require more "accommodative" footwear.

Evidence

American Orthopaedic Foot & Ankle Society: AOFAS Position Statement: Endoscopic and Open Heel Surgery. http://www.aofas.org/i4a/pages/index.cfm?pageid=3680. Accessed April 29, 2008.

Position statement of the AOFAS discussing the treatment options including surgical intervention. (Level V evidence)

DiGiovanni DF: Tissue-specific plantar fascia-stretching exercise enhances outcomes in patients with chronic heel pain. A prospective, randomized study. *J Bone Joint Surg Am* 85-A:1270–1277, 2003.

This prospective, randomized, non-blinded study compared calf stretches to a plantar fascia specific stretch and assessed outcome. Plantar fascia specific stretches were noted to eliminate or significantly improve symptoms versus calf stretches at 8 week follow-up. (Level I evidence)

Gudeman SD: Treatment of plantar fasciitis by iontophoresis of 0.4% dexamethasone. A randomized, double-blind, placebo-controlled study. *Am J Sports Med* 25:312–316, 1997.

This study noted very short-term improvement in the patient group treated with iontophoresis versus the group treated without this modality. Both groups were also treated with ice, stretches, and orthoses. (Level I evidence)

Osborne HR: Treatment of plantar fasciitis by LowDye taping and iontophoresis: Short term results of a double blinded, randomized, placebo controlled clinical trial of dexamethasone and acetic acid. *Br J Sports Med* 40:545–549, 2006.

The iontophoresis group had less pain in short-term follow-up versus two control groups. (Level I evidence)

Porter D: The effects of duration and frequency of Achilles tendon stretching on dorsiflexion and outcome in painful heel syndrome: A randomized, blinded, control study. *Foot Ankle Int* 23:619–624, 2000.

Three groups were compared with different frequency/duration of stretching exercises versus a no-stretch control group. The two groups that were directed to perform stretches were noted to have a decreased level of pain at follow-up compared to controls. (Level I evidence)

Radford JA: Effectiveness of low-Dye taping for the short-term treatment of plantar heel pain: A randomized trial. *BMC Musculoskelet Disord* 7:64. http://dx.doi.org/10.1186/1471-2474-7-64, 2006.

Short-term (1 week) improvement in start-up pain was noted in the group treated with taping plus ultrasound versus the group with just ultrasound treatment in a group of 92 patients. (Level I evidence)

Multiple Choice Questions

QUESTION 1. Which one of the following is one of the indications for surgical intervention in the patient with plantar fasciitis?

A. Ongoing plantar heel pain despite 9 months of conservative treatment
B. Inability of a runner to complete his or her training for a marathon
C. Patient with heel pain does not want to go through 6 weeks of physical therapy
D. Patient with 2 weeks of heel pain that is in between two sports and has a 6-week time frame to "get well"

QUESTION 2. When is a gastrocnemius release considered as an adjunctive procedure in a patient who is considered for surgical partial plantar fascia release?

A. This procedure is considered in all patients who will undergo a partial plantar fascial release.
B. A positive Silverskold test
C. In the patient who complains of "tightness" in the Achilles after a run
D. In the patient with a demonstrable hamstring contracture

QUESTION 3. During what time frame (in weeks) of rehabilitation after surgery for a partial plantar fascial release is the initiation of strengthening appropriate?

A. Week 1
B. Week 2 to 6
C. Week 6 to 12
D. Week 12 to 16

QUESTION 4. When should the athlete be ready to engage in his or her normal sporting activity?

A. Week 2 to 6
B. Week 6 to 10
C. Week 10 to 14
D. Week 14 to 24

QUESTION 5. What is the amount of ankle dorsiflexion is needed for normal gait?

A. 10°
B. 20°
C. 30°
D. dorsiflexion to a neutral position

Answer Key

QUESTION 1. Correct answer: **A** (see Indications for Surgical Treatment)

QUESTION 2. Correct answer: **B** (see Indications for Surgical Treatment)

QUESTION 3. Correct answer: **B** (see Phase II)

QUESTION 4. Correct answer: **C** (see Phase IV)

QUESTION 5. Correct answer: **A** (see Phase II)

Chapter 43



Midfoot Strains and Sprains and Lisfranc Injuries

INTRODUCTION

Jason M. Jennings, MD, DPT, and Mark E. Easley, MD

Epidemiology of Tarsometatarsal Complex Injuries (Lisfranc Complex Injuries)

- Tarsometatarsal (TMT) complex injuries are rare and often subtle in athletes both clinically and radiographically.[1] They typically occur secondary to a low-energy indirect force in contrast to the majority of nonathletic injuries, which result from high-energy direct forces (i.e., motor vehicle accident).
- Midfoot sprains in athletes represent a spectrum of injuries to the Lisfranc ligament complex from partial sprains with no diastasis (stage I) to complete tears with frank diastasis (stages II and III) (Figure 43-1).[2]

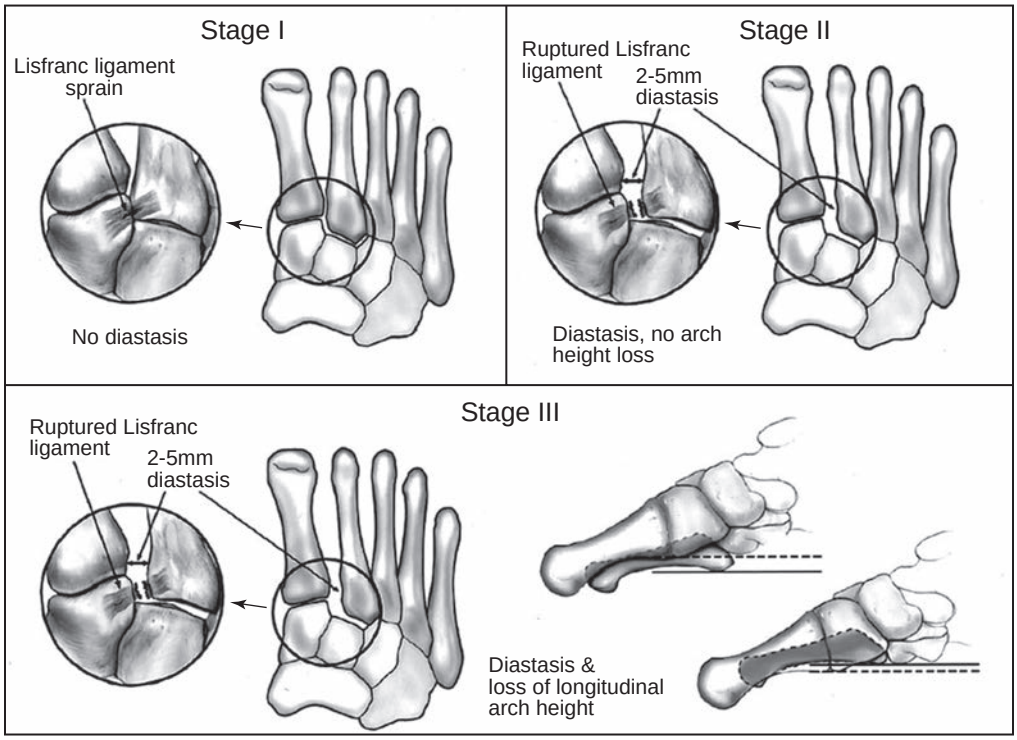

FIGURE 43-1. Nunley and Vertulla classification of ligamentous Lisfranc injuries *(Adapted from Nunley JA, Vertullo CJ: Classification, investigation, and management of midfoot sprains. Lisfranc injuries in the athlete.* Am J Sports Med *30(6):871-878, 2002, with permission.)*

- Twenty percent misdiagnosed at initial presentation, with 40% receiving no treatment in the first week.[3]

Incidence

- Increased incidence in athletes secondary to greater appreciation and recognition
- Four percent of college football players per year[4]
  - 29.2% of these players were offensive linemen

Age

- Most common in third decade

Sex

- Males affected two to four times more often than females[3]

Sport

- Most common sports: football, equestrian, windsurfing, gymnastics, basketball, baseball, other
- Women's gymnastics is one of the highest injury-producing sports, with many of these injuries requiring surgical intervention.[3]

Position

- Offensive lineman[4]

Pathophysiology

Intrinsic Factors

- The midfoot is typically divided into three columns:
  - Medial column: navicular, medial cuneiform, and the first metatarsal
  - Middle column (most rigid): articulation between the second and third metatarsals with their respective articulation
  - Lateral column (most mobile): articulation between the fourth and fifth metatarsals and the cuboid
- The Lisfranc ligament is located between the medial cuneiform and the base of the second metatarsal providing stability between the medial and middle columns.
- There is no ligamentous attachment between the first and second metatarsal joint.[5]
- The plantar ligaments are stronger than the dorsal ligaments which may account for dorsal dislocations when they occur.[6]
- The base of the second metatarsal is recessed between the medial and lateral cuneiforms creating the "keystone" in the shape of a Roman arch, which provides inherent osseous stability.
- In patients with injuries to the Lisfranc joint, the medial mortise depth (medial aspect of the TMT joint, between the medial cuneiform and the base of the second metatarsal) has been shown to be shallower, decreasing osseous stability and thus increasing risk to injury.[7]

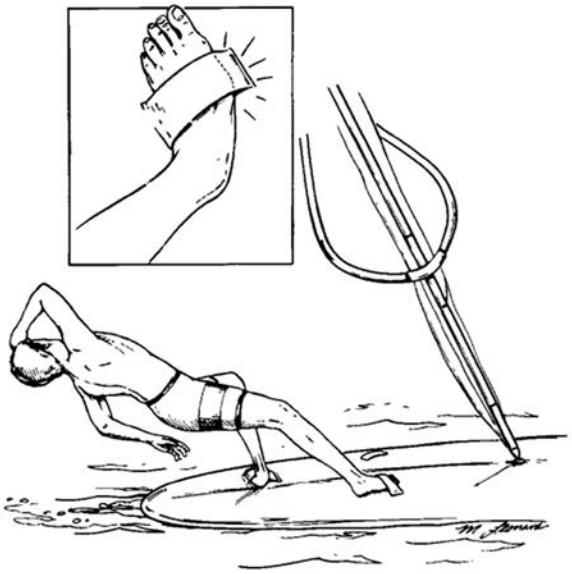

FIGURE 43-2. Mechanism of a windsurfing injury—a fall backward causing forced equines of the fixed forefoot. *(Adapted from Curtis MJ, Myerson M, Szura B: Tarsometatarsal joint injuries in the athlete.* Am J Sports Med *21:497-502, 1993, with permission.)*

Extrinsic Factors

- Interface between the athletic shoe and playing field, particularly artificial turf [8]
- Regular turf injuries in American football may be influenced by type of shoe or cleat worn and the forces on the foot when another athlete falls on it in a compromised position.[8]
- Stirrup creating a fulcrum effect on the forefoot as seen in windsurfing and equestrian sports (Figure 43-2)[9]

Traumatic Factors

- Athletic injuries of the TMT complex can be divided into three broad categories:
  - Plantar flexion injury: axial force applied along the longitudinal axis (Figure 43-3)
  - Forefoot forcefully abducted with hindfoot fixed[9] (i.e., windsurfing and equestrian sports) (see Figure 43-2)
  - Crush to the dorsum of the foot
- These mechanisms are oversimplifications, because there are probably varying patterns of each force (e.g., rotational).[8]

Clinical Presentation and Examination

- The presentation is often subtle, and one should have a high index of suspicion when the athlete presents with a midfoot "sprain."
- "Pop" felt over the dorsal aspect of the foot
- Inability to weight-bear

Abnormal Findings

- Physical examination findings are often subtle.
- Inability to weight-bear

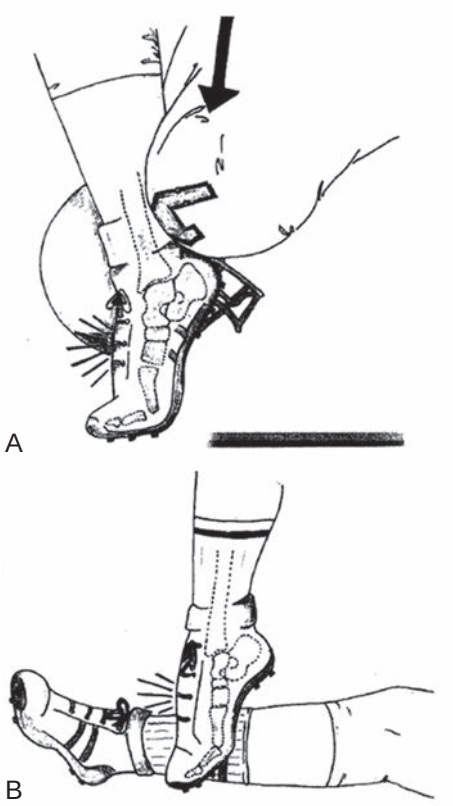

FIGURE 43-3. A, Plantarflexion of the foot driven into the ground by an opposing player falling on the hindfoot or leg. **B,** Another mechanism demonstrates a player's plantarflexed foot coming down on another player's leg during a pileup. *(Adapted from Meyer SA, Callaghan JJ, Albright JP, Crowley ET, Powell JW: Midfoot sprains in collegiate football players.* Am J Sports Med *22:392-401, 1994, with permission.)*

- Variable amount of edema
- Variable deformity
- Plantar arch ecchymosis
- Diastasis between the first and second toes
- Tender to palpation over the TMT complex
- Pain with pronation and abduction of the forefoot[9]
- Pain with passive plantar flexion, dorsiflexion, abduction, and adduction of the first and second metatarsal complex
- Coronal plane stress across the forefoot

Imaging

- Despite being associated with relatively minor radiographic changes, subtle TMT complex injuries can be a source of considerable morbidity in athletes.[3]
- Twenty to fifty percent of tarsometatarsal injuries are missed on initial non–weight-bearing radiographs.[2,6]
- False negative findings are associated with inability to weight-bear secondary to pain. If weight bearing is limited by pain, ankle block anesthesia may be used.[2]
- Standard weight-bearing radiographs
  - Anteroposterior: The medial border of the second metatarsal should be in alignment with the medial border of the middle cuneiform. With significant Lisfranc joint disruption this alignment will be compromised.



FIGURE 43-4. Radiograph of the foot demonstrating the fleck sign.

  - 30° internal oblique: The medial border of the fourth metatarsal should be aligned with the medial border of the cuboid. Disruption is indicative of a lateral column injury.
  - Lateral view: Note the continuity of the dorsal cortex of the first and second metatarsal to the medial and middle cuneiform. Flattening of the longitudinal arch, which is correlated with a worse functional outcome, is noted by measuring the distance from the plantar aspect of the fifth metatarsal and the plantar aspect of the medial cuneiform.[1]
  - Fleck sign: a small avulsion fragment noted over the lateral edge of the medial cuneiform or the medial aspect of the second metatarsal, which is indicative of a Lisfranc injury (Figure 43-4)
  - Associated injuries: base of second metatarsal, navicular, cuneiform, cuboid, or other
- Stress radiographs (pronation and abduction)[1] may be used to assist with diagnosis if weight-bearing and non–weight-bearing radiographs are normal or equivocal. Adequate anesthesia must be utilized secondary to pain when performing this maneuver. Many physicians will opt for MRI prior to performing stress radiographs.
- MRI: sensitive study for the diagnosis of subtle (stage I) midfoot ligamentous injuries when compared with intraoperative findings[10]
- Bone scintigraphy: diagnosis of subtle (stage I) midfoot injuries or those with delayed diagnosis[2]
- CT: Sensitive for fracture but remains limited in the athletic low-energy TMT complex injury for assessment of instability, and without weight-bearing stress or clear diastasis, the status of the joint stability remains unclear.[6]

Differential Diagnosis

- Midfoot sprain is a tarsometatarsal complex injury until proved otherwise.

Treatment

Nonoperative Management

- Non–weight-bearing immobilization
- Weight-bearing immobilization

Guidelines for Choosing Among the Nonsurgical Treatment Options

- Stage I (no diastasis) Lisfranc ligament sprain
- It is the authors' preference to allow the patient to weight bear as tolerated in a cam walker for the first 6 weeks. Serial weight-bearing radiographs are obtained at 2 and 6 weeks to assure there is no diastasis or instability.

Surgical Indications

- Absolute: Stage II and III Lisfranc ligament sprains, displaced fractures, subluxation/dislocation
- Relative: continued pain and failed conservative treatment for stage I injuries
- Table 43-1 lists five steps that can be used to determine the need for surgical intervention based on imaging studies

Aspects of History, Demographics, or Exam Findings That Affect Choice of Treatment

- Low-energy (athletes) versus high-energy injury
- Associated injuries
- Operative treatment is generally indicated for all obvious displaced injuries (stage II and III injuries).
- The patient with minimal ambulatory ability, an insensate foot, or preexisting inflammatory arthritis *may* be best treated nonoperatively.

Aspects of Clinical Decision Making When Surgery Is Indicated

- Open versus closed injury
- Vascular status
- Compartment syndrome
- Timing of surgery
- Delay in diagnosis
- ORIF versus arthrodesis versus percutaneous screw fixation
- Postoperative management and the patient's ability to comply with the strict non–weight-bearing status and rehabilitation protocol

Evidence

Curtis MJ, Myerson M, Szura B: Tarsometatarsal joint injuries in the athlete. *Am J Sports Med* 21:497–502, 1993.

This study was a retrospective review of 19 patients who injured the tarsometatarsal joint complex during athletic competition. Stress fluoroscopy of the articulation under anesthesia was used to supplement clinical and radiographic examination. Poor functional results were seen in those where diagnosis was delayed and inadequately treated unstable injuries with nonoperative immobilization. (Level III evidence)

DeOrio M, Erickson M, Usuelli FG, et al: Lisfranc injuries in sport. *Foot Ankle Clin N Am* 14:169–186, 2009.

This article reviews anatomy, classification, diagnosis, and treatment of Lisfranc injuries in sport. In addition, the authors' preferred operative technique is discussed in detail. (Level V evidence)

Faciszewski T, Burks RT, Manaster BJ: Subtle injuries of the Lisfranc joint. *J Bone Joint Surg* 72A:1519–1522, 1990.

Fifteen patients with 18 subtle Lisfranc joint disruption demonstrated weight-bearing. Lateral radiographs are needed to identify flattening of the longitudinal arch. Maintenance of the longitudinal arch was associated with better functional outcomes. (Level III evidence)

Meyer SA, Callaghan JJ, Albright JP, et al: Midfoot sprains in collegiate football players. *Am J Sports Med* 22:392–401, 1994.

This retrospective study of 23 collegiate football players demonstrated an incidence of 4% of football players per year, with 29.2% of these players offensive lineman. The patients

Table 43-1 Stepwise Evaluation of a Patient with Lisfranc Injury to Determine Whether to Perform Nonsurgical or Surgical Treatment

Step	Study	Result	Recommendation	Rationale
1	Physical examination	Plantar bruising, painful piano key test, midfoot swelling	Obtain weight-bearing radiographs unless injury is obvious with non–weight-bearing images	Weight-bearing radiographs are always useful, but oblique views may be helpful for the tentative patient.
2	Radiography	Loss of arch on comparative weight-bearing lateral radiograph, widening between the first and second metatarsal vases or comparative AP views, fleck sign	ORIF is indicated with positive results. External rotation views are necessary when there is uncertainty based on plain radiographs or the patient cannot bear weight. When uncertainty remains, MRI is useful.	Any measurable subluxation is an indication for ORIF. When in doubt, proceed with further tests. On MIR, edema indicates midfoot injury, and subluxation confirms Lisfranc injury.
3	MRI	Edema at the tarsometatarsal joint, bone bruise, subluxation, or ligament tear	If edema but no ligament tear or subluxation, then CT is recommended. Perform ORIF in the presence of subluxation or a clear ligament tear.	MRI is more sensitive to edema in subtle injuries. CT may better illustrate subluxation, but MRI may show both.
4	CT	1 mm of subluxation	Strong evidence for Lisfranc injury when edema is noted on MRI and subluxation on CT. ORIF is indicated.	MRI with edema and no ligament tear combined with normal CT requires stress examination under anesthesia, with possible ORIF.
5	Stress examination	Subluxation	ORIF	When negative, treat as a sprain

From Watson TS, Shurnas PS, Denker J: Treatment of Lisfranc joint injury: Current concepts. JAAOS 18(12):718–728, 2010.

were followed for a mean of 30.8 months and most of despite a prolonged restriction from activity most of the players reported minor residual problems. (Level III evidence)

Myerson MS, Cerrato RA: Current management of tarsometatarsal injuries in the athlete. *J Bone Joint Surg* 90-A:2521–2533, 2008.

This instructional course lecture presents the anatomy, clinical presentation, diagnostic imaging, nonoperative and operative management of tarsometatarsal injuries in the athlete. (Level V evidence)

Nunley JA, Vertullo CJ: Classification, investigation, and management of midfoot sprains. Lisfranc injuries in the athlete. *Am J Sports Med* 30(6):871–878, 2002.

This retrospective cohort study utilized weight bearing radiographs and bone scintigrams to diagnose Lisfranc injuries in 15 athletes who were treated operatively versus nonoperatively according to the following classification system: nonoperative management for stage I injuries (nondisplaced) and anatomic reduction with fixation of stage II (diastasis with no arch height loss) and stage III (diastasis with arch height loss) injuries (Figure 1). Excellent outcomes were reported in 93% of their patients. They concluded that weight-bearing radiographs and bone scintigrams are sensitive, reproducible, and relatively inexpensive methods to investigate this injury. Anatomic alignment was the key to excellent functional outcomes.(Level IV evidence)

Peicha G, Labovitz J, Seibert FJ, et al: The anatomy of the joint as a risk factor for Lisfranc dislocation and fracture-dislocation. An anatomical and radiological case control study. *J Bone Joint Surg Br* 84(7):981–985, 2002.

This case control study of 33 patients with Lisfranc injuries evaluated the relationship between the medial and lateral cuneiforms to determine if there were anatomical features that may predispose these patients to injury. The depth of the medial mortise (medial aspect of the tarsometatarsal joint, between the medial cuneiform and the base of the second metatarsal) in patients with injuries to the Lisfranc joint was found to be shallower than the control group. (Level III evidence)

Raikin SM, Elias I, Dheer S, et al: Prediction of midfoot instability in subtle Lisfranc injury. Comparison of magnetic resonance imaging with intraoperative findings. *J Bone Joint Surg Am* 91: 892–899, 2009.

This retrospective review of 21 tarsometatarsal complex injuries correlated conventional MRI with manual stress radiographic evaluation and surgical findings. The strongest predictor of instability, and thus an unstable midfoot, was disruption (rupture or grade 2 sprain) of the plantar ligament between the medial cuneiform and the bases of the second and third metatarsals, with sensitivity, specificity, and positive predictive value of 94%, 75%, and 94%, respectively. The appearance of a normal ligament is suggestive of a stable midfoot. An MRI may alleviate the need for stress radiographic evaluation under anesthesia. (Level II evidence)

Shapiro MS, Wascher DC, Finerman GA: Rupture of Lisfranc's ligament in athletes. *Am J Sports Med* 22: 687–691, 1994.

Nine athletes with Lisfranc ligament disruptions were presented in this retrospective review article. Nonoperative management was successful in returning the athletes back to competition in an average of 4 months. (Level III evidence)

Watson TS, Shurnas PS, Denker J: Treatment of Lisfranc joint injury: Current concepts. *J Am Acad Orthop Surg* 18:718–728, 2010.

This review article outlines current concepts regarding classification, diagnosis, and treatment of injuries to the Lisfranc complex. (Level V evidence)

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6. Watson TS, Shurnas PS, Denker J: Treatment of Lisfranc joint injury: Current concepts. *J Am Acad Orthop Surg* 18:718–728, 2010.
7. Peicha G, Labovitz J, Seibert FJ, et al: The anatomy of the joint as a risk factor for Lisfranc dislocation and fracture-dislocation. An anatomical and radiological case control study. *J Bone Joint Surg Br* 84(7):981–985, 2002.
8. Myerson MS, Cerrato RA: Current management of tarsometatarsal injuries in the athlete. *J Bone Joint Surg* 90-A:2521–2533, 2008.
9. Curtis MJ, Myerson M, Szura B: Tarsometatarsal joint injuries in the athlete. *Am J Sports Med* 21:497–502, 1993.
10. Raikin SM, Elias I, Dheer S, et al: Prediction of midfoot instability in subtle Lisfranc injury. Comparison of magnetic resonance imaging with intraoperative findings. *J Bone Joint Surg Am* 91: 892–899, 2009.

Multiple Choice Questions

QUESTION 1. Which statement is false regarding the tarsometatarsal complex?

A. The Lisfranc ligament is located between the medial cuneiform and the base of the second metatarsal.
B. The plantar ligaments are stronger than the dorsal ligaments.
C. The ligamentous attachment between the first and second metatarsal provides most of the structural support.
D. The base of the second metatarsal is recessed between the medial and lateral cuneiforms.

QUESTION 2. Which imaging modality has limited use in the diagnosis of pure ligamentous tarsometatarsal complex injuries?

A. Weight-bearing radiographs
B. Stress radiographs
C. MRI
D. Bone scintigraphy
E. CT scan

Answer Key

QUESTION 1. Correct answer: **C** (see Intrinsic Factors that Predispose to Injury)

QUESTION 2. Correct answer: **E** (see Imaging Studies)

NONOPERATIVE REHABILITATION OF MIDFOOT SPRAINS (STAGE I LIGAMENTOUS LISFRANC INJURIES)

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GUIDING PRINCIPLES OF REHABILITATION

- Understand:
  - Stage I ligamentous Lisfranc injuries in athletes (see Introduction)
  - Importance of serial radiographs throughout rehabilitation progression
  - Specific intrinsic rehabilitation strengthening exercises for the Lisfranc injury
- Proper selection of exercise and sport-specific progressions
- Provide thorough rehabilitation and treatment so to restore normal foot and lower extremity function
- Patient education regarding injury prevention and footwear modification

Phase I (weeks 0 to 6)

Protection

- Controlled ankle motion (CAM) boot immobilization at all times except for physical therapy–specific exercises
- Weight-bearing as tolerated with crutches. Pain to dictate how much weight.
- Heel lift in the opposite shoe to avoid pelvic asymmetries
- Weight-bearing radiographs at the 2- and 6-week marks. Any diastasis indicates failed nonoperative management.

Management of Pain and Swelling

- Elevate lower leg above heart level
- Nonsteroidal anti-inflammatory drugs (NSAIDs)
- Ice

TIMELINE 43-1: **Nonoperative Rehabilitation of Midfoot Sprains**

PHASE I (weeks 0 to 6)

- Cast (or CAM boot) immobilization, WBAT with crutches
- Cardiovascular conditioning: UBE, pool, bike
- Aquatic therapy: initiated at week 2 starting in shoulder deep water
- Elevated ankle pumps, circles, ABCs
- Using basic LE program with gait training WBAT
- PRICE for inflammation
- LE stretching neighboring joints and proximal joint strengthening core, hip, and knee
- Contralateral limb proprioceptive training
- X-ray at 2 and 6 weeks to determine removal of boot and WB progressions

PHASE II (weeks 6 to 10)

- PWB → WBAT over 1 week with the use of custom orthotic and
- Stiff sole shoe
- Aquatic therapy progressions:
  - Shoulder → waist deep water
  - Double leg → single leg exercises
  - Hop → jump
  - Fast walk → jog → run
- Proprioception progressions:
  - Partial weight bearing → full weight bearing
- Double leg exercise → single leg exercise
- Eyes open → eyes closed
- Level surface → uneven surface
- Perturbations:
  - Submaximal → maximal
  - Slow → fast
  - Known (proactive) → unknown (reactive) patterns
  - Strengthening:
  - Intrinsic foot musculature
  - Gastrocnemius/soleus, tibialis anterior, tibialis posterior and peroneal longus/brevis
  - Strengthening progressions
- Submaximal → maximal intensity
- Short arc → full arc
- Isometric → concentric → eccentric
- Gait training on land (aquatic → land)
- Plyometrics progressions:
  - Aquatic → land
  - In place → forward, backward and lateral over tape
  - Bilateral → Single leg
  - Flat ground → small box (2 inch) gradually increasing the size as needed for particular sport
  - One plane of movement (frontal) → multiple planes of movement (frontal and transverse)
- May begin land and jogging on the treadmill at week 8 if the athlete is able to tolerate
- Weight-bearing radiographs at 10 weeks. Evidence of diastasis is failure of nonoperative intervention.

- Ace wrap/compression
- Ankle pumps, circles, ABCs

Therapeutic Exercises

- Core exercises, upper extremity and contralateral lower extremity strengthening
  - Upper body ergometer is utilized for cardiovascular fitness
- Aquatic therapy: initiated at week 2. Basic progressions as follows:
  - Shoulder → waist deep water
  - Double leg → single leg exercises

Sensorimotor Exercises

- Contralateral limb proprioceptive training including single leg balance
- Early pain-free protected weight-bearing (CAM walker), for proprioceptive input

Milestones/Criterion-Based Rehabilitation Guidelines to Progress to the Next Stage

- Stable radiographic alignment with no evidence of diastasis at 2 and 6 weeks.
- Minimal tenderness with palpation over the Lisfranc complex—progress to Phase II.
- Diastasis indicates failure of nonoperative management.

Phase II (weeks 6 to 10)

Protection

- At 6 weeks, a custom-molded orthosis is prescribed and the athlete is allowed to ambulate in a stiff-soled shoe.
- As weight-bearing is introduced, initially reduce forefoot loading during push off.[1]
- Midfoot taping may assist in plantarflexion of the first ray, which helps to stabilize forefoot and support longitudinal arch in beginning stages of functional training (Figure 43-5).

Management of Pain and Swelling

- Gradual increase in pain-free weight-bearing therapeutic exercise will help to further reduce pain and edema. Continue with elevation as in Phase I. Begin with selective modalities as needed (i.e., ice and electrical stimulation).

TIMELINE 43-1 **Nonoperative Rehabilitation of Midfoot Sprains** (Continued)

PHASE III (weeks 10 to 12)	PHASE IV (weeks 12+)

• Continue progressions per phase II
• Sport-specific training progressions
  • Aquatic → land
  • In-line activity → cutting
  • Wide arching → tighter sharp turns
  • Slow → fast
  • Flat surface → uneven surface
  • Know → unknown game situations
• Progression of plyometrics (sport-specific)
• Rarely the patient is able to return to sport during this phase
	• Assessment of footwear (i.e., cleats and stirrup)
	• Assessment of field as related to footwear (i.e., natural grass vs. artificial turf)
	• A stiff insoled shoe with a custom orthotic should be worn when the athlete returns to sport
	• Continue sport-specific training as needed
	• Return to sport
	• If the athlete is still experiencing pain or unable to progress according to the rehabilitation protocol refer back to MD (orthopaedic foot and ankle specialist)



FIGURE 43-5. Lisfranc taping technique. Tape begins and ends on dorsomedial aspect of the first metatarsal and loops around the heel as pictured. The tape aims to improve plantarflexion of the first ray, as can be seen in the positional relationship versus the second ray in the picture. A horizontal anchor across the midfoot is also shown. *(From Wadsworth DJ, Eadie NT: Conservative management of subtle Lisfranc injury: A case report.* J Orthop Sports Phys Ther *35:154–164, 2005, with permission.)*

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- No joint mobilizations because of emphasis on stabilization of the midfoot

Stretching/Flexibility Techniques for the Musculotendinous Unit

- Gastrocnemius/soleus complex stretching with care not to fulcrum across the midfoot region (i.e., standing wall stretch recommended over long sit towel stretching) (Figure 43-6).
- Continue stretching proximal musculature as needed.



FIGURE 43-6. Ankle dorsiflexion measurement and treatment in weight bearing. Measure how far the athlete can slide foot away, keeping the heel planted, and touch the knee to the wall. Hold the subtalar joint in neutral throughout the test. Measure from tip of the hallux to the wall. *(From Hudson Z: Rehabilitation and return to play after foot and ankle injuries in athletes.* Sports Med Arthrosc Rev *17:203–207, 2009.)*

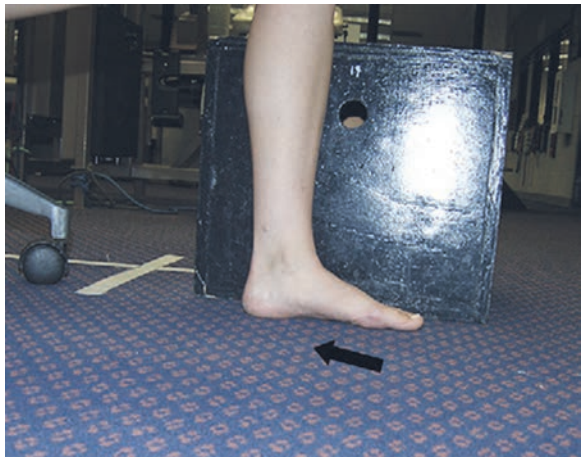

FIGURE 43-7. Short foot exercise contracts the plantar intrinsic muscles. Ask the patient to "cup" the arch upward as a palm of a hand might cup water. Emphasis should be placed on minimizing extrinsic muscle activity. *(From Chin L, Hertel J: Rehabilitation of ankle and foot injuries in athletes.* Clin Sports Med *29:157–167, 2010, with permission.)*

Other Therapeutic Exercises

- Continue core, hip, and knee therapeutic exercise. Treatment adjusted based on residual deficits found in ongoing reevaluations.
- Progression of aquatic therapy regimen—basic progressions as the athlete tolerates:
  - Shoulder → waist-deep water
  - Double leg → single-leg exercises
  - Hop → jump
  - Fast walk → jog → run

Activation of Primary Muscles Involved

- Intrinsic foot muscle strengthening (Figures 43-7 and 43-8):
  - Towel scrunches and marble grabs

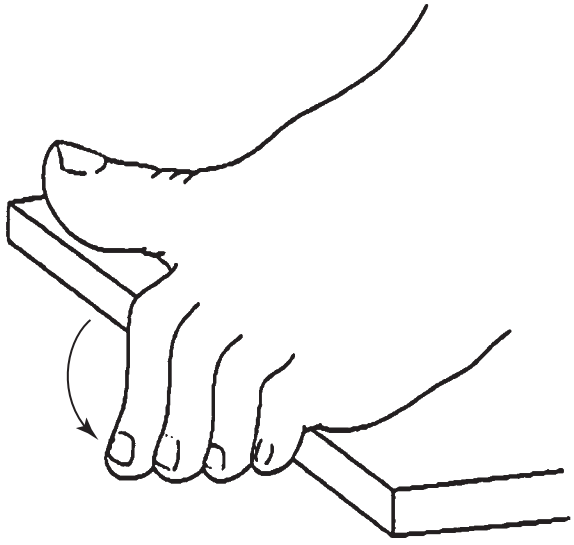

FIGURE 43-8 Intrinsic toe flexors isolation by contracting the extensor hallicus longus to inhibit the ability of the long toe flexors to contract. *(Redrawn from Mulligan E: Leg, ankle and foot rehabilitation. In: Andrews JR, Harrelson GH, Wilk KE, editors.* Physical rehabilitation of the injured athlete, *3rded. Philadelphia, 2004, Saunders, pp. 329-376, withpermission.)*

- Gastrocnemius and soleus:
  - Concentric progressed to eccentric
  - Retrain at heel strike to decelerate tibial internal rotation and control the lower limb moving over the foot.
  - Controlled pronation by gastrocnemius and soleus allows forces to disperse to avoid excessive loading on individual tissues.
- Posterior tibialis:
  - Supination and inversion allow the foot to become a rigid lever for push off, which stabilizes the midtarsal joint in the stance phase.
  - The broad insertion of the posterior tibialis tendon plantar supports the transverse arch.[2]
- Peroneus longus:
  - Supports the transverse arch in the late stage midstance and early heel off
  - Primary function is plantarflexion of the first ray
  - It is the primary stabilizer of the first ray (Figure 43-9).[1]
  - Assists with the transfer of body weight from the lateral to the medial side of the foot by everting the foot[2]

Sensorimotor Exercises

- Proprioception progressions: Particular exercises are selected based on the athletes' stage and progression. Begin gentle and progress with objectively demonstrated tolerance:
  - Partial weight bearing → full weight bearing
  - Double leg exercise → single leg exercise
  - Eyes open → eyes closed
  - Level surface → uneven surface
  - Shoes on → shoes off
  - Perturbations:
    - Submaximal → maximal
    - Slow → fast
    - Known (proactive) → unknown (reactive) patterns



FIGURE 43-9. Isometric contraction of the first metatarsal head into the ground while maintaining longitudinal arch for peroneus longus strengthening. *(From Wadsworth DJ, Eadie NT: Conservative management of subtle Lisfranc injury: A case report.* J Orthop Sports Phys Ther *35:154–164, 2005.)*

Open and Closed Kinetic Chain Exercises

- Principles of therapeutic exercise parameter progressions are based on the athlete's progress. Refer to the muscle activation section for specific exercises.
  - Submaximal → maximal intensity
  - Short arc → full arc
  - Isometric → concentric → eccentric
- OKC exercises:
  - Plantarflexion (gastrocnemius/soleus)
  - Dorsiflexion (tibialis anterior)
  - Inversion (tibialis posterior)
  - Eversion (peroneal longus/brevis)
- CKC exercises:
  - Heel raises (gastroc/soleus)
  - Exercises using an unstable surface
  - Kinetic chain exercises

Techniques to Increase Muscle Strength, Power, and Endurance

Neuromuscular Dynamic Stability Exercises

- Single leg stance on foam/disc with opposite limb moving against band resistance × 4 cardinal planes
- Lunging into disc/foam
- Lunge off elevated surface for increased loading

Plyometrics

- Initial plyometric type exercises are started in aquatic therapy (i.e., hop, jump)
- Jumping
- In place → forward, backward, and lateral over tape
- Flat ground → small box (2-inch) gradually increasing the size as needed for particular sport
- Bilateral → single leg
- One plane of movement (frontal) → multiple planes of movement (frontal and transverse)

Functional Exercises

- Gait training with use of aquatic therapy and treadmill training.
- Combine movements and various challenges to improve functional strength and proprioception (Figure 43-10)

Sport-Specific Exercises

- May begin sport-specific drills utilizing aquatic therapy
- The athlete may initiate running at 8 weeks when he or she has achieved full pain-free ROM, strength, balance, and normalization of gait mechanics. In our experience, the athlete typically is unable to begin these progressions on land until 10 weeks postinjury.
  - Jogging → running → sprints

Milestones/Criterion-Based Rehabilitation Guidelines to Progress to the Next Stage

- Pain-free activity
- Full ROM, balance and strength
  - Star excursion balance test criteria: pain free activity, no diastasis on follow-up weight-bearing radiographs, normalization of gait mechanics with normal forefoot loading during push-off.

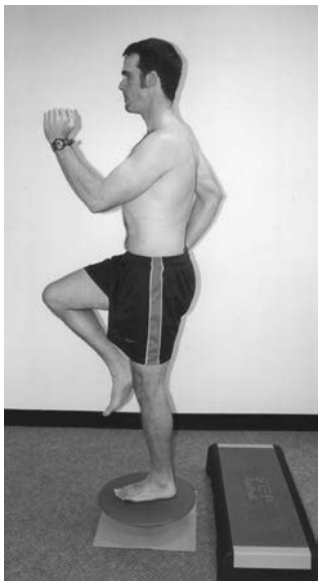

FIGURE 43-10. "Running Man." This exercise combines proprioception and gluteal strengthening with contraction of the peroneus longus and tibialis posterior. The stance foot can be on a multiplane board (start with flat surface) while the other foot is on a step. The athlete performs a running action using hip and knee flexion while swinging the arms and focusing on contracting the gluteals by maintaining neutral pelvis height and preventing internal rotation of stance leg. The swing phase leg should be going through hip and knee flexion without rotation or abduction. It is important that an athlete is able to isolate the gluteal activation independently before performing this exercise. *(From Wadsworth DJ, Eadie NT: Conservative management of subtle Lisfranc injury: A case report.* J Orthop Sports Phys Ther *35:154–164, 2005, with permission.)*

  - Strength testing: manual muscle testing, isometric, isotonic and isokinetic strength testing, single leg calf raises with knee extended and flexed.
  - Muscle groups: dorsiflexion, plantarflexion, eversion, inversion
- Normalization of gait mechanics
- Tolerates initial sport-specific exercises
- No evidence of diastasis on follow-up weight-bearing radiographs

Phase III (weeks 10 to 12)

Protection

Continued custom orthotic use for support of tarsometatarsal complex.

Techniques for Progressive Increase in Range of Motion

Stretching/Flexibility Techniques for the Musculotendinous Unit

- Continued stretching per Phase II. Serial assessments will guide specific changes.

Other Therapeutic Exercises

- Functional sport-specific strengthening
  - Core—planks, side planks, quadruped UE/LE lifts, therapeutic activity progressions, Pilates-based abdominal series and hip series: hundreds, roll up, single and double leg stretch, hip circles, hip abduction and flexion/extension, hip passes

Activation of Primary Muscles Involved

- Continue specific muscle strengthening per Phase II as needed

Sensorimotor Exercises

- Proprioception progressions per Phase II with emphasis on perturbation and sport-specific training
  - Perturbations
    - Submaximal → maximal
    - Slow → fast
    - Known (proactive) → unknown (reactive) patterns
  - Sport specific
    - Known → unknown game situations
- Open (OKC) and closed (CKC) kinetic chain exercises:
  - Sport-specific OKC and CKC strengthening (Figures 43-11 and 43-12)

Techniques to Increase Muscle Strength, Power, and Endurance

Neuromuscular Dynamic Stability Exercises

- Plyometrics:
  - Sport-specific hopping and jumping exercises. Progress per Phase II.
- Functional exercises:
  - Agility ladder drills
  - Box jumps—double leg to single leg—varying heights
- Sport-specific exercises:
  - Varies depending on the particular sport. Here are the general guidelines for progression in a pain-free manner:



FIGURE 43-11. Closed kinetic chain foot therapeutic exercise.



FIGURE 43-12. Open and closed kinetic chain therapeutic exercise for entire lower extremity.

- Aquatic → land
- In-line activity → cutting
  - Wide arching → tighter sharp turns
  - Slow → fast
- Flat surface → uneven surface
- Known → unknown game situations

Milestones/Criterion-Based Rehabilitation Guidelines to Progress to the Next Stage

- Pain-free sport-specific activity
- Occasionally the athlete is able to return to his or her respective sport before 12 weeks. We allow this on a case-by-case basis provided the athlete is able to demonstrate pain-free activity and has no limitations with functional and sports-specific drills.

Phase IV (greater than weeks 12): Return to Function/Sport

Protection

- Assessment of footwear (i.e., cleats and stirrup)
- Assessment of field as related to footwear (i.e., natural grass vs. artificial turf)
- A stiff-soled shoe should be worn to provide midfoot stability.
- Continued use of custom orthotics

Therapeutic Exercises

- Continue functional sport-specific strengthening as needed.
- Sport-specific balance and proprioception stimulation as needed
- Sport specific open and closed chain therapeutic exercise as needed
- Increase muscle strength, power, and endurance: Continue per Phase III.
- Neuromuscular dynamic stability exercises: Continue per Phase III.
- Sport-specific plyometric training as needed
- Functional exercises mimicking the sport-specific movements as needed
- Sport-specific exercises mimicking the sport-specific movements as needed

Milestones for Progression to Advanced Sport-Specific Training and Conditioning

- Demonstrates proficiency in initial sport-specific training drills
- Pain-free sport specific training drills

Criteria for Abandoning Nonoperative Treatment and Proceeding to Surgery or Other More Invasive Intervention

- Diastasis noted on serial weight-bearing radiographs
- Persistent pain and dysfunction with inability to progress through rehabilitation protocol

Transition to Performance Enhancement: Tips and Guidelines

- Once pain is eliminated and full sport tolerance is achieved, established performance enhancement concepts may be applied to the athlete's training.

Performance Enhancement and Beyond Rehab: Training/Trainer, and Optimization of Athletic Performance

- Performance enhancement will depend on the athlete's sport. Advanced, sport-specific plyometrics is an example of appropriate performance enhancement for running, cutting, and jumping sports. Typically Phases III and IV are performed by the athlete in conjunction with the team trainer, with serial assessments from the treating physician and physical therapist.

Specific Criteria for Return to Sports Participation: Tests and Measurements

- Serial weight-bearing radiographs without evidence of diastasis or instability
- Pain-free sport-specific drills

Evidence

Chin L, Hertel J: Rehabilitation of ankle and foot injuries in athletes. *Clin Sports Med* 29:57–167, 2010.

This article details the general principles associated with rehabilitation of ankle and foot injuries in the athlete. Many of the therapeutic exercises and other treatments proposed for common foot/ankle injuries can be applied to midfoot sprains. (Level V evidence)

Curtis MJ, Myerson M, Szura B: Tarsometatarsal joint injuries in the athlete. *Am J Sports Med* 21:497–502, 1993.

This study was a retrospective review of 19 patients who injured the tarsometatarsal joint complex during athletic competition. Stress fluoroscopy of the articulation under anesthesia was used to supplement clinical and radiographic examination. Poor functional results were seen in those where diagnosis was delayed and inadequately treated unstable injuries with nonoperative immobilization. (Level III evidence)

DeOrio M, Erickson M, Usuelli FG, et al: Lisfranc injuries in sport. *Foot Ankle Clin North Am* 14:169–186, 2009.

This article reviews anatomy, classification, diagnosis, and treatment of Lisfranc injuries in sport. In addition, the authors' preferred operative technique is discussed in detail. (Level V evidence)

McKeon PO, Hertel J: Systematic review of postural control and lateral ankle instability, part II: Is balance training clinically effective? *J Athl Train* 43(3);305–315, 2008.

This study is a systematic review to see if prophylactic balance and coordination training can reduce risk of lateral ankle sprains, improve treatment outcomes associated with acute lateral ankle sprains, and improve outcomes in patients with chronic ankle instability. This study showed that balance training can be used prophylactically or after acute ankle strains to help reduce further ankle sprains, but unable to determine the effectiveness with outcomes of chronic ankle sprains. (Level V evidence)

Meyer SA, Callaghan JJ, Albright JP, et al: Midfoot sprains in collegiate football players. *Am J Sports Med* 22:392–401, 1994.

This retrospective study of 23 collegiate football players demonstrated an incidence of 4% of football players per year, with 29.2% of these players offensive lineman. The patients were followed for a mean of 30.8 months and most, despite a prolonged restriction from activity, reported minor residual problems. (Level III evidence)

Myerson MS, Cerrato RA: Current management of tarsometatarsal injuries in the athlete. *J Bone Joint Surg* 90-A:2521–2533, 2008.

This instructional course lecture presents the anatomy, clinical presentation, diagnostic imaging, and nonoperative and operative management of tarsometatarsal injuries in the athlete. (Level V evidence)

Nunley JA, Vertullo CJ: Classification, investigation, and management of midfoot sprains. Lisfranc injuries in the athlete. *Am J Sports Med* 30(6):871–878, 2002.

This retrospective cohort study used weight-bearing radiographs and bone scintigrams to diagnose Lisfranc injuries in 15 athletes who were treated operatively versus nonoperatively according to the following classification system: nonoperative management for stage I injuries (nondisplaced) and anatomical reduction with fixation of stage II (diastasis with no arch height loss) and stage III (diastasis with arch height loss) injuries. Excellent outcomes were reported in 93% of their patients. They concluded that weight-bearing radiographs and bone scintigrams are sensitive, reproducible and relatively inexpensive methods to investigate this injury. Anatomic alignment was the key to excellent functional outcomes. (Level IV evidence)

Shaffer PT, Shaffer MA, Okereke E, et al: Effects of immobilization on plantar-flexion torque, fatigue resistance and functional ability following an ankle fracture. *Phys Ther* 80:769–780, 2000.

Study to investigate the effects of 8 weeks of immobilization on plantarflexion peak torque, fatigue resistance and functional ability (walking, stairs). They found decreased performance and functional ability after 8 weeks immobilization which can be reversed in 10 weeks of supervised physical therapy. (Level II evidence)

Shapiro MS, Wascher DC, Finerman GA: Rupture of Lisfranc's ligament in athletes. *Am J Sports Med* 22:687–691, 1994.

Nine athletes with Lisfranc ligament disruptions were presented in this retrospective review article. Nonoperative management was successful in returning the athletes back to competition in an average of 4 months. (Level III evidence)

Wadsworth DJ, Eadie NT: Conservative management of subtle Lisfranc Injury: A case report. *J Orthop Sports Phys Ther* 35: 154–164, 2005.

This is a case report that outlines the rehabilitation of a grade 1 Lisfranc injury in a 21-year-old professional basketball player. The authors report successful treatment included restricted activities, orthotic management, normalization of gait pattern, proprioceptive retraining, taping, and graduated return to sport. The athlete returned to sport 12 weeks post injury. Two year follow-up found no symptoms or restrictions in sport performance. (Level IV evidence)

Watson TS, Shurnas PS, Denker J: Treatment of Lisfranc joint injury: Current concepts. *J Am Acad Orthop* 18:718–728, 2010.

This review article summarizes the current concepts associated with Lisfranc injuries. It details the anatomy, mechanisms of injury, classifications, and diagnosis and nonoperative and operative management. (Level V evidence)

REFERENCES

1. Wadsworth DJ, Eadie NT: Conservative management of subtle Lisfranc Injury: A case report. *J Orthop Sports Phys Ther* 35:154–164, 2005.
2. Watson, TS, Shurnas, PS, Denker J: Treatment of Lisfranc joint injury: Current concepts. *J Am Acad Orthop* 18:718–728, 2010.

Multiple Choice Questions

QUESTION 1. What are common mechanisms of injury for a Lisfranc injury?

A. Axial longitudinal force sustained while the foot is plantarflexed and slightly rotated
B. Forced dorsiflexion
C. External rotation—stirrup
D. Internal rotation
E. Both a and c

QUESTION 2. When can an athlete return to sports after a stage I Lisfranc injury?

A. 12 weeks
B. 2 to 4 weeks
C. 5 to 7 weeks
D. 6 months

QUESTION 3. An example of strengthening for foot intrinsic muscles is:

A. aquatic therapy running
B. plyometrics
C. toe curls/scrunches
D. peroneal strengthening with Thera-Band.

QUESTION 4. Choose the best way to avoid placing a fulcrum over the midfoot during calf stretching.

A. In long sitting, wrap the stretching strap over the metatarsal heads instead of the midfoot
B. Stretch the soleus more than the gastrocnemius
C. In standing, place the involved foot behind with knee extended
D. Keep the subtalar joint in neutral during the calf stretch

Answer Key

QUESTION 1. Correct answer: **E** (see Introduction)

QUESTION 2. Correct answer: **A** (see Phase III)

QUESTION 3. Correct answer: **C** (see Phase II)

QUESTION 4. Correct answer: **C** (see Phase II)

POSTOPERATIVE REHABILITATION OF MIDFOOT SPRAINS (STAGE II-III LIGAMENTOUS LISFRANC INJURIES)

Eric R. Schweitzer, DPT, OCS, MTC, Lacy D. Jennings, DPT, SCS, MTC, Mark E. Easley, MD, and Jason M. Jennings, MD, DPT

Indications for Surgical Treatment

- Diastasis between the first and second metatarsals, based on weight-bearing radiographs.
- Asymmetry compared with contralateral foot.
- Failed nonoperative management of apparently stable Lisfranc injuries.
  - Empirically we have found that open reduction and internal fixation (in lieu of tarsometatarsal arthrodesis) may still be feasible up to 4 to 6 months postinjury.

Brief Summary of Surgical Technique

Percutaneous Fixation for Isolated Stage II and III Lisfranc Injuries

- Supine position with calf tourniquet
- Fluoroscopic guidance
- Pointed reduction clamp for reduction with the points positioned at the lateral aspect of the base of the second metatarsal and the medial aspect of the cuneiform (Figure 43-13)
- If the joint is anatomically reduced, a fully threaded percutaneous 3.5-mm screw is placed from the medial cuneiform to the base of the second metatarsal (Figure 43-14)
- If anatomical reduction is not possible via percutaneous attempts, convert to an open approach.



FIGURE 43-13. In the authors' preferred technique of percutaneous reduction, a large, pointed reduction clamp is used. *(From DeOrio M, Erickson M, Usuelli FG, Easley M: Lisfranc injuries in sport.* Foot Ankle Clin North Am *14:169–186, 2009, Figure 3, with permission.)*



FIGURE 43-14. Anteroposterior radiograph demonstrating complete reduction of the diastasis in a collegiate lacrosse player. *(From DeOrio M, Erickson M, Usuelli FG, Easley M: Lisfranc injuries in sport.* Foot Ankle Clin North Am *14:169–186, 2009, Figure 9, with permission.)*



FIGURE 43-15. K-wires are used to assist with provisional fixation. *(From DeOrio M, Erickson M, Usuelli FG, Easley M: Lisfranc injuries in sport.* Foot Ankle Clin North Am *14:169–186, 2009, Figure 6, with permission.)*

Open Reduction Internal Fixation for Isolated Stage II and III Lisfranc Injuries

- The joint is exposed through the interval between the extensor hallucis longus tendon and the deep neurovascular bundle located immediately deep to the extensor hallucis brevis tendon.
- The dorsal interosseous ligaments will be visibly torn.
- Rongeur to remove tissue deep within articulation between the medial cuneiform and the base of the second metatarsal, allowing anatomical reduction with a pointed reduction clamp per the preceding.
- Use K-wires for provisional fixation (Figure 43-15).
- Once anatomical reduction achieved, place a guide wire from the medial cuneiform to the base of the second metatarsal.
- The authors recommend making a 1- to 2-cm incision for placing this guide pin to retract the tibialis anterior tendon to be certain it is not injured during drilling and screw insertion.
- A cannulated drill is used over the guide pin.
- Although the authors use a cannulated drill system to create the drill hole, they prefer to use a stronger solid screw for fixation.
- An appropriate-length screw is advanced from the medial cuneiform to the base of the second metatarsal.

Factors That May Affect Details of Rehabilitation

- Plate fixation that spans the affected joints without violating the articular surfaces may minimize additional iatrogenic trauma. This may allow for earlier postoperative range of motion.
- Although the authors prefer open reduction and internal fixation (ORIF) over arthrodesis, purely ligamentous injuries or severely comminuted fracture-dislocations may have better outcomes if treated with arthrodesis.

Phase I (postoperative weeks 1 to 2)

Goals

- Protect the healing tissue.
- Control pain and swelling.
- Minimize the effects of immobilization.

Clinical Pearl

> Encourage activities that do not stress the healing tissues but still allow the athlete to move his/her proximal tissues (i.e., core and contralateral lower and bilateral upper extremity activities).

Protection

- Strict non–weight bearing (NWB) with crutches
- The authors typically place postoperative patients in a controlled ankle motion (CAM) walker (worn at all times) with the ankle in neutral dorsiflexion. If compliance is in question, then the patient is placed in a short leg cast.

Treatment of Pain and Inflammation

- Elevate lower leg above heart level
- Ice
- Modalities (electrical stimulation)
- ACE wrap/compression
- Nonsteroidal anti-inflammatory drugs (NSAIDs) and oral narcotics as needed

Techniques for Progressive Increase in Range of Motion

Stretching/Flexibility Techniques for the Musculotendinous Unit

- NWB: lower kinetic chain stretching as needed. No active or passive stretching of muscles crossing the foot and/or ankle

Other Therapeutic Exercises

- The athlete is encouraged to continue with core abdominal exercises and upper and contralateral lower extremity strengthening.
- Upper body ergometer (UBE) is utilized for cardiovascular fitness.

Sensorimotor Exercises

- Contralateral limb proprioceptive training including single leg balance

Milestones/Criterion-Based Rehabilitation Guidelines to Progress to the Next Phase

- Stable postoperative radiographs

Phase II (postoperative weeks 2 to 6)

Goals

- Protect the healing tissue.
- Control pain and swelling.
- Minimize the effects of immobilization.
- Stable radiographs week 6

Protection

- NWB with CAM walker or cast
- Crutches

Treatment for Pain/Analgesia

- NSAIDs

Treatment to Decrease Swelling

- Lower leg elevation above heart level
- Ice
- Modalities (electrical stimulation)
- ACE wrap/compression

Techniques for Progressive Increase in Range of Motion

Stretching/Flexibility Techniques for the Musculotendinous Unit

- Continue as per Phase I

Other Therapeutic Exercises

- Continue as per Phase I

Milestones/Criterion-Based Rehabilitation Guidelines to Progress to the Next Phase

- Stable postoperative radiographs

Phase III (postoperative weeks 6 to 10)

Goals

- Protect the healing tissue.
- Control pain and swelling.
- Minimize the effects of immobilization.
- Stable weight-bearing radiographs week 10

Protection

- NWB in a CAM walker
- If the patient was previously in a cast, then this is transitioned to a CAM walker.

Treatment for Pain/Analgesia

- Continue with selective modalities as needed (i.e., ice and electrical stimulation).
- NSAIDs as needed

Treatment to Decrease Swelling

- Continue with ice and elevation as in Phases I and II
- Ankle pumps, circles, ABCs

Techniques for Progressive Increase in Range of Motion

Soft Tissue Techniques

- Gentle techniques that help with reducing edema and mobilizing scar tissue once soft tissue scar healing has occurred

Stretching/Flexibility Techniques for the Musculotendinous Unit

- Continue as per phases I and II
- Gentle ankle and toe range of motion (ROM) at 6 weeks

Other Therapeutic Exercises

- Continue as per Phases I and II

Milestones/Criterion-Based Rehabilitation Guidelines to Progress to the Next Phase

- Stable weight-bearing postoperative radiographs

Phase IV (postoperative weeks 10 to 14)

Goals

- Protect the healing tissue: gradual transfer into partial weight bearing (PWB) followed by full weight bearing (FWB) with a custom orthotic and a stiff-soled shoe.
- Gradual restoration of gastrocnemius/soleus muscle length
- Initiate ankle/foot therapeutic exercises for strengthening and dynamic stability.
- Begin restoration of ankle/foot proprioception.

Clinical Pearl

- Gradually progress from PWB to FWB using a stiff-soled shoe and custom orthotic as well as taping as needed.
- Avoid passive towel stretches to gastrocnemius/soleus to avoid placing a fulcrum at the Lisfranc joint.

Protection

- Begin PWB (one-third body weight) in CAM walker at postoperative week 10
- PWB (two-thirds body weight) in CAM walker postoperative week 11
- FWB in a stiff-soled shoe with a custom orthotic postoperative week 12
- Midfoot taping may assist in plantarflexion of first ray, which helps to stabilize forefoot and support longitudinal arch in beginning stages of gait and functional training. Taping is not initiated until adequate soft tissue healing (scar) has occurred (see Figure 43-5).

Treatment for Pain/Analgesia

- NSAIDs as needed
- If significant pain is a limiting factor, return to physician for evaluation.
- Ice and modalities as needed

Treatment to Decrease Swelling

- Ice
- Compression
- Elevation

TIMELINE 43-2: **Postoperative Rehabilitation of Stage II to III Ligamentous Lisfranc Injuries**

PHASE I (weeks 1 to 2)	PHASE II (weeks 2 to 6)	PHASE III (weeks 6 to 10)
• NWB • CAM walker (cast for noncompliant patients) • PRICE and NSAIDs for inflammation	• NWB • CAM walker • Radiographs week 6	• NWB • CAM walker • If previously in a cast, then this is transitioned to a CAM walker • Gentle ankle and toe ROM • Weight-bearing radiographs week 10

- Ankle pumps, circles, ABCs
- Progressive weight bearing

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- No joint mobilizations due to emphasis on stabilization of the midfoot
- May perform talocrural joint mobilizations as needed to gain ankle joint mobility

Soft Tissue Techniques

- Gentle techniques that help with reducing edema and mobilizing scar tissue (respect soft tissue healing)

Stretching/Flexibility Techniques for the Musculotendinous Unit

- Gastrocnemius/soleus complex stretching with care not to create a fulcrum across midfoot region (recommend standing gastrocnemius wall stretch and weight bearing lunge stretch over long sitting towel stretch) (see Figure 43-6)
- Continue with proximal musculature stretching as needed

Other Therapeutic Exercises

- Begin aquatic therapy regimen—basic progressions as follows:
  - Shoulder → waist deep water
  - Double leg → single leg exercises
- Progress upper and lower extremity and core exercises as the athlete tolerates

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Intrinsic foot exercises starting at postoperative weeks 10 to 12
  - Towel scrunches/marble grabs
  - Intrinsic foot muscle strengthening (see Figure 43-7)
  - Isometric contraction of the first metatarsal head into the ground for peroneus longus strengthening (see Figure 43-9)
  - Intrinsic toe flexors isolation by contracting the extensor hallices longus to inhibit the ability of the long toe flexors to contract (see Figure 43-8)
- Gastrocnemius and soleus
  - Concentric progressing to eccentric
  - Retrain at heel strike to decelerate tibial internal rotation and control the lower limb moving over the foot

TIMELINE 43-2 **Postoperative Rehabilitation of Stage II to III Ligamentous Lisfranc Injuries** (Continued)

PHASE IV (weeks 10 to 14)

- Begin PWB (1/3 body weight) in CAM walker at postoperative week 10
- PWB (2/3 body weight) in CAM walker postoperative week 11
- FWB in stiff-soled shoe with custom orthotic
- Avoid fulcrum type force across the Lisfranc joint with stretching (i.e. towel stretch and strengthening)
- Talocrural mobilizations as needed to gain full ankle ROM
- Scar tissue mobilizations
- Intrinsic foot strengthening
- Extrinsic foot strengthening
- OKC/CKC progressions
  - Submaximal → maximal intensity
  - Short arc → full arc
  - Isometric → concentric → eccentric
- Aquatic therapy progressions
  - Shoulder → waist deep water
  - Double leg → single leg exercises
- Proprioception progressions
  - Sitting → standing
  - Partial weight-bearing → full weight-bearing
  - Double leg exercise → single leg exercise
  - Eyes open → eyes closed
- Gait training (aquatic → land)

PHASE V (weeks 14 to 24)

- Weight-bearing radiographs week 16 and 20
- Continued use of custom orthotic and stiff-soled shoe
- Begin running 20 weeks (aquatic → land) after hardware removal
- Aquatic therapy progression
  - Hop → jump
  - Fast walk → jog → run
- Continued proprioceptive progressions
  - Level surface → uneven surface
  - Shoes on → shoes off
  - Perturbations
  - Submaximal → maximal
  - Slow → fast
  - Known (proactive) → unknown (reactive) patterns
- Plyometrics
  - Aquatic → land
  - Bilateral → single leg
  - Jumping in place → forward, backward, and lateral over tape
  - Flat ground → small box (2-inch) gradually increasing the size as needed for particular sport
  - One plane of movement (frontal) → multiple planes of movement (frontal and transverse) → sport-specific drills
- Sport-specific activity at 20 weeks—after hardware removal
- Aquatic → land
- Jogging → running → sprints
- In-line activity → cutting
- Wide arching → tighter sharp turns
- Slow → fast
- Flat surface → uneven surface
- Known → unknown game situations

PHASE VI (weeks 24 to 52)

- Weight-bearing radiographs week 24
- If no evidence of reduction loss may return to full unrestricted athletics with the use of custom orthotic and a stiff-soled shoe

  - Controlled pronation by gastrocnemius and soleus allows forces to disperse to avoid excessive loading on individual tissues
- Posterior tibialis
  - Supination and inversion turns the foot into a rigid lever for push off. These actions also assist with stabilization of the midtarsal joints in stance phase.
  - The broad insertion of the posterior tibialis tendon plantar supports the transverse arch.[2]
- Peroneus longus
  - Supports the transverse arch in the late stage midstance and early heel off
  - Primary function is plantarflexion of the first ray
  - It is the primary stabilizer of the first ray.[1]
  - Assists with the transfer of body weight from the lateral to the medial side of the foot by everting the foot.[2]

Sensorimotor Exercises

- Per weight-bearing restrictions, progress week by week until able to fully bear weight
  - Proprioception progressions: Particular exercises are selected based on the athlete's stage and progression. Begin gentle and progress with objectively demonstrated tolerance:
    - Sitting → standing
    - Partial weight bearing → full weight bearing
    - Double leg exercise → single leg exercise
    - Eyes opened → eyes closed

Open and Closed Kinetic Chain Exercises

- Progress per weight-bearing status: use crutches or assistance with PWB and progress to FWB.
  - Principles of therapeutic exercise parameter progressions are based on the athlete's progress. Refer to the muscle activation section for specific exercises.
    - Submaximal → maximal intensity
    - Short arc → full arc
    - Isometric → concentric → eccentric
    - OKC exercises:
      - Plantarflexion (gastrocnemius/soleus)
      - Dorsiflexion (tibialis anterior)
      - Inversion (tibialis posterior)
      - Eversion (peroneal longus/brevis)
    - CKC exercises:
      - Heel raises (gastrocnemius/soleus)
      - Exercises using an unstable surface (see Figure 43-11)
      - Kinetic chain exercises (see Figure 43-12)

Techniques to Increase Muscle Strength, Power, and Endurance

- Per OKC/CKC progressions
- Bike, UBE, elliptical

Milestones/Criterion-Based Rehabilitation Guidelines to Progress to the Next Phase

- Stable postoperative radiographs
- Normal ROM, flexibility, and strength
- Minimal pain with FWB
- Normalizing gait

Phase V (postoperative weeks 14 to 24)

Goals

- Progression of proprioceptive and therapeutic exercise from Phase IV
- Stable weight-bearing radiographs weeks 16, 20, and 24
- Initiate plyometrics after hardware removal
- Begin sport-specific drills after hardware removal
- Initiate return to running program after hardware removal

Protection

- Assessment of footwear (i.e., cleats and stirrup)
- Assessment of field as related to footwear (i.e., natural grass vs. artificial turf)
- A stiff-soled shoe should be worn to provide midfoot stability.
- Continued use of custom orthotics

Treatment for Pain/Analgesia

- Ice and modalities as needed
- NSAIDs as needed

Techniques to Decrease Swelling

- Ice and modalities as needed

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- As per Phase IV

Soft Tissue Techniques

- As per Phase IV

Stretching/Flexibility Techniques for the Musculotendinous Unit

- As per Phase IV

Other Therapeutic Exercises

- We typically will not progress to the higher-intensity aquatic therapy progressions below until after hardware removal at 20 weeks:
  - Hop → jump
  - Fast walk → jog → run
- Progress upper and lower extremity and core exercises as the athlete tolerates.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

Continue with exercises in Phase IV, progress as tolerated

BOX 43-1 Gradual Return to Running Program

Guidelines

1. Do every other day only (i.e., do not run daily).
2. Use running shoes when running (not court or cross trainers).
3. Begin at an easy pace on level surfaces, no hills.
4. Stop if you experience increasing excessive pain, swelling or stiffness, especially the next morning.
5. Try the phase at least twice. Progress to next phase if no increased pain, swelling or stiffness.
6. After Phase VIII: gradually increase your running without walking.

Phase I: Walk 2 miles at your own pace.

Phase II: Progress to walking 2 miles in 35 minutes.

Phase III (miles)	Walk 1/4	Run 1/4	Walk 1/4	Run 1/4				
Phase IV (miles)	Walk 1/4	Run 1/4	Walk 1/4	Run 1/4	Walk 1/4	Run 1/4	Walk 1/4	Run 1/4
Phase V (miles)	Walk 1/4	Run 1/2	Walk 1/4	Run 1/2	Walk 1/4	Run 1/2		
Phase VI (miles)	Walk 1/4	Run 3/4	Walk 1/4	Run 3/4				
Phase VII (miles)	Walk 1/4	Run 1	Walk 1/4	Run 1				

Sensorimotor Exercises

- Continue per Phase IV with advancement of proprioceptive progressions:
  - Level surface → uneven surface
  - Shoes on → shoes off
  - Perturbations
    - Submaximal → maximal
    - Slow → fast
    - Known (proactive) → unknown (reactive) patterns

Open and Closed Kinetic Chain Exercises

- Progress as per Phase IV

Techniques to Increase Muscle Strength, Power, and Endurance

- Progress as per Phase IV

Neuromuscular Dynamic Stability Exercises

- Progress as per Phase IV

Plyometrics

- Begin after removal of hardware (≈20 weeks).
- Initial plyometric type exercises are started in aquatic therapy (i.e., hop, jump).
- Progressions are slow, controlled, and advanced when the athlete demonstrates completion of a specific drill without compensation.
  - Bilateral → single leg
  - Jumping in place → forward, backward, and lateral over tape.
  - Flat ground → small (2-inch) box gradually increasing the size as needed for particular sport.
  - One plane of movement (frontal) → multiple planes of movement (frontal and transverse) → sport-specific drills

Functional Exercises

- Intertwine exercise principles from above with sport-specific movements (see Figure 43-10)

Sport-Specific Exercises

- We begin jogging/running after hardware removal at approximately week 20. Initiating a running program before hardware removal places the athlete at risk for subsequent hardware failure and/or loss of reduction. Running is initiated with aquatic therapy with the transition to land as the athlete tolerates. The return to running program we utilize is outlined in Box 43-1.
- Sport-specific activity such as cutting drills may begin after hardware removal at 5 months. Typically, secondary to the immediate postoperative period this occurs at around 5½ months.
- Return to sport is allowed at 6 months, but this will vary depending on the particular sport. Here are the general guidelines for progression in a pain-free (or minimal pain) manner.
  - Aquatic → land
  - Jogging → running → sprints
  - In-line activity → cutting
    - Wide arching → tighter sharp turns
    - Slow → fast
  - Flat surface → uneven surface
  - Known → unknown game situations

Milestones/Criterion-Based Rehabilitation Guidelines to Progress to the Next Phase

- Stable postoperative radiographs (weight-bearing) weeks 16, 20, 24
- The athlete may return to sport if he or she meets the return to sport criteria (see the following); otherwise, selective rehabilitation is continued.

Phase VI (postoperative weeks 24 to 52)

Goals

- Stable weight-bearing radiographs week 24
- Return to sport based on radiographs and physical performance during sport-specific training.
- Continue with progressions from Phase V

Protection

- Continued use of custom orthotic and stiff-soled shoe

Techniques for Progressive Increase in Range of Motion

Stretching/Flexibility Techniques for the Musculotendinous Unit

- Continue flexibility throughout lower extremity as needed

Other Therapeutic Exercises

- Continue as per Phase V

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Continue as per Phase V

Sensorimotor Exercises

- Continue as per Phase V

Open and Closed Kinetic Chain Exercises

- Continue as per Phase V

Techniques to Increase Muscle Strength, Power, and Endurance

- Continue as per Phase V

Neuromuscular Dynamic Stability Exercises

- Continue as per Phase V

Plyometrics

- Continue as per Phase V

Functional Exercises

- Continue as per Phase V

Sport-Specific Exercises

- Continue as per Phase V

Criteria for Return to Sport

- Stable postoperative radiographs
  - Weight-bearing radiographs with no loss of reduction
- Appropriate protective footwear
  - Custom orthotic
  - Stiff-soled shoe
  - Assessment of footwear (i.e., cleats)
  - Assessment of field as related to footwear (i.e., natural grass vs. artificial turf)
- Able to perform sports-specific drills
  - In our experience, the athlete will still experience some discomfort in the area of the Lisfranc complex initially, but this usually resolves with time.
- Specific criteria for return to sport are analyzed by the rehabilitation specialist for each athlete. The athlete is thoroughly tested to assure readiness for return to preinjury levels of activity.

After Return to Sport

Continuing Fitness or Rehabilitation Exercises

- Sport-specific fitness and lower kinetic chain exercises

Exercises and Other Techniques for Prevention of Recurrent Injury (see Box 43-1)

- Custom orthotics
- Stiff-soled shoe
- Assessment of footwear (i.e., cleats)
- Assessment of field as related to footwear (i.e., natural grass vs. artificial turf)

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This instructional course lecture presents the anatomy, clinical presentation, diagnostic imaging, and nonoperative and operative management of tarsometatarsal injuries in the athlete. (Level V evidence)

Nunley JA, Vertullo CJ: Classification, investigation, and management of midfoot sprains. Lisfranc injuries in the athlete. *Am J Sports Med* 30(6):871–878, 2002.

This retrospective cohort study used weight-bearing radiographs and bone scintigrams to diagnose Lisfranc injuries in 15 athletes who were treated operatively versus nonoperatively according to the following classification system: nonoperative management for stage I injuries (nondisplaced) and anatomical reduction with fixation of stage II (diastasis with no arch height loss) and stage III (diastasis with arch height loss) injuries. Excellent outcomes were reported in 93% of their patients. They concluded that weight-bearing radiographs and bone scintigrams are sensitive, reproducible, and relatively inexpensive methods to investigate this injury. Anatomic alignment was the key to excellent functional outcomes. (Level IV evidence)

Shaffer PT, Shaffer MA, Okereke E, et al: Effects of immobilization on plantar-flexion torque, fatigue resistance and functional ability following an ankle fracture. *Phys Ther* 80:769–780, 2000.

Study to investigate the effects of 8 weeks of immobilization on plantarflexion peak torque, fatigue resistance, and functional ability (walking, stairs). They found decreased performance and functional ability after 8 weeks immobilization which can be reversed in 10 weeks of supervised physical therapy. (Level II evidence)

Shapiro MS, Wascher DC, Finerman GA: Rupture of Lisfranc's ligament in athletes. *Am J Sports Med* 22:687–691, 1994.

Nine athletes with Lisfranc ligament disruptions were presented in this retrospective review article. Nonoperative management was successful in returning the athletes back to competition in an average of 4 months. (Level IV evidence)

Wadsworth DJ, Eadie NT: Conservative management of subtle Lisfranc injury: A case report. *J Orthop Sports Phys Ther* 35: 154–164, 2005.

This is a case report that outlines the rehabilitation of a grade 1 Lisfranc injury in a 21-year-old professional basketball player. The authors report successful treatment included restricted activities, orthotic management, normalization of gait pattern, proprioceptive retraining, taping, and graduated return to sport. The athlete returned to sport 12 weeks post injury. Two-year follow-up found no symptoms or restrictions in sport performance. (Level IV evidence)

Watson, TS, Shurnas PS, Denker J: Treatment of Lisfranc joint injury: Current concepts. *J Am Acad Orthop* 18:718–728, 2010.

This review article summarizes the current concepts associated with Lisfranc injuries. It details the anatomy, mechanisms of injury, classifications, and diagnosis and nonoperative and operative management. (Level V evidence)

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1. Wadsworth DJ, Eadie NT: Conservative management of subtle Lisfranc Injury: A case report. *J Orthop Sports Phys Ther* 35:154–164, 2005.
2. Watson, TS, Shurnas PS, Denker J: Treatment of Lisfranc joint injury: Current concepts. *J Am Acad Orthop* 18:718–728, 2010.

Multiple Choice Questions

QUESTION 1. Which of the following is an example of strengthening for foot intrinsic muscles?

A. Aquatic therapy running
B. Plyometrics
C. Toe curls/scrunches
D. Peroneal strengthening with Thera-Band

QUESTION 2. Which of the following is the best type of footwear for the athlete once he or she is cleared to return to sport?

A. Cushioned shoe
B. Motion control shoe with off-the-shelf orthotic
C. Stiff-soled sole with custom orthotic
D. Any type of shoe with midfoot taping technique

QUESTION 3. When is it appropriate to start plyometric/jumping activities after surgery?

A. Once athlete is able to fully weight-bear
B. After hardware removal, approximately 5 to 6 months
C. Before hardware removal around 4 months
D. Once athlete has no pain and swelling

QUESTION 4. Postoperatively, patients are placed in a CAM walker (worn at all times) with the ankle in what position?

A. Neutral dorsiflexion
B. Relaxed plantarflexion
C. Slight inversion
D. Calcaneal eversion

Answer Key

QUESTION 1. Correct answer: **C** (see Phase IV)

QUESTION 2. Correct answer: **C** (see Criteria for Return to Sport)

QUESTION 3. Correct answer: **B** (see Phase V)

QUESTION 4. Correct answer: **A** (see Phase I)

Chapter 44



Fifth Metatarsal Fractures

INTRODUCTION

Timothy S. Mologne, MD

Epidemiology

- Fractures of the fifth metatarsal are relatively common in athletic individuals.
- There is no association with age or sex, but they are more common in athletes who participate in cutting type sports, particularly basketball and football players. They are also seen in female dancers.

Pathophysiology

Intrinsic Factors

- Fractures at the base of the fifth metatarsal can result from an inversion injury, with resultant avulsion of the peroneal brevis tendon or plantar aponeurosis. The injury mechanism is similar to that seen with an acute lateral ankle sprain.
- Fractures of the middle and distal diaphysis commonly involve a fall on a plantarflexed and inverted foot. This mechanism is often seen in dancers.
- Fractures of the proximal fifth metatarsal distal to the tuberosity (Jones fracture) usually occur from a vertical oriented force, a medial-lateral force, or a combination of the two as the patient raises the heel and puts pressure on the metatarsal head.
- There are strong stabilizing ligaments between the base of the fifth metatarsal and the cuboid and fourth metatarsal. These ligaments and the capsular attachments help to stabilize the fifth metatarsal and result in force concentration to the fifth metatarsal just distal to the articulation with the fourth metatarsal.
- A varus hindfoot has been associated with fifth metatarsal Jones fractures.[1]

Traumatic Factors

- Dancer's fracture
- Inversion injury and styloid avulsion
- Vertical/medial-lateral force as the heel is raised

Classic Pathological Findings

- Fractures of the fifth metatarsal can be divided into shaft and neck fractures, styloid fractures, and fractures at the metadiaphyseal junction—the so-called Jones fracture.
- Stress fractures at the metadiaphyseal junction can results in cortical hypertrophy, periosteal new bone formation, and widening at the fracture site.
- Nonunions can also be seen, with intramedullary sclerosis.

Clinical Presentation

History

- A thorough evaluation of the patient's history may help distinguish a stress fracture from an acute fracture.
- Prodromal pain at the site of the fracture prior to an acute injury might signify a stress type fracture.
- Patients often report a twisting injury to the ankle or an inversion injury to the foot.
- Patients with acute fractures usually have difficulty ambulating or applying pressure on the affected foot.

Physical Examination

- Tenderness to palpation at the fracture site
- Accentuation of pain with foot inversion
- Occasional swelling and ecchymosis at the fracture site
- Difficulty bearing weight on the affected foot

Imaging

- An anteroposterior, oblique, and lateral radiograph of the affected foot are helpful in establishing a diagnosis.
- A styloid fracture should be assessed for displacement and comminution (Figure 44-1)

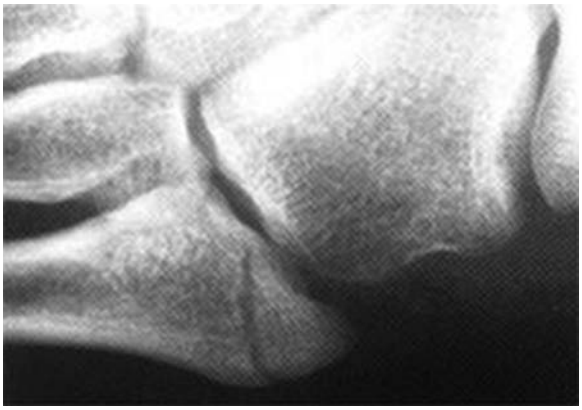

FIGURE 44-1. A nondisplaced styloid avulsion fracture.

- Fractures of the proximal fifth metatarsal distal to the tuberosity (Jones fracture) should be assessed for chronicity. Torg[2] classified Jones fractures as (1) acute fractures, (2) delayed unions, and (3) nonunions. The acute fracture was defined as a fracture with a sharp fracture line with no widening, no intramedullary sclerosis, and little to no cortical hypertrophy (Figure 44-2). The delayed union was defined as a fracture with a widened fracture line, a fracture involving both cortices and with a periosteal reaction, and some intramedullary sclerosis (Figure 44-3). The nonunion was defined as a fracture with a wide fracture line, periosteal new bone, and complete obliteration of the intramedullary canal with sclerotic bone (Figure 44-4).
- In skeletally immature patients, the base of the fifth metatarsal has an apophysis, which should not be confused for a fracture. The apophysis is parallel to the shaft of the metatarsal.



FIGURE 44-3. A delayed union Jones fracture with widening of the fracture line, and some intramedullary sclerosis.

Differential Diagnosis

- Fractures at the base of the fifth metatarsal can be mimicked by:
  - Fifth metatarsal apophysis in skeletally immature patients. The apophysis is parallel to the shaft and does not extend proximally into the fifth metatarsal-cuboid articulation.
  - Os peroneum. An ossicle in the peroneus longus tendon adjacent to the base of the fifth metatarsal. The ossicle is rounded as compared to an acute fracture.



FIGURE 44-2. An acute Jones fracture with a sharp fracture line, no widening, no periosteal reaction, and no cortical hypertrophy.



FIGURE 44-4. A nonunion of a Jones fracture with a widened fracture line and obliteration of the intramedullary canal with sclerotic bone.

Treatment

Nonoperative Management

- Styloid avulsion fractures have an excellent chance of successful treatment with conservative treatment. Treatments can vary with the size of the fracture fragment, displacement, and amount of comminution, and can include protective ambulation in a hard sole shoe, a firm last boot, a CAM walker, or a short leg walking cast.[3]
- Metatarsal shaft and neck fractures also have an excellent chance of successful treatment without surgery. Immobilization in a CAM walker or short leg walking cast for 4 to 6 weeks is common.[3]
- Jones fractures can be challenging to get to heal conservatively. Nonunions and refractures are common.[4] If conservative treatment is elected, a short leg non–weight-bearing cast for 6 to 8 weeks, followed by protected weight bearing until fracture union.[2,3]

Guidelines for Choosing Among Nonoperative Treatments

- In general, styloid avulsion fractures and shaft and neck fractures are treated conservatively.
- Acute Jones fractures can be successfully treated with nonsurgical treatment but can result in a lengthy recovery. Athletes may be less tolerant of prolonged immobilization, especially if there is a real probability of a refracture once they return to competitive sports.
- Conservative management of Jones fractures may be very dysfunctional for nonathletes, especially those who have difficulty ambulating with crutches and those who do not have the balance or upper body strength to ambulate non–weight-bearing on the affected limb.

Surgical Indications

- There are no absolute surgical indications.
- Widely displaced or angulated shaft fractures can be managed with open reduction and internal fixation.
- Large, displaced styloid fractures can also be managed with reduction and internal fixation.
- Although rare, symptomatic styloid fracture nonunions are also an indication for surgical intervention.
- Relative indications for surgical intervention include Jones fractures that are classified as delayed unions or nonunions at initial presentation; refractures; Jones fractures in athletes; and Jones fractures in individuals who are unwilling or unable to adhere to the 6 to 8 week non–weight-bearing guideline for conservative treatment.

Aspects of Clinical Decision Making When Surgery Is Indicated

- Size of the metatarsal and intramedullary canal will influence the size of screw used for fixation. Intramedullary screws smaller than 4.5 mm have been associated with a failure of surgery for Jones fractures (Figure 44-5).[5]



FIGURE 44-5. Successful union of a Jones fracture using an intramedullary 4.5-mm malleolar screw.

- For displaced and angulated shaft fractures, one must decide whether the fracture can be managed with interfragmentary screws, plate fixation, or a combination.

Evidence

Clapper M, O'Brien T, Lyons P: Fractures of the fifth metatarsal. *Clin Orthop* 315:238–241, 1995.

The authors reported on outcomes of treatment of 100 patients enrolled in a fifth metatarsal fracture registry. Styloid avulsion fractures healed without immobilization and shaft/neck fractures healed with weight-bearing casting. Jones fracture treated in a non–weight-bearing cast was only successful in 72% of the patients and the average time to healing in this successful group was 21 weeks. (Level 4 evidence)

Glasgow MT, Naranja RJ, Glasgow SG, et al: Analysis of failed surgical management of fractures of the base of the fifth metatarsal distal to the tuberosity: The Jones fracture. *Foot Ankle Int* 17(8):449–457, 1996.

This retrospective study reported on 11 patients who had failed screw fixation for a Jones fracture. Screw sizes less than 4.5 mm and an early return to vigorous physical activity correlated with delayed union and refracture. (Level 4 evidence)

Mologne TS, Lundeen J, Clapper M, et al: Early screw fixation versus casting in the treatment of acute Jones fractures. *Am J Sports Med* 33(7):970–975, 2005.

This prospective, randomized control study compared early screw fixation to casting in the treatment of acute Jones' fractures. Screw fixation was successful in 95% and allowed patients to return to running and jumping in 8 weeks. Cast treatment resulted in failure of treatment in 44%. In the successfully treated patients, the median time to return to running and jumping sports was 15 weeks. (Level 1 evidence)

Raikin SM, Slenker N, Ratigan B: The association of a varus hindfoot and fracture of the fifth metatarsal metaphyseal-diaphyseal junction: The Jones fracture. *Am J Sports Med* 36(7):1367–1372, 2008.

In this case series of 21 Jones fractures, the authors found hindfoot varus alignment by radiographic parameters in 86%. Based on this association, the authors have recommended a varus unloading orthotic insert to help prevent reinjury or refracture. (Level 4 evidence)

Torg J, Balduini F, Zelko R, et al: Fractures of the base of the fifth metatarsal distal to the tuberosity. *J Bone and Joint Surg* 66A:209–214, 1984.

In this retrospective review, the authors described the outcomes of 46 Jones fractures. They defined the acute fracture, delayed union, and nonunion, and showed a 93% healing rate in acute fractures treated with non–weight-bearing short leg casting for 6 to 8 weeks. (Level 4 evidence)

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2. Torg J, Balduini F, Zelko R, et al: Fractures of the base of the fifth metatarsal distal to the tuberosity. *J Bone and Joint Surg* 66A:209–214, 1984.
3. Clapper M, O'Brien T, Lyons P: Fractures of the fifth metatarsal. *Clin Orthop* 315:238–241, 1995.
4. Mologne TS, Lundeen J, Clapper M, et al: Early screw fixation versus casting in the treatment of acute Jones fractures. *Am J Sports Med* 33(7):970–975, 2005.
5. Glasgow MT, Naranja RJ, Glasgow SG, et al: Analysis of failed surgical management of fractures of the base of the fifth metatarsal distal to the tuberosity: The Jones fracture. *Foot Ankle Int* 17(8):449–457, 1996.

Multiple-Choice Questions

QUESTION 1. Fractures of the middle and distal diaphysis commonly involve a fall on the

A. inverted foot.
B. plantarflexed foot.
C. plantarflexed and inverted foot.
D. plantarflexed and everted foot.

QUESTION 2. Which foot postural alignment is associated with a Jones fracture?

A. Hindfoot varus
B. Hindfoot valgus
C. Forefoot valgus
D. Forefoot varus

QUESTION 3. Stress fractures at the metadiaphyseal junction can result in

A. cortical hypertrophy.
B. periosteal new bone formation.
C. widening at the fracture site.
D. All of the above.

QUESTION 4. Immobilization in a CAM walker or short leg walking cast for metatarsal shaft and neck fractures should be done for

A. 10 weeks.
B. 4 to 6 weeks.
C. 2 to 3 weeks.
D. 10 to 12 weeks.

QUESTION 5. Jones fractures, if treated conservatively, should be in a short leg non–weight-bearing cast for

A. 6 to 8 weeks.
B. 2 weeks.
C. 10 to 12 weeks.
D. 4 to 6 weeks.

Answer Key

QUESTION 1. Correct answer: **C** (see Pathophysiology, Intrinsic Factors)

QUESTION 2. Correct answer: **A** (see Pathophysiology, Intrinsic Factors)

QUESTION 3. Correct answer: **C** (see Pathophysiology, Classic Pathological Findings)

QUESTION 4. Correct answer: **B** (see Treatment, Nonoperative Management)

QUESTION 5. Correct answer: **A** (see Treatment, Nonoperative Management)

NONOPERATIVE REHABILITATION OF FIFTH METATARSAL FRACTURES (INCLUDING JONES FRACTURE)

Brad McMahon, MPT, Laura Lundgren, PA-C, and Timothy S. Mologne, MD

GUIDING PRINCIPLES OF NONOPERATIVE REHABILITATION

- Restore ankle and subtalar range of motion.
- Restore ankle and foot strength.
- Improve proprioception and balance.
- Protect the healing of the bone during the rehabilitation process.
- Maintain cardiovascular fitness throughout the rehabilitation process.
- Possibly improve mechanics and shoe wear to help prevent future injury.

Phase I (weeks 4 to 8 depending on the fracture site)

- In general, physical therapy is not initiated in the early phases of treatment of fifth metatarsal fractures.
- Cardiovascular fitness can be maintained by the use of an upper extremity bike and upper extremity workouts can be continued to maintain the fitness of the athlete.

Protection

- Fifth metatarsal shaft/neck fractures are managed in a walking cast or walking boot for 4 to 6 weeks. Immobilization is critical for fracture union, and as such, therapy, other than instruction and education in the proper use of crutches, is not indicated.
- Jones fractures are managed in a non–weight-bearing short leg cast for 6 to 8 weeks. Therapy other than crutch training is also not indicated in this phase.
- Styloid avulsion fractures can be managed in a protective boot or shoe, usually for 4 weeks because the ankle does not need to be immobilized.
- Bone stimulators (pulsed electromagnetic fields) have been shown to be effective in the management and healing of nonunions and delayed unions.[1]

Management of Pain and Swelling

- Pain can be managed with appropriate use of analgesics.
- Because nonsteroidal anti-inflammatory agents have been shown to delay bone healing, these are generally avoided for the first 6 weeks.
- Ice and electrical stimulation can also be used to manage pain and swelling.

Phase II (Shaft and neck fractures: weeks 4 to 6; styloid avulsion fractures, weeks 4; Jones fractures: weeks 8 to 16)

Protection

- Shaft and neck fractures should be nearly asymptomatic at 6 weeks.
- A firm last shoe can help to limit stress across the metatarsal.
- Patients with styloid avulsion fractures can usually resume regular shoe wear by 4 weeks.
- Patients with Jones fractures are managed in a removable CAM walker boot after the initial 6 to 8 weeks of non–weight-bearing immobilization.

TIMELINE 44-1: **Nonoperative Rehabilitation of Fifth Metatarsal Fracture**

PHASE I (weeks 4 to 8 depending on fracture site)	PHASE II (weeks 4 to 16)	PHASE III (weeks 8 to 16)
• Fifth metatarsal shaft/neck fractures in walking cast or walking boot for 4 to 6 weeks • Jones fractures in non-WB'ing short leg cast for 6 to 8 weeks • Styloid avulsion fractures in a protective boot or shoe for 4 weeks (ankle does not need to be immobilized). • Ice and pain meds as needed • Maintain cardiovascular fitness (upper extremity bike or upper extremity workouts)	• Fifth metatarsal shaft/neck fractures 4 to 6 weeks can be full weight bearing in firm last or hard-soled shoe • Jones fractures 8 to 16 weeks are managed in CAM walker boot • Styloid avulsion fractures 4 weeks can usually resume regular show wear. • Ankle ROM and plantar fascia stretching • Manual resistance exercises in all ankle planes • Start single leg balance and sensorimotor exercises. • Gait training with no gait deviations • Ice as needed for inflammation	• Fifth metatarsal shaft/neck fractures 10 to 12 weeks • Jones fractures 14 to 16 weeks • Styloid avulsion fractures 8 to 10 weeks • Attempt to get patient back to prior level of function • Patient should have full ankle ROM • Strengthening of foot and ankle continued • Single leg balance and proprioception exercises progressed • Dynamic reaction drills • Jumping and plyometrics added • Running and sport specific drills



FIGURE 44-6. Towel stretch for dorsiflexion ROM.

Management of Pain and Swelling

- Swelling is usually not present in this phase, but again can be managed with ice and electrical stimulation if needed.

Techniques for Progressive Increase in Range of Motion

- Prolonged immobilization can result in ankle stiffness, muscle weakness, ligamentous and fascial tightness, and disuse atrophy of the foot and leg muscles.
- Full range of motion needs to be achieved.
- Ankle range of motion exercises in all planes (dorsiflexion, plantar flexion, inversion and eversion)
  - Wall stretch, towel stretch, self-stretches with wobble boards or hand (Figure 44-6)
- Plantar fascia stretching
  - Rolling with a can or bottle (Figure 44-7)



FIGURE 44-7. Plantar fascia stretching with bottle.



FIGURE 44-8. Balance and proprioception rehabilitation using the biomechanical ankle platform system (BAPS).

Other Therapeutic Exercises

- Again, maintaining whole-body cardiovascular fitness is a main goal. Pool workouts, stationary bike, and stair climbers can all be used as an alternative to running.
- Core stability exercises and upper extremity strengthening can be continued.

Activation of Primary Muscles Involved

- Peroneals, gastrocnemius, soleus, tibialis anterior/posterior, toe extensors/flexors
  - Thera-Band ankle strengthening in all directions
  - Balance exercises (see the following)
  - Calf raises (knee extended/knee bent)
  - Towel pick-ups
  - Heel/toe walks

Sensorimotor Exercises

- Start with weight-shifting and progress to single leg balance.
- Single leg balance on wobble boards, Dyna Discs, trampoline, incline surfaces, biomechanical ankle platform system (BAPS) (Figure 44-8)

Open and Closed Kinetic Chain Exercises

- Thera-Band ankle strengthening in all directions, toe flexor/extensor exercises (towel pick-ups), heel raises, squats/lunges, hip strengthening with Thera-Band (Figure 44-9)

Neuromuscular Dynamic Stability Exercises

- Dynamic reaction drills on the trampoline and progression into ball toss and perturbations on balance boards (Figure 44-10).



FIGURE 44-9. Hip strengthening with Thera-Band.

- Standing single balance movement drills
- Slide board or Pro-fitter

Functional Exercises

- Will start with early weight shifting, gait training, and eventual walking with no gait deviations

Milestones for Progression to the Next Phase

- The patient's pain level over the fracture area dictates the level of activity or progression of stages.



FIGURE 44-10. Single balance on wobble boards.

- Absence of pain, full ankle range of motion, restoration of strength in the foot and ankle
- Evidence of union of the fracture on follow up radiographs

Phase III (weeks 10 to 12, shaft and neck fractures; weeks 8 to 10, styloid avulsion fractures; weeks 14 to 16 Jones fractures)

Management of Pain and Swelling

- Ice and electrical stimulation if needed.

Techniques for Progressive Increase in Range of Motion

- In this phase, we attempt to get the athlete and patient back to his or her preinjury level of function. This includes running and jumping sports.
- The patient should have full ankle and subtalar range of motion.
- Stretching techniques from Phase II can be continued for warm-up or cool-down before heavy work-out or sport practice.

Other Therapeutic Exercises

- Continued from Phase II

Activation of Primary Muscles Involved

- Peroneals, gastrocnemius, soleus, tibialis anterior/posterior, toe extensors/flexors
  - Thera-Band ankle strengthening in all directions
  - Balance exercises (see the following)
  - Calf raises (knee extended/knee bent)
  - Towel pick-ups
  - Heel/toe walks

Sensorimotor Exercises

- Continue with Phase II exercises.
- Progressing to Thera-Band resistance, ball toss, and perturbations

Open and Closed Kinetic Chain Exercises

- Continue with Phase II exercises.

Neuromuscular Dynamic Stability Exercises

- Continue with Phase II exercises.

Plyometrics

- Starting with double leg and progressing to single leg (Figure 44-11)
- Platform jumps, progressing height depending on difficulty

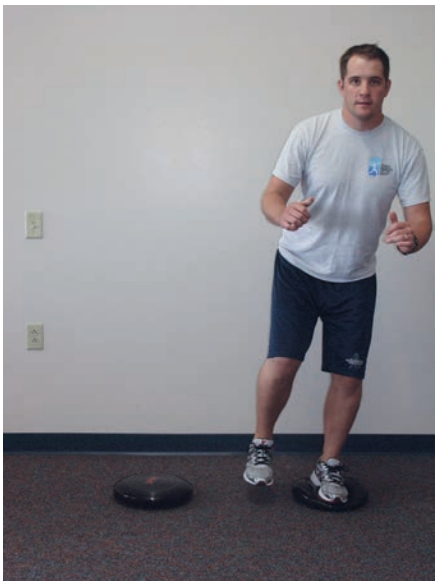

FIGURE 44-11. Single balance hopping progression exercise.

Functional Exercises

- Jogging to running with progression from straight forward to side to side and cutting agility drills

Sport-Specific Exercises

- Depending on the sport, cutting, twisting, pivoting, and other sport-related drills

Milestones for Progression to Advanced Sport-Specific Training and Conditioning

- The rehabilitation program needs to be individualized and adjusted for each athlete depending on the sport and the initial fracture site.
- Absence of pain, full ankle range of motion, restoration of strength in the foot and ankle
- Evidence of union of the fracture on follow-up radiographs

Criteria for Abandoning Nonoperative Treatment and Proceeding to Surgery or More Intensive Intervention

- Fifth metatarsal shaft and neck fractures, as well as styloid avulsion fractures are well managed conservatively. Successful union is nearly universal, and abandoning nonoperative treatment should not be necessary unless significant fracture displacement is noted on interval follow-up radiographs.
- Symptomatic fractures with evidence of nonunion by radiographs. For Jones fractures, union can take up to 21 weeks.[2]
- Patient reluctance or inability to adhere to the non–weight-bearing recommendations in the first phase

Performance Enhancement and Beyond Rehabilitation: Training/Trainer and Optimization of Athletic Performance

- Mechanism of jumping and running to prevent reinjury
- Proper shoe wear, possible use of orthotics or external support during competition
- Maintaining foot and ankle strength/ROM, balance, and proprioception

Specific Criteria for Return to Sports Participation: Tests and Measurements

- Absence of pain, full ankle range of motion, restoration of strength in the foot and ankle
- Evidence of union of the fracture on follow-up radiographs

Evidence

Aaron RK, Ciombor DM, Simon BJ: Treatment of nonunions with electric and electromagnetic fields. *Clin Orthop Relat Res* (419):21–29, 2004.

This is a review article were the authors concluded that electric and electromagnetic fields had improved results in delayed and nonunion fractures compared with placebo treatment. (Level IV evidence)

Clapper MF, O'Brien TJ, Lyons PM: Fractures of the fifth metatarsal. Analysis of a fracture registry. *Clin Orthop Relat Res* 238–241, 1995.

In this article a fracture registry was established. The authors found that avulsion fractures healed with immobilization usually in 4 weeks, shaft/neck fractures healed in casts with WBAT in 4 to 6 weeks, and Jones fractures required a prolonged time to heal, on average 21.2 weeks. (Level IV evidence)

Collins KS, Streitz W: Bilateral Jones fractures in a high school football player. *J Athl Train* 31:253–256, 1996.

This is a case report that presented a high school football player with bilateral Jones fractures who was treated both conservatively and with a screw fixation. It is specific to football and shows the progression of both surgical and nonsurgical treatments. (Level IV evidence)

Holmes GB, Jr: Treatment of delayed unions and nonunions of the proximal fifth metatarsal with pulsed electromagnetic fields. *Foot Ankle Int* 15:552–556, 1994.

This study looked at nine delayed unions and nonunions of the proximal fifth metatarsal that were treated with pulsed electromagnetic fields and found that the mean time of fracture healing was 3 months compared with 4 months without the pulsed electromagnetic fields. (Level IV evidence)

Mologne TS, Lundeen JM, Clapper MF, et al: Early screw fixation versus casting in the treatment of acute Jones fracture. *Am J Sports Med* 33:970–975, 2005.

In this randomized controlled trial, 18 patients were randomized to cast treatment and 19 patients were randomized to screw fixation. The authors found that early screw fixation results in faster times to union and return to sport compared with cast treatment. (Level I evidence)

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1. Aaron RK, Ciombor DM, Simon BJ: Treatment of nonunions with electric and electromagnetic fields. *Clin Orthop Relat Res* 419:21–29, 2004.
2. Clapper MF, O'Brien TJ, Lyons PM: Fractures of the fifth metatarsal. Analysis of a fracture registry. *Clin Orthop Relat Res* 238–241, 1995.

Multiple Choice Questions

QUESTION 1. Styloid avulsion fractures can be managed in a

A. CAM walker boot for 10 weeks.
B. short leg cast for 6 to 8 weeks.
C. protective boot or shoe, usually for 4 weeks.
D. CAM walker for 6 weeks.

QUESTION 2. For Jones fractures, radiographic union has been shown to take up to

A. 4 weeks.
B. 10 weeks.
C. 8 weeks.
D. 21 weeks.

QUESTION 3. Shaft and neck fractures should be nearly asymptomatic at

A. 6 weeks.
B. 10 weeks.
C. 16 weeks.
D. 2 weeks.

QUESTION 4. Activation of these primary muscles are important in the nonoperative rehabilitation of the Jones fracture?

A. Peroneals
B. Gastroc/soleus
C. Toe extensors/flexors
D. All of the above

QUESTION 5. The key milestone for progression to the next phase of the rehab process is from Phase II to Phase III is

A. the patient's pain level over the fracture site.
B. full ankle ROM.
C. evidence of union of the fracture on follow-up radiographs.
D. all of the above

Answer Key

QUESTION 1. Correct answer: **C** (see Phase I)

QUESTION 2. Correct answer: **D** (see Criteria for Abandoning Nonoperative Treatment and Proceeding to Surgery or More Intensive Intervention)

QUESTION 3. Correct answer: **A** (see Phase II)

QUESTION 4. Correct answer: **D** (see Phase II)

QUESTION 5. Correct answer: **D** (see Phase II)

POSTOPERATIVE REHABILITATION AFTER INTERNAL FIXATION OF FIFTH METATARSAL FRACTURES

Timothy S. Mologne, MD, Laura Lundgren, PA-C, and Brad McMahon, MPT

Indications for Surgical Treatment

- Acute Jones fracture in athletes
- Symptomatic delayed union or non-union Jones fracture
- Refractures
- Patients that are unwilling or unable to adhere to nonoperative treatment guidelines with non–weight-bearing immobilization

Brief Summary of Surgical Treatment

- Supine position with a bump under the ipsilateral hemipelvis
- Use of tourniquet not necessary but can be used per surgeon's choice
- Radiolucent table and use of fluoroscopy
- Anesthesia options per surgeon's choice, including regional block, spinal, local anesthesia with MAC, and general anesthesia
- A 1-cm longitudinal incision is made proximal to the base of the fifth metatarsal.
- The sural nerve is dorsal to the skin incision but blunt dissection to the base of the fifth metatarsal is recommended.
- A 3.2-mm drill guide is placed at the tip of the fifth metatarsal styloid. Fluoroscopy is used to assure the drill is centered on the tip.

- A 3.2-mm drill is then drilled through the intramedullary canal of the metatarsal and across the fracture. Fluoroscopy is also used to assure the drill is passing through the canal. The drill can be used as a "power sound," stopping the drill if the cortex is felt.
- The drill will eventually contact the dorsal and medial aspect of the distal portion of the metatarsal shaft, because the shaft is curved and not purely linear.
- The length of the drill canal can be measured with a depth gauge but is usually between a 55- and 65-mm screw.
- Various screw types have been used. We have not found it necessary to use a cannulated screw and use a 4.5-mm malleolar screw.
- Care must be made to assure that screw threads are distal to the fracture line.
- The screw can be countersunk to help keep it from being prominent.
- Fluoroscopy is used to assure the screw is properly placed and that the screw head is not prominent.
- The incision is then closed in layers and a sterile dressing is applied.
- Patients are placed in a CAM (controlled ankle motion) walker boot.

Before Surgery: Overview of Goals, Milestones, and Guidelines[1]

GUIDING PRINCIPLES OF POSTOPERATIVE REHABILITATION

- Achieve full foot and ankle ROM
- Restoration of strength in the foot/ankle and lower extremity
- Protect fracture site and healing of bone in each phase of the rehab process
- Maintain cardiovascular fitness

[1]Prehabilitation, if appropriate, is described in the Nonoperative Rehabilitation section of this chapter.

Phase I (days 0 to 14): Immediate Postoperative Period

Goals

- Protected weight bearing until the wound has healed
- Reduce swelling and pain with ice and medications
- Maintain ankle and subtalar joint motion
- Maintain cardiovascular fitness with arm bike
- Possible bone stimulator if ordered for delayed or nonunions

Protection

Patients use crutches and CAM walker boot. Once the sutures are removed, they can begin weight bearing as tolerated in a firm last boot, CAM walker boot, or hard sole shoe.

Management of Pain and Swelling

For Pain

- Pain following the surgery is usually quite minimal, and can be managed with acetaminophen and/or a mild oral narcotic for a few days. Ice is also used to help reduce pain.

For Swelling

- Ice can be used to help reduce swelling. However, as the surgery is done nearly percutaneously, swelling is usually minimal.

Techniques for Progressive Increase in Range of Motion

- Gentle ROM exercises can be done at the ankle: self-stretches with wobble boards or hand (Figures 44-12 and 44-13)

Other Therapeutic Exercises

- Again maintaining whole body cardiovascular fitness is a main goal. An arm bike can be used and the patient can continue with upper extremity strengthening, and core exercises maintain the weight-bearing status
- Usually at 3 to 5 days the patient may start stationary bicycle with a protective boot on.

TIMELINE 44-2: Postoperative Rehabilitation after Internal Fixation of Fifth Metatarsal Fractures

PHASE I (weeks 0 to 2)	PHASE II (weeks 2 to 6)	PHASE III (weeks 6 to 10)
• Protected weight bearing with CAM walker boot and crutches • Early and gentle ankle ROM • Ice and pain meds as needed • Maintain cardiovascular fitness (stationary bicycle)	• Full weight bearing in firm last or hard sole shoe • Continued ankle ROM and plantar fascia stretching • Ice as needed for swelling • Start single leg balance exercises • Manual resistance exercises in all ankle planes	• Foot orthotic still may be used with an external support • Full ankle ROM • Strengthening of foot and ankle with resistance bands • Single leg balance and proprioception exercises progressed • Dynamic reaction drills • Jumping and plyometrics added • Running and sport-specific drills

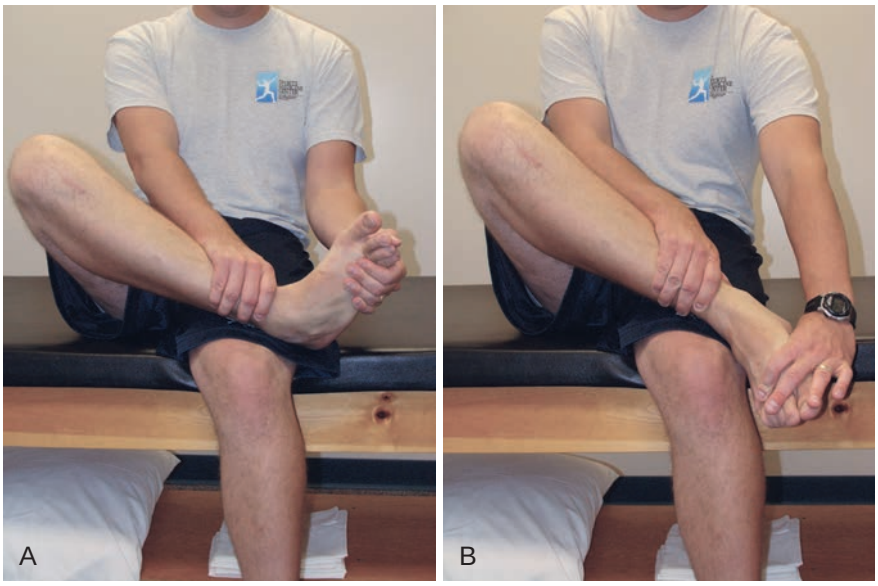

FIGURE 44-12. Self stretches for inversion and eversion.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Strengthening is not indicated at this time period.

Functional Exercises

- Gaiting training with crutches can be done to minimize gait deviations.

Milestones for Progression to the Next Phase

- Pain-free ambulation with protective boot

Phase II (weeks 2 to 6)

Clinical Pearls

Peroneus brevis tendon may be irritated from the surgical approach, so strengthening may need to be delayed until inflammation subsides. Other strengthening is usually tolerated without problems.

Goals

- Progression into weight bearing
- Reduce swelling and pain with ice and medications
- Maintain ankle and subtalar joint motion
- Maintain cardiovascular fitness with stationary bike now
- Continued bone stimulator if ordered.

Protection

- Progression into weight bearing so crutches may be discontinued as tolerated. Patient still may be wearing firm last shoe or hard sole shoe at this point if she or he is still having pain with walking.

Management of Pain and Swelling

For Pain

- Should be minimal at this point, but can be managed with acetaminophen and ice.

For Swelling

- Continued ice can be used to help reduce the swelling if any is present with the increase in weight bearing.

Techniques for Progressive Increase in Range of Motion

- Full range of motion needs to be achieved
- Ankle range of motion exercises in all planes (dorsiflexion, plantar flexion, inversion and eversion)
  - Wall stretch, towel stretch, self-stretches with wobble boards or hand



FIGURE 44-13. Wobble board PROM for inversion and eversion.

- Plantar fascia stretching
  - Rolling with a can or bottle

Other Therapeutic Exercises

- Again maintaining whole body cardiovascular fitness is a main goal. Pool workouts, stationary bike, and stair climbers can all be used as an alternative to running at this point.
- Core stability exercises and upper extremity strengthening can be continued.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Peroneals, gastrocnemius, soleus, tibialis anterior/posterior, toe extensors/flexors
  - Thera-Band ankle strengthening in all directions
  - Balance exercises—see below
  - Calf raises (knee extended/knee bent)
  - Towel pick-ups
  - Heel/Toe walks

Sensorimotor Exercises

- Will start with weight shifting and progress to single leg balance.
  Single leg balance on wobble boards, Dyna Discs, trampoline, incline surfaces, Biomechanical Ankle Platform System (BAPS).

Open and Closed Kinetic Chain Exercises

- Manual resistance exercises in all ankle planes added
- Hip strengthening with Thera-Band and weight-bearing exercises can be done at this time.

Functional Exercises

- Continued gait training if needed at this point

Milestones for Progression to the Next Phase

- Absence of pain and evidence of union of the fracture on radiographs

Phase III (weeks 6 to 10)

Clinical Pearls

- Consider a firm last athletic shoe to minimize the stress at the fracture site.
- The screw head may be prominent and may become symptomatic in some patients when they return to normal shoe wear. Consider using a cut out pad to alleviate pressure at the styloid.

Goals

- Progression in activities as symptoms dictate
- Once asymptomatic and with evidence of fracture healing, patients can progress to running and jumping.
- Strengthening of the foot and ankle muscles is initiated and progression is carried out until discharge.
- Continued ankle and subtalar joint motion
- Continued cardiovascular fitness

Management of Pain and Swelling

- Pain should be minimal. Ice if needed.
- Continued ice can be used to help reduce the swelling if any is present with the increase in activity.

Techniques for Progressive Increase in Range of Motion

- Full range of motion should be achieved at this point
- Ankle range of motion exercises in all planes can be continued (dorsiflexion, plantar flexion, inversion and eversion)
  - Wall stretch, towel stretch, self-stretches with wobble boards or hand
- Plantar fascia stretching can be continued
  - Rolling with a can or bottle

Other Therapeutic Exercises

- Again, maintaining whole body cardiovascular fitness is a main goal.
- Core stability exercises and upper extremity strengthening can be continued.
  - Stability ball, planks, bridges, superman exercises

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Peroneals, gastrocnemius, soleus, tibialis anterior/posterior, toe extensors/flexors
  - Thera-Band ankle strengthening in all directions
  - Balance exercises—see below
  - Calf raises (knee extended/knee bent)
  - Towel pick-ups
  - Heel/Toe walks

Sensorimotor Exercises

- Continued single leg balance on wobble boards, Dyna Discs, trampoline, incline surfaces, BAPS
- Progressing to Thera-Band resistance bands, ball toss, and perturbations.

Open and Closed Kinetic Chain Exercises

- Thera-Band ankle strengthening in all directions (Figure 44-14), toe flexor/extensor exercises (towel pick-ups), heal raises/soleus raises (Figure 44-15), squats/lunges, hip strengthening with Thera-Band



FIGURE 44-14. Therband strengthening of the ankle invertors.

Neuromuscular Dynamic Stability Exercises

- Dynamic reaction drills on the trampoline and progression into ball toss and perturbations on balance boards
- Standing single balance movement drills (Figure 44-16)
- Slide board or Pro Fitter

Plyometrics

- Starting with double leg and progressing to single leg (Figure 44-17)
- Platform jumps, progressing height depending on difficulty

Functional Exercises

- Jogging to running with progression from straight forward to side to side and cutting agility drills

Sport-Specific Exercises

- Depending on the sport, cutting, twisting, pivoting, and other sport related drills



FIGURE 44-15. Soleus raises using leg extension machine.

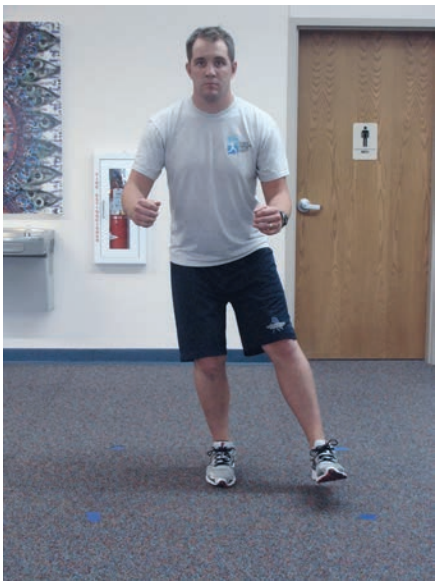

FIGURE 44-16. Standing single-leg balance dot drill.

Milestones for Progression to the Next Phase

- The rehab program needs to be individualized and adjusted for each athlete depending on the sport and the initial fracture site.
- Absence of pain on pain scale (0 to 10), full ankle range of motion per procedures of Norkin and White, restoration of strength in the foot and ankle measured by manual muscle testing per procedures of Daniels and Worthingham
  - Strength MMT 5/5 for peroneals, gastrocnemius, soleus, tibialis anterior/posterior, toe extensors/flexors
  - ROM
    - Dorsiflexion—20°
    - Plantarflexion—50°
    - First MTP flexion—30 to 45°
    - First MTP extension—50 to 70°
- Evidence of union of the fracture on follow-up radiographs

Criteria for Return to Sport

- Absence of pain, full ankle range of motion, restoration of strength in the foot and ankle
- Evidence of union of the fracture on follow-up radiographs

After Return to Sport

Continuing Fitness or Rehabilitation Exercises

- Total body fitness and overall cardiovascular fitness is very important and should be continued following this injury.

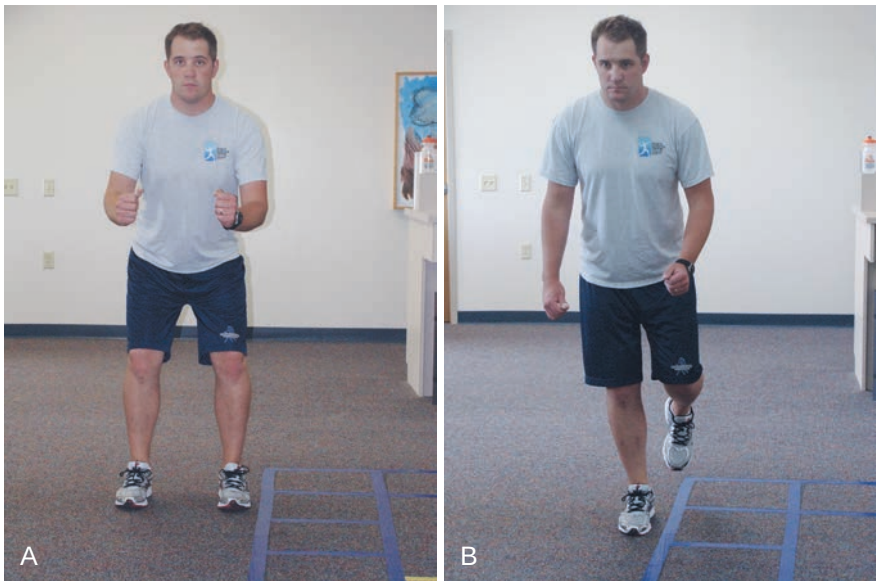

FIGURE 44-17. Progression of double leg jumping over line to single leg hoping.

- Maintaining foot and ankle strength/ROM, balance, and proprioception

Exercises and Other Techniques for Prevention of Recurrent Injury

- Mechanism of jumping and running to prevent reinjury
- Proper shoe wear, possible use of orthotics or external support during competition

Evidence

Aaron RK, Ciombor DM, Simon BJ: Treatment of nonunions with electric and electromagnetic fields. *Clin Orthop Relat Res* (419):21–29, 2004.

This is a review article in which the authors concluded that electric and electromagnetic fields had improved results in delayed and nonunion fractures compared with placebo treatment. (Level 4 evidence)

Clapper MF, O'Brien TJ, Lyons PM: Fractures of the fifth metatarsal. Analysis of a fracture registry. *Clin Orthop Relat Res* 238–241, 1995.

In this article a fracture registry was established. The authors found that avulsion fractures healed with immobilization, usually in 4 weeks; shaft/neck fractures healed in casts with WBAT in 4 to 6weeks; and Jones' fractures required a prolonged time to heal, on average 21.2 weeks. (Level 4 evidence)

Hislop H, Montgomery J: *Daniels and Worthingham's muscle testing: Techniques of manual examination*, ed 7, Philadelphia, 2002, Saunders.

This is a handbook on the manual evaluation of muscle strength testing. It provides instructions and guidance on patient positioning, muscle anatomy, grading, and assessment of every muscle. (Level 5 evidence)

Holmes GB, Jr: Treatment of delayed unions and non-unions of the proximal fifth metatarsal with pulsed electromagnetic fields. *Foot Ankle Int* 15:552–556, 1994.

This study looked at nine delayed unions and nonunions of the proximal fifth metatarsal that were treated with pulsed electromagnetic fields and found that the mean time of fracture healing was 3 months compared to 4 months without the pulsed electromagnetic fields. (Level 4 evidence)

Mindrebo N, Shelbourne KD, Van Meter CD, et al: Outpatient percutaneous screw fixation of the acute Jones fracture. *Am J Sports Med* 21:720–723, 1993.

This study used 9 varsity athletes, seven Division 1 scholarship athletes who sustained a Jones fracture that were treated with percutaneous screw fixation. The authors found an average return time to full competition was 8.5 weeks. (Level 4 evidence)

Mologne TS, Lundeen JM, Clapper MF, et al: Early screw fixation versus casting in the treatment of acute Jones fracture. *Am J Sports Med* 3:970–975, 2005.

In this randomized controlled trial, eighteen patients were randomized to cast treatment and nineteen patients were randomized to screw fixation. The authors found that early screw fixation results in faster times to union and return to sport compared with cast treatment. (Level 1 evidence)

Norkin C, White DJ: *Measurement of joint motion: A guide to goniometry*, ed 3, Philadelphia, 2003, F.A. Davis Company.

This is a handbook that describes in detail the standard way to perform goniometry. Every procedure is described in detail with documented norms of each joint. (Level 5 evidence)

Porter DA, Duncan M, Meyer SJ: Fifth metatarsal Jones fracture fixation with a 4.5-mm cannulated stainless steel screw in the competitive and recreational athlete: A clinical and radiographic evaluation. *Am J Sports Med* 33:726–733, 2005.

This is a case series where 23 consecutive athletes (24 feet) who were treated surgically were followed. The authors showed that a 4.5-mm cannulated screw could provide reliable and effective healing. The authors also demonstrated a functional progression program and postoperative rehabilitation program for the competitive and recreational athlete. (Level 4 evidence)

Multiple-Choice Questions

QUESTION 1. At what time frame is the athlete allowed to start running and jumping?

A. Week 2
B. Week 6
C. Week 12
D. Week 20

QUESTION 2. What is one of the main criteria that allow an athlete to start the running and jumping progression?

A. Normal mechanics of jumping
B. Full ROM
C. Full ankle and foot strength
D. Evidence of union of the fracture on follow up radiographs

QUESTION 3. Which tendon is sometimes irritated following the surgical approach so strengthening is sometimes delayed?

A. Peroneus brevis
B. Anterior tibialis
C. Posterior tibialis
D. Peroneus longus

QUESTION 4. Following the surgical fixation of a fifth metatarsal fracture, the patient is placed in?

A. CAM walker boot
B. Firm last shoe
C. Short leg cast
D. Normal foot wear

QUESTION 5. Indications for surgical treatment of fifth metatarsal fractures include?

A. Refractures
B. Symptomatic delayed union or non-union Jones Fracture
C. Acute Jones Fractures in athletes
D. All of the above

Answer Key

QUESTION 1. Correct answer: **B** (see Phase III Goals and Figure 44-17)

QUESTION 2. Correct answer: **D** (see Phase II Milestones for Progression to the Next Phase)

QUESTION 3. Correct answer: **A** (see Phase II Clinical Pearl)

QUESTION 4. Correct answer: **A** (see Brief Summary of Surgical Treatment)

QUESTION 5. Correct answer: **D** (see Indications for Surgical Treatment)

BEYOND BASIC REHABILITATION: RETURN TO FOOTBALL AFTER OPEN REDUCTION AND INTERNAL FIXATION OF JONES FRACTURE

Brad McMahon, MPT, and Timothy S. Mologne, MD

Introduction

ASPECTS OF FOOTBALL THAT REQUIRE SPECIAL ATTENTION IN REHABILITATION

- Football requires the athlete to run, plant, and cut effectively to perform at his or her highest level.
- Jones fractures are often caused by force overload as the athlete attempts to push off from the forefoot, but can also result from repetitive stress to the same area

- Historically Jones fractures have been challenging to get to heal with conservative treatment, with some patients not healing the fracture for 21.2 weeks.[1]
- These fractures have a high rate of nonunion and re-fracture despite prolonged treatment.[2]
- Conservatively managed patients are held out of running and jumping sports until there is fracture union.
- Surgical intervention is offered to patients to avoid prolonged immobilization and limited weight bearing, lessen the length of time away from the desired sport, and prevent future reinjury to the fifth metatarsal during sports participation.

Literature

- Jones fractures are well managed with intramedullary screw fixation with a shortened time to clinical and radiographic union as compared with cast treatment. The surgery group had median times to union and return to sport of 7.5 to 8 weeks.[2]
- Athletes returned to running by 5.5 weeks, full practice by 7.5 weeks, and full competition by 8.5 weeks on average.[3]
- In Collins case study the player began light football drills 21 days post surgery, full practice at the start of the fifth week, and back to competition by the end of the sixth week.[4]

Phase III: Sport-Specific Training

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- To start with sport-specific training the patient should be pain free, have full ROM per procedures of Norkin and White, restoration of strength in the foot and ankle measured by manual muscle testing per procedures of Daniels and Worthingham, and have evidence of union of fracture on radiographs.
  - Strength MMT 5/5 for peroneals, gastrocnemius, soleus, tibialis anterior/posterior, toe extensors/flexors
    - Thera-Band ankle strengthening in all directions
    - Balance exercises (see the following)
    - Calf raises (knee extended/knee bent)
    - Towel pick-ups
    - Heel/toe walks
  - ROM
    - Dorsiflexion: 20°
    - Plantarflexion: 50°
    - First MTP flexion: 30° to 45°
    - First MTP extension: 50° to 70°



FIGURE 44-18. Single leg balance with body blade.

- Concepts that are included in the training for a football player are multiplanar running, cutting, strength, power, speed, agility, and contact drills.
  - Flexibility joint mobility
    - Maintain ankle and subtalar motion. (Calf stretching against wall, towel stretch, and self-stretching for inversion/eversion.)
- Sensorimotor and balance training
  - Single-leg balance on wobble boards, Dyna Disc, trampoline, and inclined surfaces.
  - Progressing to Thera-Band resistance bands, ball toss, and perturbations (Figure 44-18).
  - Biomechanical ankle platform system (BAPS) and dynamic reaction drills on the wobble board, Dyna Disc, and trampoline.
  - Slide board (Figure 44-19) or Pro-fitter
- Core training
  - Stability ball, planks, bridges, superman exercises (Figure 44-20).

TIMELINE 44-3: **Return to Football After Open Reduction and Internal Fixation of Jones Fracture**

PHASE I (weeks 0 to 2)	PHASE II (weeks 2 to 6)	PHASE III (weeks 6 to 10)

• Protected weight bearing with CAM walker boot and crutches
• Early and gentle ankle ROM
• Ice and pain meds as needed
• Maintain cardiovascular fitness (stationary bicycle)
	• Full weight bearing in firm last or hard-soled shoe
	• Continued ankle ROM and plantar fascia stretching
	• Ice as needed for swelling
	• Start single leg balance exercises
	• Manual resistance exercises in all ankle planes
		• Foot orthotic still may be used with an external support
		• Full ankle ROM
		• Strengthening of foot and ankle with resistance bands
		• Single leg balance and proprioception exercises progressed
		• Dynamic reaction drills
		• Jumping and plyometrics added
		• Running and sport-specific drills
		  • Cone/ladder drills
		  • Cutting/twisting drills
		  • Figure-eight/zig-zag running
		  • Backpedaling
		  • Shuttle runs/40-yard dash
		• Depending on the position played
		  • Route running
		  • Blocking and tackling drills
		  • Noncontact/contact drills

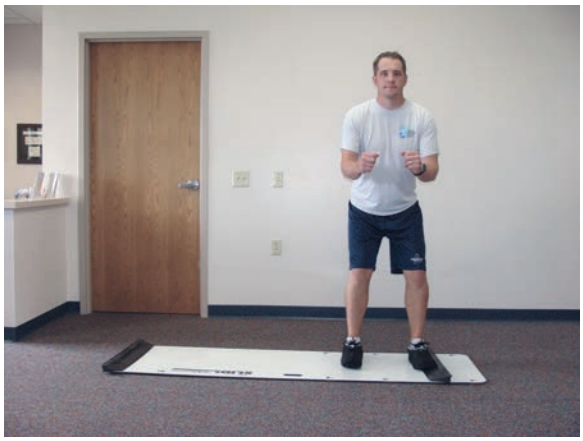

FIGURE 44-19. Rehabilitation on slide board.



FIGURE 44-20. Core strengthening side plank exercise.

- Cardio respiratory training
  - Should be maintained initially with cycling, pool workouts, or stair stepping until progression into running is approved.
- Training for speed, agility, and quickness (SAQ)
  - Jogging to running with progression from straight forward to side-to-side and cutting agility drills
  - Cone/ladder drills
  - Cutting/twisting drills
  - Figure-eight/zig-zag running
  - Backpedaling
  - Shuttle runs/40-yard dash
- Plyometric training
  - Starting with double leg and progressing to single leg (Figure 44-21)
  - Platform jumps, progressing height depending on difficulty
- Sport-specific training
  - Depending on the position played: route running, blocking, and tackling drills. All drills being progressed from noncontact to contact.

Olympic Lifts Used in the Training Program

Training Principles Used in the Design of the Program

- The principles of progression, overload, variation, and individuation are all used. Treatment should be individualized and based on the patient's needs.
- Intensity and the duration of the activities and programs are increased over time and as the patient can tolerate.
- Monitoring of patient pain and swelling of the foot must be done closely.

Sports Performance Testing

General Information

- General history
- Medical history, including medical ailments, genetic conditions that might affect strength, ligamentous laxity, and proprioception

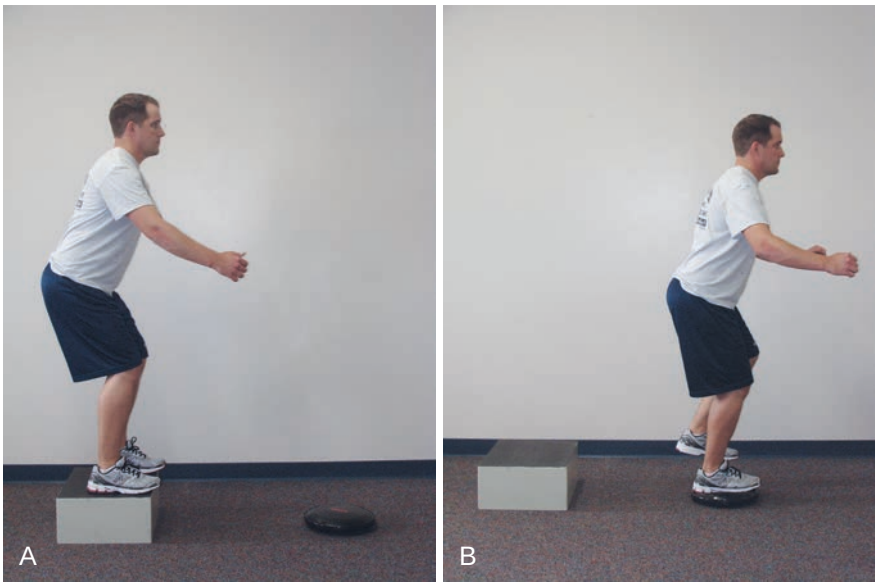

FIGURE 44-21. Single leg Plyometric jump onto Dyna Disc starting position (**A**) and landing position (**B**).

- Sports injury history, including the specifics of the current foot injury and prior injuries
- Surgical history, occurrence of any postoperative complications, including motion loss, infection, neurological injury, and thromboembolic events

Specific Objective Tests

- ROM measurements of foot and ankle
- Dorsiflexion: 20°
- Plantarflexion: 50°
- First MTP flexion: 30° to 45°
- First MTP extension: 50° to 70°
- Manual muscle testing of foot and ankle
  - Strength MMT 5/5 for peroneals, gastrocnemius, soleus, tibialis anterior/posterior, toe extensors/flexors
    - Thera-Band ankle strengthening in all directions
    - Balance exercises (see the following)
    - Calf raises (knee extended/knee bent)
    - Towel pick-ups
    - Heel/toe walks
- Single leg balance assessment (with perturbations) in comparison to nonoperative side hop and jumping tests
  - Single leg hop and standing vertical in comparison to nonoperative side
- Analysis of gait cycle and biomechanics
- Orthopaedic Foot Ankle Society Mid Foot Score

Specific Criteria for Release to Unsupervised Complete Participation in Football

- Pain-free, full ROM, and strength of the foot and ankle, and have evidence of union of fracture on radiographs.
- A pain-free functional progression program of running 3 to 4 days a week, 30 minutes at a time.[5]

Recommended Ongoing Exercises

- Football requires a lot of fast movements, running, cutting, and contact. Total body fitness and overall cardiovascular fitness is very important and should be continued following this injury.
- Maintaining foot and ankle strength/ROM, balance, and proprioception
- Proper shoe wear, possible use of custom orthotics or external support during competition

Evidence

Clapper MF, O'Brien TJ, Lyons PM: Fractures of the fifth metatarsal. Analysis of a fracture registry. *Clin Orthop Relat Res* 238–241, 1995.

A fracture registry was established in this article. The authors found that avulsion fractures usually healed with immobilization in 4 weeks, shaft/neck fractures healed in casts with WBAT in 4 to 6 weeks, and Jones' fractures required a prolonged time to heal, on average 21.2 weeks. (Level IV evidence)

Collins KS, Streitz W: Bilateral Jones fractures in a high school football player. *J Athl Train* 31:253–256, 1996.

This is a case report that presented a high school football player with bilateral Jones fractures who was treated both conservatively and with a screw fixation. It is specific to football and shows the progression of both surgical and nonsurgical treatments. (Level IV evidence)

Hislop H, Montgomery J: *Daniels and Worthingham's muscle testing: Techniques of manual examination*, ed 7, 2002, Saunders.

This is a handbook on the manual evaluation of muscle strength testing. It provides instructions and guidance on patient positioning, muscle anatomy, grading, and assessment of every muscle. (Level V evidence)

Low K, Noblin JD, Browne JE, et al: Jones fractures in the elite football player. *J Surg Orthop Adv* 13:156–160, 2004.

This study characterized Jones fracture treatments in the National Football League between 1988 and 2002. There were 86 Jones fractures identified, with 46 treated surgically. A questionnaire was also sent out to all team physicians, and the consensus was that surgical treatment is recommended 77% of the time over nonsurgical treatment and is the treatment of choice for most physicians. (Level IV evidence)

Magalaya CL, Cook C, Zarzour H, et al: Return to division IA football following a 1st metatarsophalangeal joint dorsal dislocation. *Am J Sports Phys Ther* 5:131–142, 2010.

This is a case report that focuses on returning an athlete to football following a metatarsophalangeal joint dorsal dislocation. It is very specific to football and shows a rehabilitation program for a collegiate football player returning from a foot/ankle injury. (Level IV evidence)

Mindrebo N, Shelbourne KD, Van Meter CD, et al: Outpatient percutaneous screw fixation of the acute Jones fracture. *Am J Sports Med* 21:720–723, 1993.

This study used nine varsity athletes and seven Division 1 scholarship athletes who sustained a Jones fracture and who were treated with percutaneous screw fixation. The authors found an average return time to full competition of 8.5 weeks. (Level IV evidence)

Mologne TS, Lundeen JM, Clapper MF, et al: Early screw fixation versus casting in the treatment of acute Jones fracture. *Am J Sports Med* 33:970–975, 2005.

In this randomized controlled trial, 18 patients were randomized to cast treatment and 19 were randomized to screw fixation. The authors found that early screw fixation results in faster times to union and return to sport compared with cast treatment. (Level I evidence)

Norkin C, White DJ: *Measurement of joint motion: A guide to goniometry*, ed 3, Philadelphia, 2003, F.A. Davis.

This is a handbook that describes in detail the standard way to perform goniometry. Every procedure is described in detail with documented norms of each joint. (Level V evidence)

Porter DA, Duncan M, Meyer SJ: Fifth metatarsal Jones fracture fixation with a 4.5-mm cannulated stainless steel screw in the competitive and recreational athlete: A clinical and radiographic evaluation. *Am J Sports Med* 33:726–733, 2005.

This is a case series in which 23 consecutive athletes (24 feet) who were treated surgically were followed. The authors

showed that a 4.5-mm cannulated screw could provide reliable and effective healing. The authors also demonstrated a functional progression program and postoperative rehabilitation program for the competitive and recreational athlete. (Level IV evidence)

REFERENCES

1. Clapper MF, O'Brien TJ, Lyons PM: Fractures of the fifth metatarsal. Analysis of a fracture registry. *Clin Orthop Relat Res* 238–241, 1995.
2. Mologne TS, Lundeen JM, Clapper MF, et al: Early screw fixation versus casting in the treatment of acute Jones fracture. *Am J Sports Med* 33:970–975, 2005.
3. Mindrebo N, Shelbourne KD, Van Meter CD, et al: Outpatient percutaneous screw fixation of the acute Jones fracture. *Am J Sports Med* 21:720–723, 1993.
4. Collins KS, Streitz W: Bilateral Jones fractures in a high school football player. *J Athl Train* 31:253–256, 1996.
5. Porter DA, Duncan M, Meyer SJ: Fifth metatarsal Jones fracture fixation with a 4.5-mm cannulated stainless steel screw in the competitive and recreational athlete: a clinical and radiographic evaluation. *Am J Sports Med* 33:726–733, 2005.

Multiple Choice Questions

QUESTION 1. On average an athlete who sustains a Jones fracture and elects to have surgery by screw fixation can expect to return to competition at

A. 2 to 3 weeks.
B. 12 to 14 weeks.
C. 7 to 9 weeks.
D. 4 to 5 weeks.

QUESTION 2. To return to competition an athlete must have which of the following?

A. Full ROM of foot/ankle
B. Evidence of union of fracture upon radiographs.
C. Pain-free running
D. All of the above

QUESTION 3. Intervention for a Jones Fracture is offered to patients to

A. avoid prolonged immobilization.
B. lessen the length of time away from the sport.
C. prevent future reinjury of the fifth metatarsal.
D. All of the above

QUESTION 4. Jones fractures sometimes are a challenge to heal with conservative treatment. According to the literature some can take as long as _____ weeks to heal.

A. 21
B. 3
C. 30
D. 12

QUESTION 5. According to Norkin and White (*Measurement of Joint Motion: A Guide to Goniometry*), ankle dorsiflexion norms are

A. 10°.
B. 30°.
C. 20°.
D. 25°.

Answer Key

QUESTION 1. Correct answer: **C** (see Introduction: Literature)

QUESTION 2. Correct answer: **D** (see Specific Criteria for Release to Unsupervised Complete Participation in Football)

QUESTION 3. Correct answer: **A** (see Introduction)

QUESTION 4. Correct answer: **A** (see Introduction)

QUESTION 5. Correct answer: **D** (see Phase III)

Chapter 45



First Metatarsophalangeal Joint Sprain (Turf Toe)

INTRODUCTION

Stephen Gould, MD, MPH, and Kenneth J. Mroczek, MD

Epidemiology

- The term *turf toe* first appeared in literature in 1976 as reported by Bowers and Martin to describe plantar capsuloligamentous sprain of the first metatarsophalangeal (MTP) joint related to hard artificial surfaces and insubstantial footwear.[1]

Age and Sex

- There are no age or sex predilections for this injury.
- Mechanism of injury, playing surface, and individual biomechanics are predisposing factors to the injury.[2]

Sport and Position

- Football players (running backs, wide receivers, defensive backs, offensive linemen, tight ends) have a higher incidence of turf toe injury[3] but the injury is also seen in other sports/activities such as soccer and dance.
- Forty-five percent of professional football players surveyed reported suffering from turf toe.[3]
- Turf toe can cause significant functional disability.
- Coker et al. reported a series of injuries in University of Arkansas football players. The authors described the severity of turf toe injury in terms of lost playing time and delayed return to play, even when compared with more common, but debilitating injuries.[4]
- Hallux metatarsophalangeal joint sprains occur in other sporting activities such as dance (modern and classical) and beach volleyball. "Sand Toe" is the term used to describe this injury in beach volleyball.[5]

Pathophysiology

Intrinsic Factors

- Major contributors
  - Increased ankle dorsiflexion[2]
    - Mean ankle dorsiflexion of the uninjured side in injured players was 13.33° compared with 7.87° in uninjured players.[3]
  - Flattening of the first MTP[2]
  - Foot pronation[2]
- Minor contributors
  - Decreased first metatarsophalangeal dorsiflexion is associated with turf toe injury (40.6 ± 15.1° in football players with turf toe versus 48.4 ± 12.8° in football players without history of turf toe)[6]
  - Hallux degenerative joint disease[2]
  - Prior first MTP joint injury
  - Pes planus
  - Athlete's weight[2]
  - Number of years in professional football
    - 5.2 years for injured versus 3.0 for controls[3]

Extrinsic Factors

- Playing surface
  - Artificial turf and playing surfaces.[2] The introduction of these manufactured surfaces in the mid-1960s resulted in a loss of shock-absorbing characteristics compared with grass turf.
  - Eighty-three percent of patients report initial injury on an artificial surface.[3]
- Footwear
  - The forces the halluces experience are compounded by the friction between athletic shoe and turf.[2]

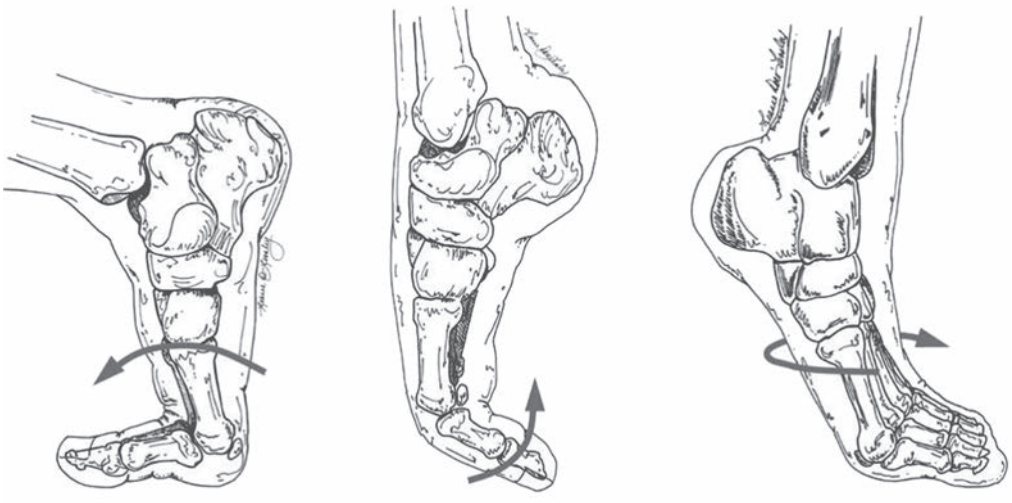

FIGURE 45-1. Loading mechanisms that can result in turf toe injury.

- Lighter, more flexible shoes with increased toe box flexibility and decreased number of cleats in the shoe[2] provide greater agility but offer less protection to the halluces from impact.

Traumatic Factors

- The most common mechanism of injury, accounting for 85% of injuries, results from forced hyperdorsiflexion at the first MTP.[3] This occurs when the forefoot is planted and the heel rises from the ground. If this stress causes the hallux to dorsiflex beyond its biomechanical limits, damage to the capsule at the neck of the first MTP will occur.[2] This is because the joint capsule attachment is weaker at this site than at the proximal phalanx.[3]
- The biomechanics of this injury results from distal traction on the medial and lateral sesamoids during forced hyperextension. This transfers the mechanical load to the dorsal aspect of the metatarsal head. This stress can cause partial or complete disruption of the plantar plate. Injury to the plantar plate results in impaction of the articular surfaces of the proximal phalanx to the metatarsal head during extension of the MTP. This is the most severe form of injury to the soft tissues of the first MTP.[5]
- Eighty-five percent of turf toe injuries result from hyperextension of the first metatarsophalangeal joint.[3] Less common mechanisms of injury include plantar flexion injury to the first MTP joint, and varus or valgus stress injuries.[7] Hyperplantarflexion injuries are more commonly seen in dance and beach volleyball (Figure 45-1).[5]
- Various football positions are susceptible to this injury.
  - Offensive linemen when pushing off from a stance, can hyperextend the first MTP.
  - Running backs and receivers may be also be injured if tackled from behind, with their forefoot planted on the ground, if another player falls onto their leg causing hyperextension at the first MTP (Figure 45-2).
  - Essentially, any activity that results in forced hyperdorsiflexion on the great toe can result in damage to the first MTP. Additional examples include forced dorsiflexion due to tackling or due to impact of the first MTP against the toe box of the shoe during rapid deceleration.

Classic Pathological Findings

- While initially used to describe only a sprain or strain of the soft tissue support structures of the first MTP, the term turf toe has come to designate a spectrum of injuries from sprains to frank dorsal dislocation of the toe.[8]
- Clanton et al developed a classification system to describe the severity of turf toe injuries. This system remains utilized today to help dictate treatment and return to play.[9]

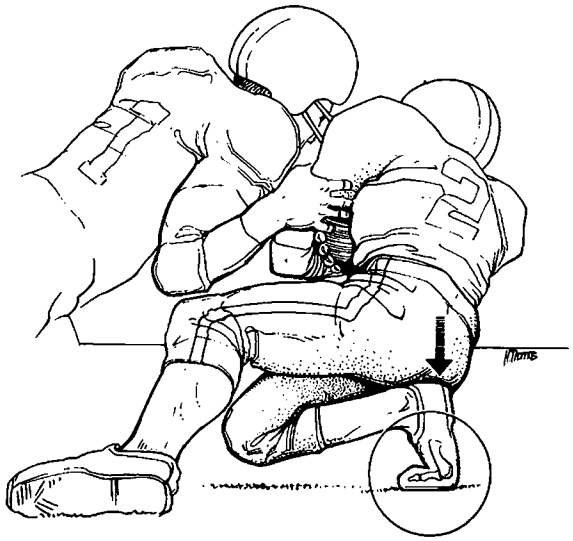

FIGURE 45-2. Forced dorsiflexionflexion injury in football. *(Redrawn from Rodeo SA, O'Brien S, Warren RF, Barnes R, Wickiewicz TL, Dillingham MF: Turf-toe: An analysis of metatarsophalangeal joint sprains in professional football players. Am J Sports Med 18(3):280–285, 1990.)*

- Grade I injuries: least severe; strain of the capsuloligamentous complex without loss of its functional integrity.[7,10,11]
- Grade II injuries are more severe and represent partial thickness tearing of the plantar plate and capsular structures.[7,10,11]
- Grade III injuries are the most severe. This grade of injury may be used to describe either chronic effects of a disrupted capsule,[7] or to describe an acute injury with complete disruption of the capsuloligamentous complex. With this grade of injury, the plantar plate may be completely avulsed from the metatarsal neck, resulting in impaction of the metatarsal head during full extension of the joint.[3,7,10,11]

Clinical Presentation

History

- Typical presentation includes great toe pain in an athlete whose sport exposes him or her to hyperextension of the toe on a hard surface. Football players, soccer players, and dancers, among others may suffer from this injury.
- The patient may complain of pain, swelling, and tenderness of the plantar aspect of the MTP, as well as inability to push off with the great toe.[7]

Physical Examination

Key Elements of Exam

- Observe for general deformity of the toe, presence of swelling and ecchymosis (ecchymosis indicates fracture or disruption of tendon/ligament).[11]
- Palpate joint structures including dorsal metatarsal head and neck, dorsal aspect of the proximal phalanx, and the sesamoids to assess integrity and presence of tenderness to palpation.[11]
- Stress tests
  - Abduction stress test: assesses medial collateral ligament, medial capsule, abductor halluces[11]
  - Adduction stress test: assesses lateral collateral ligament, lateral capsule, and adductor halluces[11]
  - Lachman-type maneuver to assess plantar plate[10,11]
  - Flexor hallucis brevis strength and integrity assessment[11]

Abnormal Findings

- Grade I: Plantar or medial tenderness to palpation; minimal to no swelling; minimal or no ecchymosis[7,8,10]
- Grade II: Diffuse tenderness to palpation; moderate swelling and ecchymosis; painful and restricted range of motion. Symptoms may progress and athletes can lose up to 2 weeks of play.[7,8,10]
- Grade III: Severe tenderness to palpation; marked swelling and ecchymosis, and restricted range of motion. The patient usually will avoid weight bearing due to pain. Athletes can miss up to 6 weeks or more of play. Hallux plantarflexion weakness or frank instability of hallux MTP can occur.[7,8,10,11]

Pertinent Normal Findings

- Grade 1: no visible bruising. There is little change in the range of motion and the patient can continue to bear weight.[7]

Imaging

Grade I

- Radiographs are normal. An MRI may demonstrate mild soft tissue edema surrounding the capsule; however, all components of the capsule remain intact.[7,10]

Grade II

- Radiographs are typically normal. An MRI will show adjacent soft tissue edema. Partial thickness disruption may be seen as fluid signal intensity extending partially through the plantar plate and capsular structures. The sesamoid bones typically remain in normal position.[7,10]

Grade III

- Radiographs are abnormal and may demonstrate an associated capsular avulsion, compression fracture; sesamoid fracture, diastasis, or proximal migration. Comparison films with the contralateral foot or preinjury radiographs may be helpful in detecting sesamoid abnormalities.[7,10,11]
- A small fleck of bone might be found avulsed from the proximal phalanx or the sesamoid, suggesting a capsular disruption.[8]
- An MRI will also demonstrate these findings and can also reveal the extent of injury to each component of the capsuloligamentous structure (Figure 45-3), including the plantar plate, collateral ligaments, as well as the flexor and extensor tendons.[7,10,11]
- An MRI can also assess the integrity of the articular surface of the MTP joint.[7]

General Imaging

- Comparison radiographs of the contralateral foot are mandatory as patients with a rupture of the plantar plate will have proximal migration of one or both sesamoids.[8]
- Forced dorsiflexion lateral radiographs should be obtained if there is clinical suspicion for a plantar plate disruption. If there is a complete disruption of the MTP joint complex, the sesamoids will not track distally with the hallux extension and will appear to be located proximally.[8]
- An MRI is useful for both soft-tissue injury and osseous damage. T2-weighted images will identify subtle injuries. An MRI is recommended for all grade II or III injures to help guide the treatment plan and return to play.[8]

Differential Diagnosis

- Gout: differentiated by associated erythema and warmth of joint; no ecchymosis present; severe pain and restriction of motion

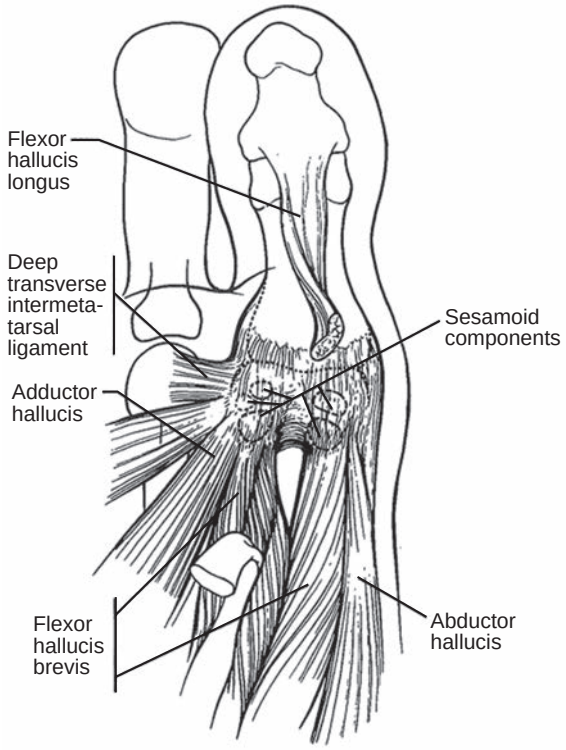

FIGURE 45-3. Anatomy of the capsuloligamentous structures. *(Redrawn from Rodeo SA, O'Brien S, Warren RF, Barnes R, Wickiewicz TL, Dillingham MF: Turf-toe: An analysis of metatarsophalangeal joint sprains in professional football players. Am J Sports Med 18(3):280–285, 1990.)*

- First metatarsal stress fracture: differentiated by lack of erythema/ecchymosis; point tenderness and indolent course
- Soft tissue mass (bursitis, granuloma, Morton neuroma): differentiated by minimal pain with palpation; lack of skin findings

Treatment

Nonoperative Management

- Immobilization, cryotherapy, NSAIDS
- Nonsurgical treatment options involve limiting the range of motion of the first MTP
  - Taping of the toe[7,10,11]
  - Orthotics or "turf toe plate" in the shoe[7,11]
  - Rocker sole shoe[10]
- Walking boot and crutches as needed[8,11]
- Long-term immobilization in boot or cast[8,11]
- Steroid injection is controversial; some authors believe it may predispose to further soft tissue damage.[11]

Guidelines for Choosing Among Nonoperative Treatments

- Grade I: The prognosis for full recovery is good and the patient can usually continue to play with only mild discomfort.[3,7,12] Grade I injuries may be treated with taping of the toe and the use of a stiff insole in the shoe.[7] Grade II: Treatment of grade II injuries is usually conservative with pain control, elevation, rest, and icing of the joint. Motion of the joint may be permitted in several days as symptoms permit.[7] Walking boot and crutches as needed; may need taping on return to play.[8]
- Grade III: The athlete will lose a minimum of 4 to 6 weeks of playing time, and treatment may require prolonged immobilization or surgery.[7]

Surgical Indications

Relative

- Large capsular avulsion with unstable joint
- Diastasis of bipartite sesamoid
- Diastasis of sesamoid fracture
- Retraction of sesamoid(s)
- Traumatic hallux valgus deformity
- Vertical instability (positive Lachman test)
- Loose body
- Chondral injury
- Failed conservative treatment[8,11]

Absolute

- Irreducible joint dislocation

Aspects of History, Demographics, or Exam Findings that Affect Choice of Treatment

- Grade I injury, or sprain of the capsuloligamentous structures, allows athletes to return to competition as tolerated. Taping in slight plantarflexion to diminish motion at the first MTP may alleviate symptoms. In addition, athletes can use orthotics or turf toe plates to minimize hallux MTP extension.[8]
- Grade II injuries, or partial plantar capsular ligamentous rupture, will generally result in loss of playing time of at least 2 weeks. These injuries are treated with a similar regimen of relative immobilization of the first MTP, similar to that used for grade I injuries.[7] Some authors further advocate a 2-week period of non–weight-bearing.[11]
- Grade III injury, or complete plantar capsular ligamentous rupture, can have a prolonged recovery time. With these injuries, a 4- to 8-week period of immobilization followed by rehabilitation is appropriate before return to play.[8,11]

Aspects of Clinical Decision Making When Surgery Is Indicated

- Conservative treatment with immobilization, cryotherapy, and NSAIDS is usually successful, so operative management is rarely considered in acute injury.
- However, operative intervention is required in the acute setting in the case of irreducible joint dislocation.
- If conservative measures fail, surgical intervention should be considered. This is especially true if the patients suffer loss of performance, such as loss of push-off strength.[8]
- Because of the infrequency with which these injuries are surgically repaired, some authors recommend that they should be referred to a foot and ankle specialist.[8]
- Consideration should be given to surgical repair of the ruptured capsuloligamentous complex (Grade III) in collegiate and professional athletes, particularly football players.[13]

Evidence

Bowers KD, Jr, Martin RB: Turf-toe: A shoe-surface related football injury. *Med Sci Sports* 8(2):81–83, 1976.

This paper is the first to describe turf toe injuries, or plantar capsule-ligament sprains of the great toe metatarsophalangeal joint. Predisposing factors were noted to be playing surface hardness and shoe stiffness. (Level V evidence)

Brophy RH, Gamradt SC, Ellis SJ, et al: Effect of turf toe on foot contact pressures in professional American football players. *Foot Ankle Int* 30(5):405–409, 2009.

In an assessment of 44 players on one National Football League team, this study showed that turf toe injury is associated with decreased MTP motion, 40.6 ± 15.1° in football players with turf toe versus 48.4 ± 12.8° in football players without history of turf toe. (Level IV evidence)

Coker TP, Arnold JA, Weber DL: Traumatic lesions of the metatarsophalangeal joint of the great toe in athletes. *Am J Sports Med* 6(6):326–334, 1978.

In a case series of injuries in University of Arkansas football players over three seasons, turf toe injuries caused more lost playing time and delayed return to play when compared to ankle sprains. The authors noted an average of 6.0 turf toe injuries per season. (Level IV evidence)

Rodeo SA, O'Brien S, Warren RF, et al: Turf-toe: An analysis of metatarsophalangeal joint sprains in professional football players. *Am J Sports Med* 18(3):280–285, 1990.

A case series of eighty active professional football players with first metatarsophalangeal joint sprains found the primary mechanism of injury (85%) to be hyperextension. The majority of initial injuries (83%) occurred on artificial turf and decreased range of motion of the first metatarsophalangeal joint was a significant outcome after turf toe injury.) Level IV evidence)

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Multiple-Choice Questions

QUESTION 1. What biomechanical factor predisposes an athlete to a turf toe injury?

A. Decreased ankle dorsiflexion
B. Increased ankle dorsiflexion
C. High arches
D. Prior anterior talofibular ligament injury

QUESTION 2. The most common mechanism of injury to the first metatarsal ligaments is

A. hyperplantarflexion.
B. hyperextension/hyperdorsiflexion.
C. varus stress.
D. valgus stress.

QUESTION 3. Which grade of injury represents partial thickness tearing of the plantar plate and capsular structures?

A. Grade 1
B. Grade 2
C. Grade 3
D. Grade 4

QUESTION 4. Which of the following is not an indication for surgical repair?

A. Vertical instability
B. Loose body
C. Partial tear of the capsuloligamentous complex
D. Chondral injury

QUESTION 5. If treated conservatively, Grade 3 injuries are usually treated with immobilization for what period of time?

A. 1 week
B. 2 weeks
C. 3 weeks
D. 4 or more weeks

Answer Key

QUESTION 1. Correct answer: **A** (see Pathophysiology, Major Contributors)

QUESTION 2. Correct answer: **B** (see Pathophysiology; Mechanism of Injury)

QUESTION 3. Correct answer: **B** (see Clinical Presentation)

QUESTION 4. Correct answer: **C** (see Treatment; Surgical Indications)

QUESTION 5. Correct answer: **D** (see Treatment)

NONOPERATIVE REHABILITATION OF FIRST METATARSOPHALANGEAL SPRAIN (TURF TOE)

Smita Rao, PT, PhD, and Kenneth J. Mroczek, MD

GUIDING PRINCIPLES OF NONOPERATIVE REHABILITATION

- Treatment of turf toe is based on the grade of injury (Grade I, II, or III).
- Excessive dorsiflexion at the first metatarsophalangeal joint must be prevented.
- Return to activity decisions are sport- and position-dependent.

Phase I (weeks 0 to 4): Early Protection

Note: The duration of this phase depends on the Grade of injury. Progression to Phase II is based on resolution of symptoms.

- For Grade I injuries, minimal immobilization and early progression to Phase II is recommended.
- For Grade II injuries, the Early Protection phase may be expected to last 2 weeks.
- Grade III injuries, immobilization may be part of nonsurgical as well as postoperative management.
- As part of the initial nonsurgical treatment, immobilization may last up to 4 weeks based on the severity of symptoms.
- After surgical reconstruction, the patient is non-weight bearing for 4 weeks. Although gentle range of motion can be initiated 5 to 7 days postoperatively, immobilization in a toe spica and joint protection is maintained the remainder of the time.

Goals

- The main goals of Phase I (early protection) are to reduce pain and swelling and facilitate the healing of injured tissue.

Protection

- For Grade I injuries, immobilization with taping and early progression to Phase II is recommended.
- Grade II injuries are treated with immobilization in the form of taping, or a short leg walking boot with crutches. A short leg walking cast may be used in lieu of the walking boot. A toe extension spica may be incorporated in the cast to prevent excessive dorsiflexion of the first metatarsophalangeal (MTP) joint. The patient is allowed to bear weight as tolerated.
- Grade III injuries usually require immobilization in plantar flexion to facilitate healing of ruptured plantar structures, consequently a short leg cast with toe spica or walking boot with crutches is used.

TIMELINE 45-1: **Nonoperative Rehabilitation of First Metatarsophalangeal Sprain (Turf Toe)**

PHASE I (weeks 0 to 4)	PHASE II (weeks 4 to 12)		PHASE III (weeks 12 to 16)
	(weeks 4 to 8)	(weeks 8 to 12)	
• Toe spica in 10° of plantarflexion, and walking boot (non–weight-bearing) • Elevation • PT modalities to address pain, swelling • Supervised passive motion initiated on day 5 to 7 • Transition to removable splint with walking boot	• Active first MTP motion • Partial weight bearing/ weight bearing as tolerated (WBAT) • Weight bearing may be deferred if osteochondral injury present • PT modalities to address pain, swelling, scar healing, and range of motion • Hydrotherapy if available • Therapeutic exercise (muscle strengthening, balance) • Taping	• DC walker, transition to rocker sole shoe or stiff-sole shoe • PT modalities as needed • PROM—full • Mobilizations as needed • Therapeutic exercise (muscle strengthening, balance, bicycling) • Graduated increase in intensity and duration of weight-bearing activity • Taping and/or Morton's extension	• PT modalities as needed • PROM—full • Mobilizations as needed • Taping and/or Morton's extension as needed • Return to activity, sport-specific training • Patient education: Full recovery may take from 24 to 52 weeks. • Injury surveillance and prevention (maintain conditioning and form)

Management of Pain and Swelling

- Although taping is recommended for Grade I and II injuries, it should be noted that taping is not used in the acute setting because of the risk of circulatory compromise.
- Rest, ice, compression, and elevation (RICE) are used in the acute stage to manage pain and swelling. Additional modalities such as cryotherapy (in the form of cold packs), contrast baths, pulsed ultrasound, and interferential electrical stimulation may be used if needed.[1]
- When swelling is well controlled and there is no risk of circulatory compromise, taping may be instituted.

Techniques for Progressive Increase in Range of Motion

- With the first MTP joint immobilized and protected from excessive dorsiflexion, the patient is encouraged to perform ankle circles and ankle pumps.

Other Therapeutic Exercises

- Strength training for the core, upper extremities, and the contralateral extremity should continue.
- Aerobic conditioning can be maintained using an upper extremity bicycle ergometer.
- Open chain exercises for the proximal muscles of the involved lower extremity are allowed (hamstring curls, leg extensions)

Activation of Primary Muscles Involved

- In this phase, activation of the flexor hallucis longus and extensor hallucis longus is minimized.
- To minimize loads at the forefoot and hallux, the patient is advised to limit activities involving strong push-off phase and strong contraction of the calf muscles.

Open and Closed Kinetic Chain Exercises

- CKC exercises are limited to the contralateral limb.
- Resisted OKC exercises of the proximal muscles (hamstrings, quadriceps, glutei) are recommended.
- Ankle circles and ankle pumps (OKC ankle exercises) are used to reduce swelling and maintain range of motion.

Sport-Specific Exercises

- Aerobic fitness should be maintained through cross-training.

Milestones for Progression to the Next Phase

- Resolution of symptoms (pain and swelling) is the chief criterion used to progress to the Phase II (activity progression)

Phase II (weeks 4 to 12): Activity Progression

Note: The duration of this phase depends on the grade of injury. Resolution of swelling and pain serve as criteria for progression from Phase I (early protection) to Phase II (activity progression).

- For Grade I injuries, Phase II rehabilitation may begin as soon as swelling is well controlled and the risk of circulatory compromise is ruled out.
- Grade II injuries may begin Phase II rehabilitation within 3 to 7 days following the initial injury.
- For Grade III injuries, Phase II rehabilitation may be initiated at 3 to 4 weeks following injury in the initial nonsurgical management. In the postsurgical management of turf toe reconstruction, Phase II rehabilitation may being on the fifth to seventh postoperative day.

Goals

- The chief goal of Phase II is to restore pain-free range of motion and ability to walk without pain.

Protection

- Taping provides minimal mechanical restraint.
- For Grade I and II injuries during Phase II rehabilitation, the use of rigid, stiff-soled, steel-shanked shoes is recommended to limit excessive first MTP dorsiflexion during weight-bearing activities.
- Alternatively patients may prefer to use an orthotic device like a carbon graphite shoe insert or Morton's extension (Figure 45-4). These devices may be full length (extends from the posterior heel to the tip of the great toe) or three-quarter length, available over the counter or through custom fabrication. They are intended to be rigid and limit the amount of the dorsiflexion experienced at the first MTP joint. They are available in varying grades of carbon graphite and



FIGURE 45-4. Over the counter orthotic devices. From right to left: full-length carbon graphite shoe insert (*contoured*); full-length carbon graphite shoe insert (*flat*), and three-quarter length Morton's extension (*flat*).

polypropylene. Thicker grades are stiffer. For patient comfort, a soft, viscoelastic insole can be used over the carbon graphite shoe insert or Morton's extension.
- For Grade III injuries, Phase II rehabilitation includes protection in a toe spica and walking cast or walking boot with crutches.
- If required a toe spacer or separator is used to maintain frontal plane alignment of the hallux and prevent hallux valgus.
- Gentle passive range of motion is instituted by the fifth to seventh postoperative day.
- Four weeks postoperatively, active range of motion and weight bearing as tolerated are initiated.
- Eight weeks postoperatively, the patient is allowed to transition to rigid shoes. In protective footwear, gradual activity progression is encouraged.

Management of Pain and Swelling

- As in Phase I, principles of RICE (rest, ice, compression, elevation) are used to achieve pain control and reduce swelling. Additional modalities may be added if required.

Techniques for Progressive Increase in Range of Motion

- Gentle passive plantarflexion to prevent adhesions and loss of sesamoid mobility is encouraged with the overall goal of maintaining joint motion required for gait while avoiding excessive dorsiflexion.
- Manual therapy in the form of joint mobilizations can be used for pain relief and to restore range of motion. Initially, distraction and/or Kaltenborn Grade I anteroposterior glides with oscillations are recommended. As the patient progresses and range of motion improves, Kaltenborn Grade II and III glides (Figure 45-5) and mobilizations with movement (MWM) are appropriate.
- Tender points or trigger points in the calf muscles may be treated with ischemic compression and soft tissue mobilization techniques.
- Non–weight-bearing stretches for the gastrocnemius and soleus muscles should be prescribed, with progression to weight-bearing stretches.

Other Therapeutic Exercises

- Based on sport and/or activity, other therapeutic exercises are continued to maintain lower limb and core strength and flexibility. These include gastrocnemius, hamstrings, rectus femoris, iliotibial band, and iliopsoas stretches.
- Open chain resisted exercises like hamstring curls and quadriceps exercises are appropriate.
- Closed chain exercised like squats should be performed with the first MTP joint maintained in plantarflexion in a toe spica.
- Exercise performance should be supervised to ensure that the flexor and/or extensor hallucis longus muscles are not activated.
- Exercises such as the lunge that involve extreme first MTP dorsiflexion are contraindicated at this stage.

Activation of Primary Muscles Involved

- Starting with passive and then active first MTP plantarflexion, the patient starts to activate his or her flexor hallucis longus in open chain exercises.
- Over time, open chain first MTP dorsiflexion using the extensor hallucis longus is initiated, taking take to avoid impingement and avoid forcing the joint into excessive dorsiflexion.

Sensorimotor Exercises

- Hydrotherapy and whirlpools are useful adjuncts. Water aerobics and walking in the pool can be initiated.

Open and Closed Kinetic Chain Exercises

- Towel crunches are commenced for the toe flexors and extensors (Figure 45-6). Marble or rubber band pickups,

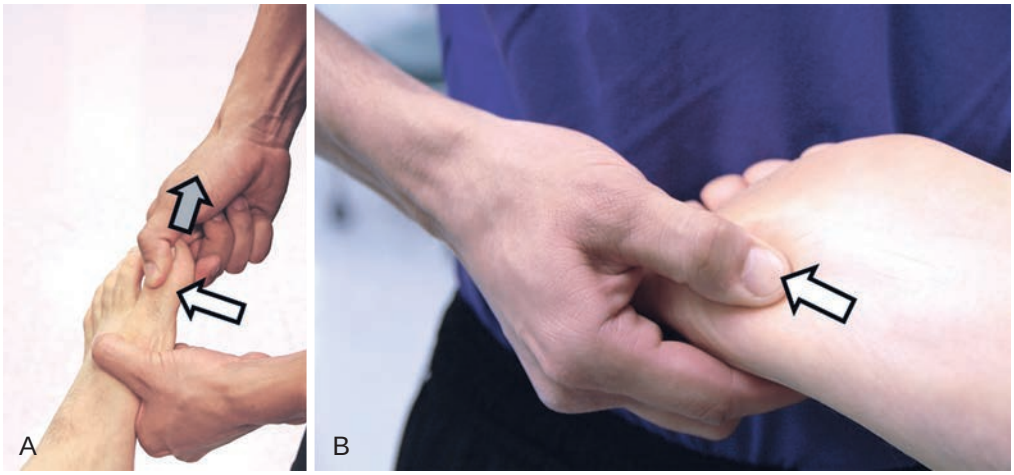

FIGURE 45-5. Manual therapy techniques may involve distraction (*gray arrow,* **A**) and anterior-posterior glides (*white arrow,* **A**) of the first MTP joint. Manual therapy to facilitate distal sesamoid glides (*white arrow,* **B**) may also be used to improve first MTP joint dorsiflexion.

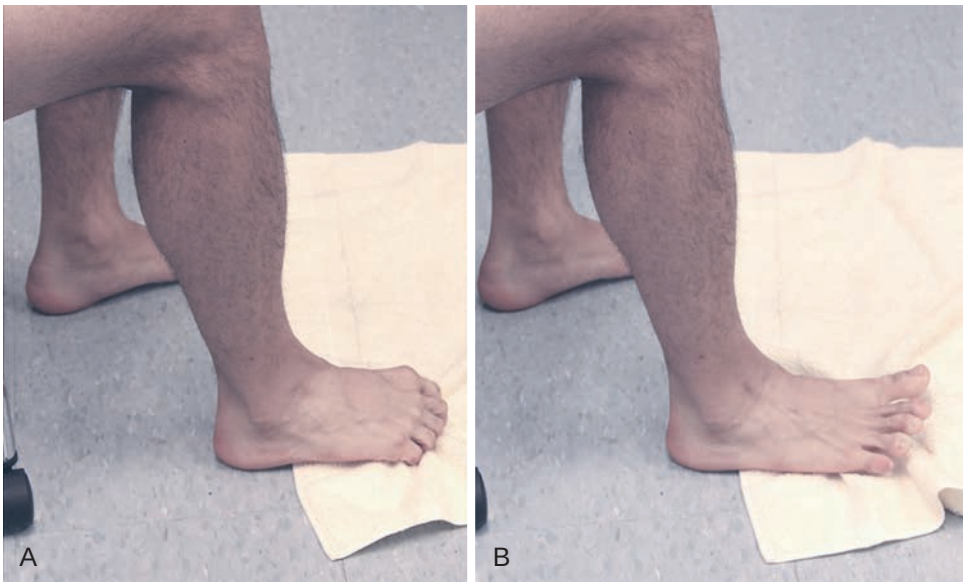

FIGURE 45-6. Exercises like towel crunches can be used to promote full range active first MTP joint dorsiflexion (**B**) and plantarflexion (**A**).

in which the patient is asked to pick up marbles from the floor and put them into a bowl using their toes, can also be instituted for the same purpose.
- Ankle circles and ankle pumps (OKC ankle exercises) are used to reduce swelling and maintain range of motion.
- As in Phase I, resisted CKC exercises are limited to the contralateral limb.
- Resisted OKC exercises of the proximal muscles (hamstrings, quadriceps, and glutei) are recommended.
- As pain and swelling subside, the patient is allowed to transition to weight bearing as tolerated, and finally to full weight bearing.

Techniques to Increase Muscle Strength, Power, and Endurance

- OKC resisted ankle plantarflexion using a Thera-Band can be initiated (Figure 45-7). Ankle dorsiflexion-plantarflexion and inversion-eversion can be performed with Thera-Band. Progression involves increasing the number of repetitions and sets, and also increasing the stiffness of the Thera-Band used.
- With the foot protected in a stiff-soled shoe, carbon graphite shoe insert, or Morton's extension, the patient can start using a stationary bicycle with instructions to avoid excessive first MTP dorsiflexion.
- Seat height needs to be adjusted and the main goal is to increase lower extremity muscle endurance while protecting the first MTP joint from excessive dorsiflexion.

Neuromuscular Dynamic Stability Exercises

- When the patient can tolerate bilateral stance with equal weight bearing, dynamic neuromuscular exercises that involve standing on surfaces of varying stability and stiffness should be commenced.
- Bilateral activities such as squats and heel raises should be initiated in the pain-free range and progress to multiple repetitions over the full range.
- During these exercises, it is important to flag and correct asymmetry in exercise performance and weight bearing.

Functional Exercises

- One of the chief goals of Phase II is to restore pain-free ambulation.
- When the patient is able to sustain unilateral single limb stance (see balance and neuromuscular stability exercises), walking should be attempted.
- Pool walking may be used to help with graduated weight bearing.
- Overground or treadmill walking should be initiated with protective footwear and/or shoe inserts.
- Pain-free and symmetrical ambulation is the primary goal. As patient progresses, speed and duration can be increased.

Sport-Specific Exercises

- Sport-specific upper limb activities such as throwing can be resumed in Phase II.
- Any weight-bearing activity should be performed with protective footwear and/or shoe inserts.
- Sport- and position-specific tasks such as the three-point stance for defensive linemen will be incorporated in Phase III.

Milestones for Progression to the Next Phase

- Pain-free range of motion (60° first MTP dorsiflexion, measured passively with a goniometer) and pain-free weight bearing (standing and walking) serve as criteria for progression to Phase III (Return to Sport).

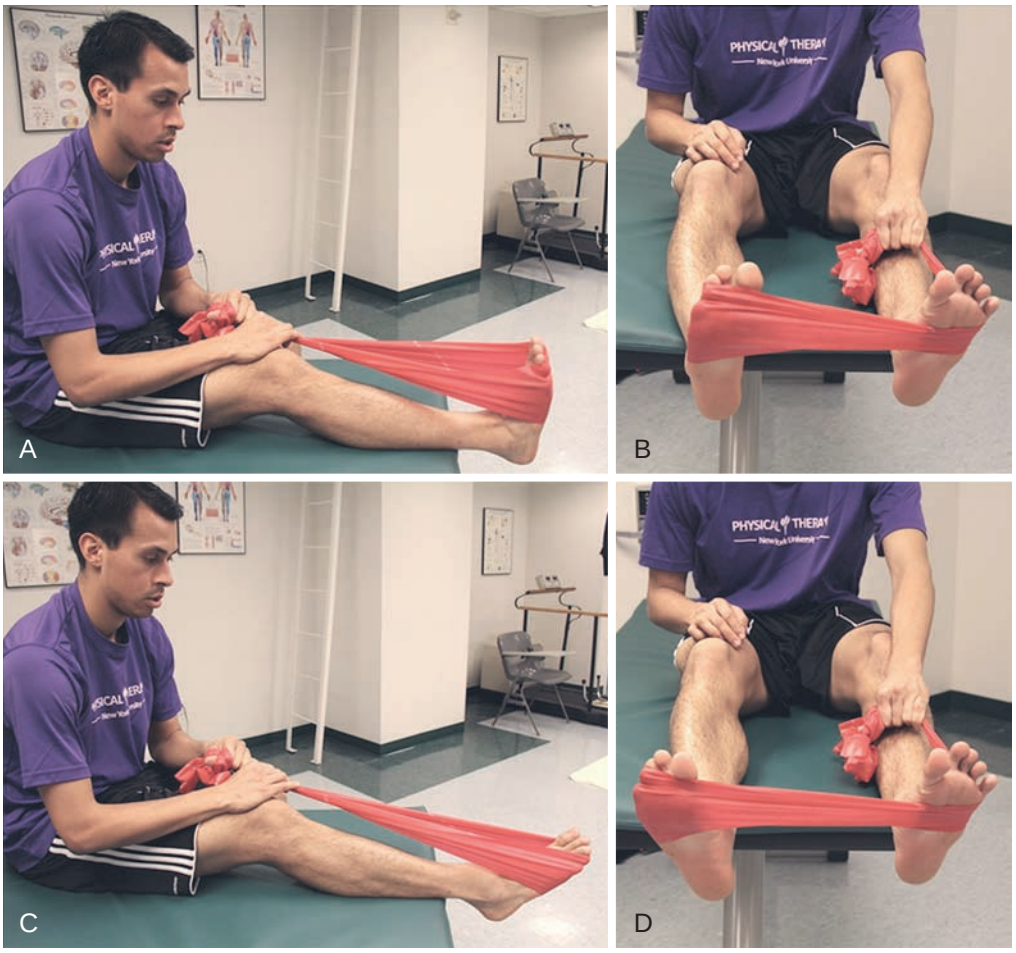

FIGURE 45-7. Open chain ankle dorsiflexion (**A**), plantarflexion (**B**), inversion (**C**), and eversion (**D**) using Thera-Band. Progression will involve increasing the number of repetitions, as well as sets and stiffness of the Thera-Band used.

Phase III (weeks 12 to 16): Return to Sport

- When the patient is able to walk without pain at the first metatarsophalangeal joint and demonstrates pain-free range of motion on clinical testing, they are ready to progress to Phase III.
- This phase may last 4 weeks to 3 months based on the severity and chronicity of the original injury, and demands of the sport and position he or she plays.

Protection

- Morton's extension or rigid sole shoes are used during high-demand activities.

Management of Pain and Swelling

- Ice, in combination with RICE if needed, is used to control pain and swelling, and is particularly useful to limit post-workout symptoms.

Techniques for Progressive Increase in Range of Motion

- Manual therapy, in the form of soft tissue and joint mobilizations, is used to ensure full range of motion and good tissue extensibility. In addition to glides and distraction at the first MTP joint, sesamoid mobilization may be employed to achieve full range of first MTP dorsiflexion.
- In addition to weight bearing and non–weight-bearing stretches for the gastrocnemius and soleus, a plantar fascia stretch may also be incorporated.
- Joint and soft tissue mobilization may be indicated to achieve full range of motion at proximal and contralateral lower extremity joints, including tarsometatarsal, talonavicular, subtalar, ankle, tibiofibular, knee, and hip joints.

Other Therapeutic Exercises

- As previously detailed, core, upper extremity and contralateral lower extremity strength training and stretching regiments should continue.

- In addition, weight-bearing closed chain exercises of the involved limb should be initiated.
- Lunges without and with additional resistance should be used. These are extremely provocative and the presence of pain and impingement should be monitored before and after each workout.

Activation of Primary Muscles Involved

- By Phase III, activation of great toe (flexor hallucis longus, extensor hallucis longus) and ankle muscles (gastrocnemius, soleus, peronei, tibialis anterior, tibialis posterior, flexor digitorum longus) should be symmetric and free from deficits.

Sensorimotor Exercises

- The patient should be able to walk barefoot without pain at the start of Phase III.
- Balance and proprioception training should begin with activities involving single limb stance (Figure 45-8). Activity-specific positions may need to be incorporated; for example, stork stance from martial arts training.
- More dynamic tasks such as the star excursion and balance test (SEBT) should be used, with cueing so the patient does not overuse the flexor hallucis longus muscle. Overuse of the flexor hallucis longus muscle will manifest as excessive flexion of the first MTP and/or interphalangeal joints. Single limb stance should be commenced in front of a mirror or with other visual feedback. Cues such as "relax the toe" should be used to prevent excessive use of the flexor hallucis longus.
- Appropriate activation of proximal muscles such as the hip rotators and abductors should be emphasized. In single limb stance, attention should be paid to maintaining proper form and balance (see Figure 45-8). Progression will involve increasing the duration (for example, three sets of 30 seconds each). Additionally balance can be challenged by presenting unstable surfaces and by adding dynamic activities (see Figure 45-8). During balance and proprioception training, a mirror or other visual feedback should be used to prevent overuse of arms, excessive trunk lean, dynamic knee valgus, and/or calcaneal pronation (see Figure 45-8).

Open and Closed Kinetic Chain Exercises

- In this phase, the patient should progress from walking to stair climbing. Stair ascent and descent place significant demands on the first MTP joint and are more challenging than straight-ahead gait.
- Bilateral graduated weight bearing in increasing amounts of first MTP dorsiflexion can be initiated using exercises like the heel raise.
- Progression involves performing single limb heel raises, first without then with additional free weights.
- When the patient can perform full range unilateral heel raises and negotiate stairs without pain, additional unilateral resisted exercises (lunges) can be instituted. Progression will include multidirectional lunges with added weights.

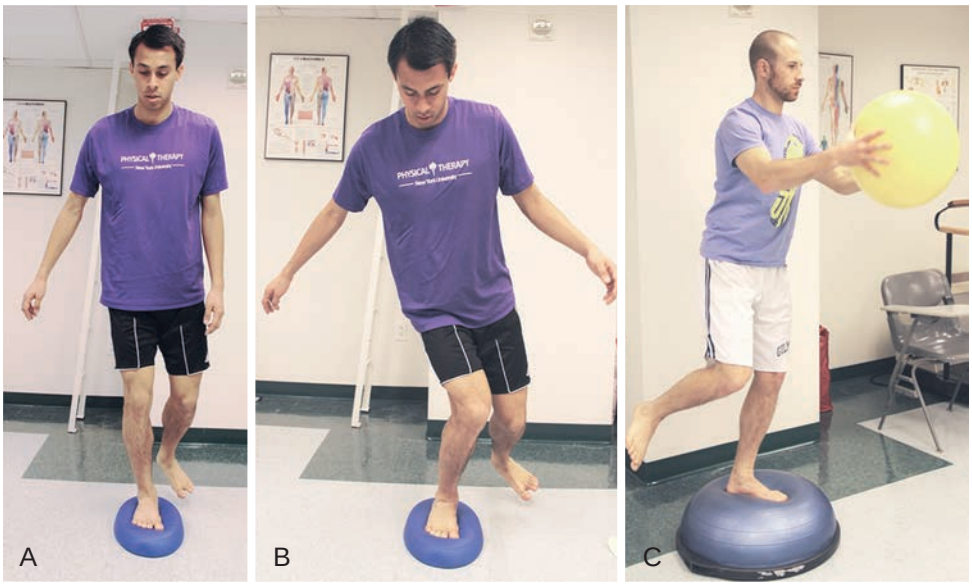

FIGURE 45-8. Single limb stance on a foam surface with good mechanics is depicted (**A**). Note the alignment of the knee over the second toe; the stance knee is not locked ("soft knee") and there is an absence of any trunk lean. Inability to maintain posture and balance in single limb stance (**B**) will manifest as excessive knee valgus, calcaneal pronation, first MTP flexion, trunk lean, and/or excessive use of arms for balance. Training to improve posture and balance in single limb stance starts with the patient barefoot on a stable surface, and progression involves increasing the duration, unstable surfaces (e.g., foam, BOSU ball), and dynamic activities (e.g., ball toss on BOSU ball) (**C**).

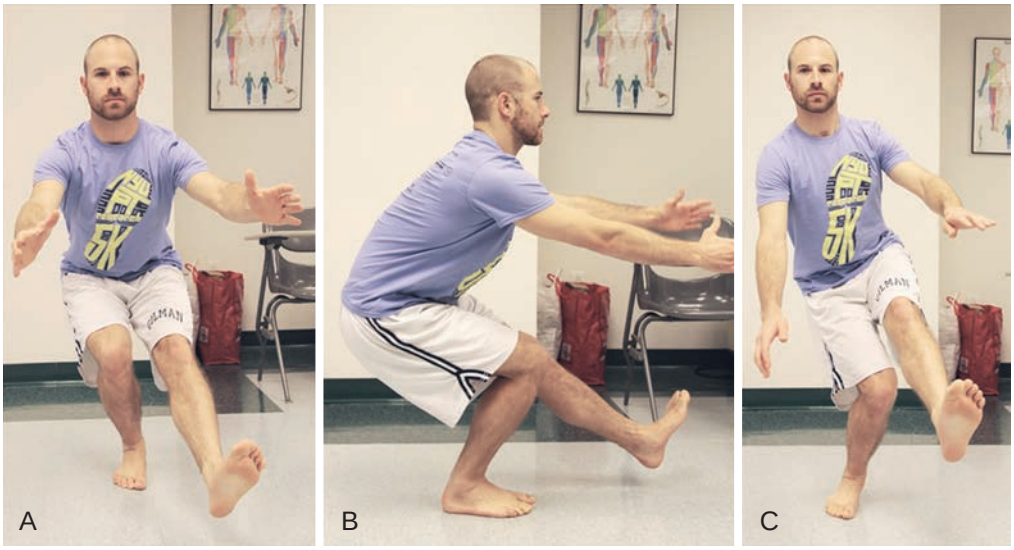

FIGURE 45-9. Single limb squats can be used in Phase III to promote closed kinetic chain function because they require activation of both proximal and distal muscles of the stance leg. Attention to good mechanics is crucial. In the frontal plane, note alignment of knee over second toe, hips and knees are level, no trunk lean is present (**A**). In the lateral view, the knee should be over the toes and arms extended (**B**). Markers of poor mechanics include excessive toe out, arch collapse, dynamic knee valgus, pelvic drop, and/or trunk lean (**C**).

- Single limb squats can also be useful in this phase (Figure 45-9).

Techniques to Increase Muscle Strength, Power, and Endurance

- See Open and Closed Kinetic Chain Exercises.

Neuromuscular Dynamic Stability Exercises

- Standing with balance and proprioception training, the patient should progress to performing more dynamic tasks such as single limb squats, single limb hops and agility drills (Figures 45-10 to 45-12).
- Progression should involve cutting and rapid changes in direction.

Plyometrics

- Eccentric exercises targeting the calf muscles in particular and the lower extremity in general are indicated.
- In athletes involved with sports such as gymnastics and martial arts, plyometrics are particularly important for

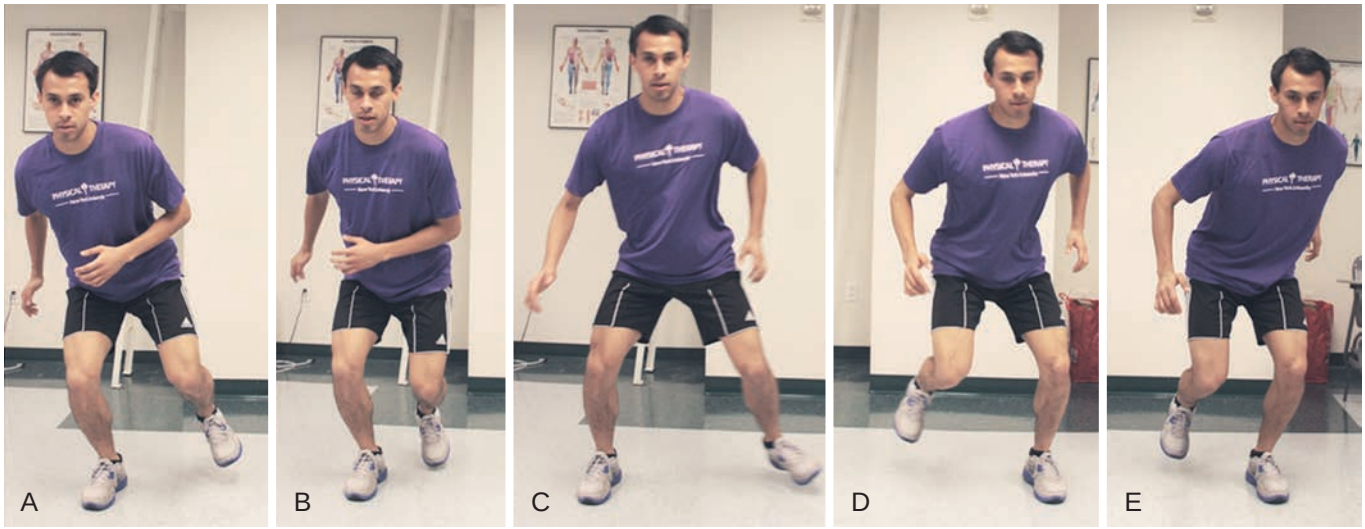

FIGURE 45-10. Drills such as the side shuffle should be used to regain agility. Panels A through E depict symmetrical performance and ideal form. Visual biofeedback using a mirror can be used to ensure good mechanics, reflected in symmetrical performance, absence of trunk lean, dynamic valgus, and arch collapse. Audio feedback in terms of curing the patient to the sound of footfalls can be used to encourage him or her to maintain a light and quick cadence.

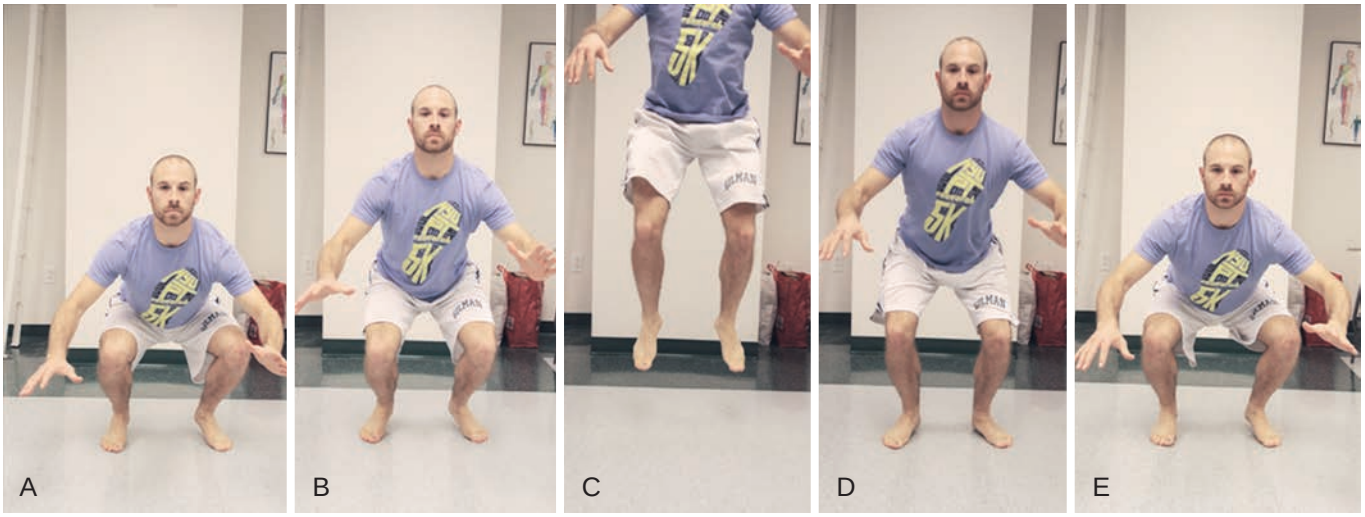

FIGURE 45-11. Return to sport (Phase III) should include sport-specific training such as jumping. Feet, knees, and hips should be symmetrical during takeoff (**A, B, C**) and landing (**D, E**).

proper technique and biomechanics during takeoff and landing.
- Motor learning and imagery techniques should be used to cue proximal muscles (core and hip muscles) and reduce the shock absorption and eccentric demand placed on distal extremity muscles like the flexor hallucis longus (e.g., the cue "pretend you're landing on marshmallows" is used to train landing in gymnasts and dancers).

Functional Exercises

- See Open and Closed Kinetic Chain Exercises and Sensorimotor and Neuromuscular Stability Exercises.

Sport-Specific Exercises

- For sports involving explosive starts and rapid changes in direction (baseball, football), agility drills incorporating these elements with are essential elements of sport-specific training.
- Additionally these drills should be performed on the playing surface with footwear used during competition to approximate realistic conditions.
- For activities involving jumping and landing (volleyball, dance), jumping drills with changes in direction should be included.

Tips and Guidelines for Transitioning to Performance Enhancement

- Prophylactic taping, the use of stiff-soled shoes (Figures 45-13 and 45-14) or Morton's extensions may facilitate the transition to performance.
  - Post-game ice and maintenance of range of motion through joint mobilization should be used to facilitate recovery.

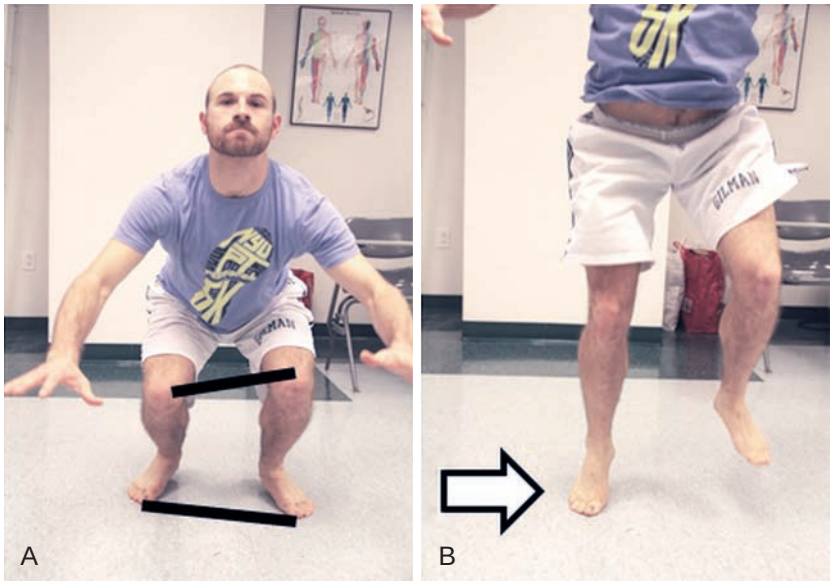

FIGURE 45-12. A, Poor mechanics during takeoff may manifest as an asymmetrical or staggered stance, which in turn may lead to asymmetry or obliquity at the knees and/or hips. **B,** Poor mechanics during landing may result in one limb contacting the floor before the other.

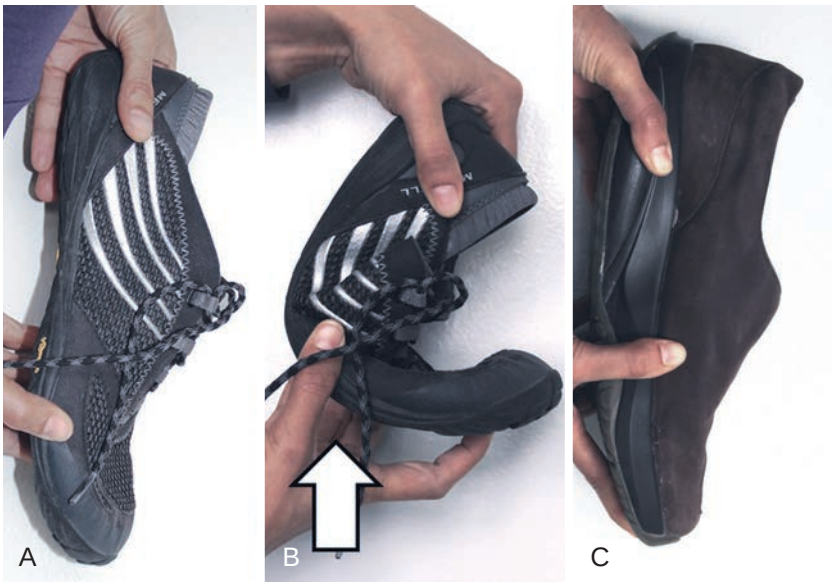

FIGURE 45-13. Athletic shoe (**A**) with high toe-break flexibility (**B**). Walking shoe with minimal toe-break flexibility (**C**).

Performance Enhancement and Beyond Rehabilitation: Training/ Trainer and Optimization of Athletic Performance

- Surveillance for impingement and/or osteochondral injuries should continue after return to performance.
- Communication with patient and trainer is essential to set realistic expectations for recovery and return to sport.
- Upon complete resolution of symptoms, taping and shoe inserts can be discontinued.



FIGURE 45-14. Athletic shoe (**A**) with high torsional flexibility (**B**).

Specific Criteria for Return to Sports Participation: Tests and Measurements

- Pain-free and full range of motion
- Pain free during weight bearing activities
- Complete resolution of symptoms

Evidence

Limited objective data are available to guide the nonsurgical management of turf toe. The following annotated bibliography highlights recent comprehensive reviews that present retrospective data and/or clinical cases.

Chinn L, Hertel J: Rehabilitation of ankle and foot injuries in athletes. *Clin Sports Med* 29(1):157–167, 2010.

This review comprehensively covers current nonsurgical options available for foot and ankle injuries, including turf toe. (Level IV evidence)

Coughlin MJ, Kemp TJ, Hirose CB: Turf toe: Soft tissue and osteocartilaginous injury to the first metatarsophalangeal joint. *Phys Sportsmed* 38(1):91–100, 2010.

This review highlights the importance of identifying and managing osteocartilaginous injury in turf toe. (Level IV evidence)

Maglaya CL, et al: Return to division 1A football following a metatarsophalangeal joint dorsal dislocation. *NAJSPT* 5(3):131–142, 2010.

This case study follows the rehabilitation protocol of a Division 1A football player following a turf toe injury. (Level IV evidence)

McCormick JJ, Anderson RB: The great toe: failed turf toe, chronic turf toe, and complicated sesamoid injuries. *Foot Ankle Clin* 14(2):135–150, 2009.

McCormick JJ, Anderson RB: Rehabilitation following turf toe injury and plantar plate repair. *Clin Sports Med* 29(2):313–323, ix, 2010.

This recent review provides an overview of the rehabilitation of turf toe as well as provides specific examples of interventions used in current clinical practice. (Level IV evidence)

Nihal A, Trepman E, Nag D: First ray disorders in athletes. *Sports Med Arthrosc* 17(3):160–166, 2009.

This review emphasizes the role of relative rest, activity modification, and insoles in the rehabilitation of individuals with turf toe injuries. (Level IV evidence)

REFERENCE

1. Maglaya CL, et al: Return to division 1A football following a metatarsophalangeal joint dorsal dislocation. *NAJSPT* 5(3):131–142, 2010.

Multiple Choice Questions

QUESTION 1. For Grade 1 turf toe injuries, which of the following is appropriate?

A. Immobilization in a toe spica in the acute postinjury phase
B. Manual therapy in the form of soft tissue and joint mobilization is the modality of choice in the acute postinjury phase.
C. Immobilization with taping and early progression to Phase II are the main goals in the acute postinjury phase.
D. Manual therapy should only be instituted after swelling subsides.

QUESTION 2. For a patient with a Grade II turf toe sprain, criteria for progression from Phase II to Phase III are:

A. Duration since injury—progress to Phase III in 4 weeks
B. Duration since injury—progress to Phase III in 2 weeks
C. Pain free full range of motion
D. Pain free on full weight bearing

QUESTION 3. A Morton's extension or turf toe plate is used to prevent

A. excessive dorsiflexion of the first metatarsophalangeal joint.
B. excessive plantarflexion of the first metatarsophalangeal joint.
C. excessive impact and cushion plantar sesamoids.
D. arch collapse by complementing the windlass effect.

Answer Key

QUESTION 1. Correct answer: **C** (see Phase I)

QUESTION 2. Correct answer: **D** (see Phase III)

QUESTION 3. Correct answer: **A** (see Phase II)