Chapter 30

Meniscus Injuries

INTRODUCTION

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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

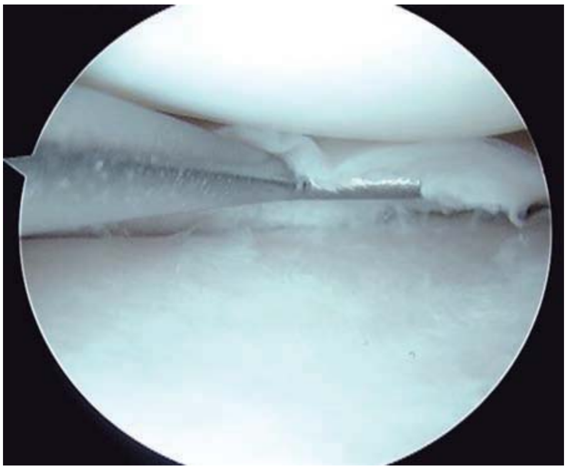

FIGURE 30-1. A degenerative longitudinal medial meniscus tear in a 55 year-old woman. *(Reprinted with permission from Noyes FR, Barber-Westin SD: Meniscus tears: Diagnosis, repair techniques, and clinical outcomes. In Noyes' knee disorders: surgery, rehabilitation, clinical outcomes, Philadelphia, 2009, 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

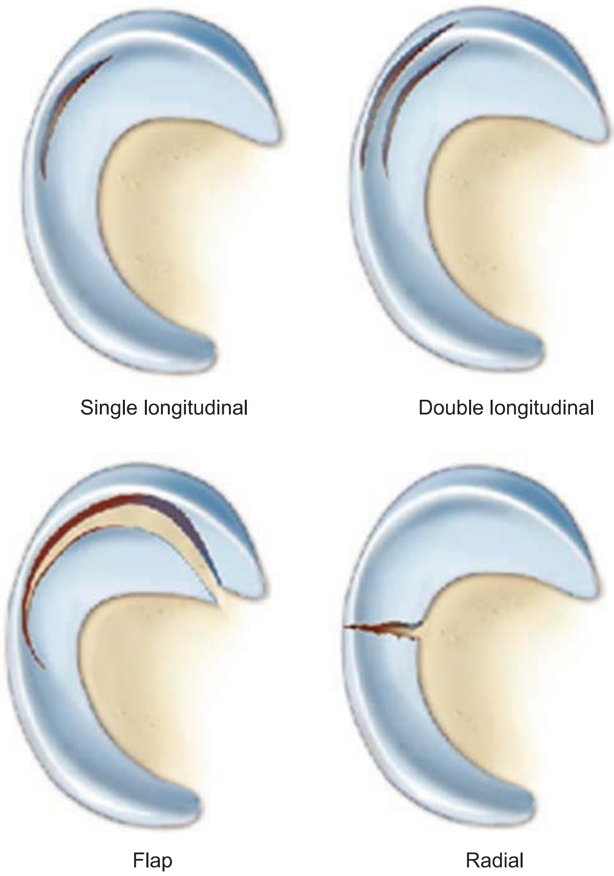

FIGURE 30-2. Illustrations of the common complex and avascular meniscus tear patterns. Note the single-plane configuration of the single longitudinal and radial tears and the multiplane (complex) configuration of the double longitudinal and flap tears. *(Redrawn with permission from Noyes FR, Barber-Westin 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.)*

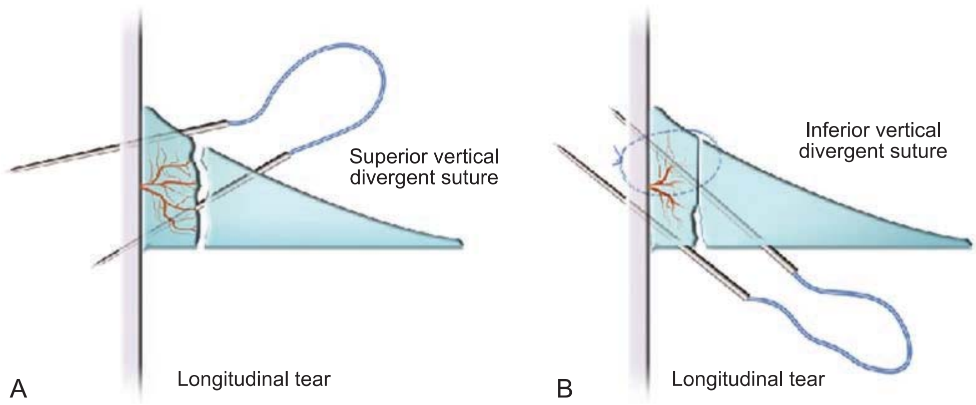

FIGURE 30-3. Double-stacked vertical suture pattern used in the repair of longitudinal meniscus tears. **A,** The superior sutures are placed first to close the superior gap and to reduce the meniscus to its bed. **B,** Then, the inferior suture is placed through the tear to close the inferior gap. *(Redrawn 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.)*

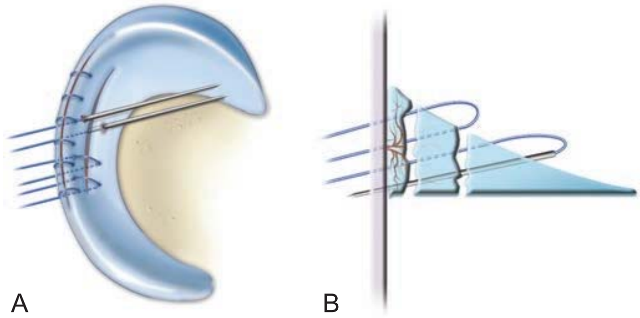

FIGURE 30-4. Double-stacked repair technique for double longitudinal tears. The peripheral tear is repaired first with superior and inferior vertical divergent sutures (**A**), followed by repair of the inner tear in the same fashion (**B**). *(Redrawn with permission from Noyes FR, Barber-Westin SD. 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.)*

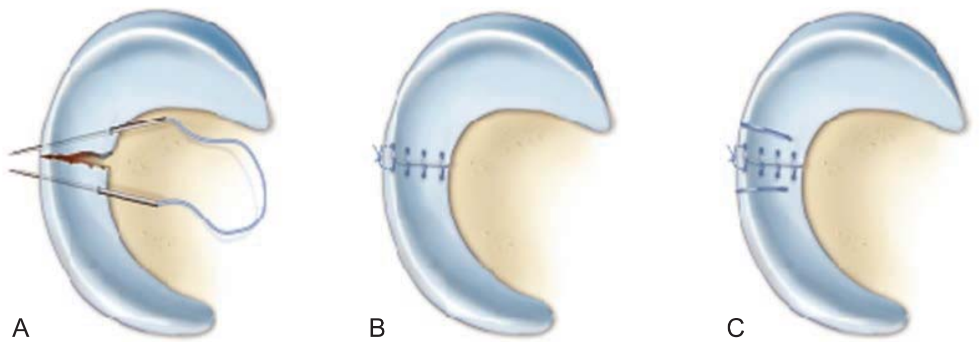

FIGURE 30-5. Repair technique for radial meniscus tears. The inner sutures (**A**) are placed first, followed by the peripheral sutures (**B**). The first suture needle is placed midway through the meniscus body, then used to apply a circumferential tension to reduce the tear gap, and then advanced through 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.)*

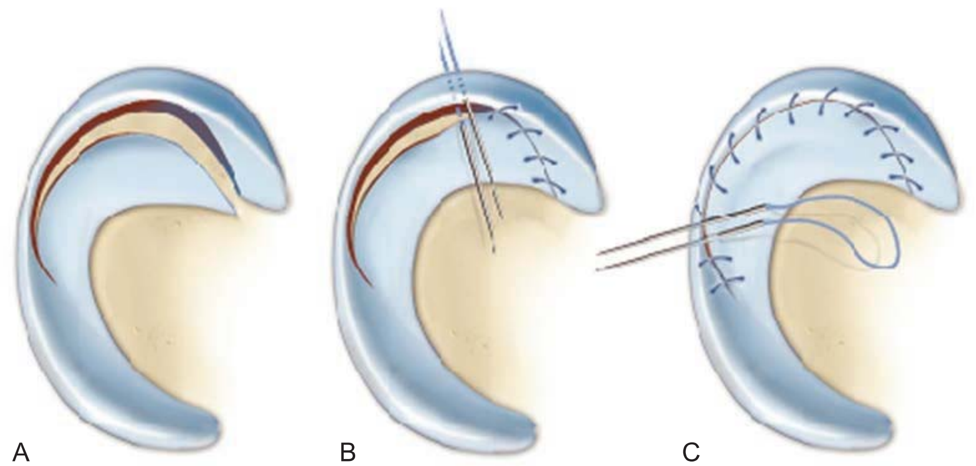

FIGURE 30-6. Repair technique for flap tears. **A,** the tear is identified and reduced. **B,** Horizontal tension sutures are placed to anchor the radial component of the tear. **C,** The longitudinal component is sutured using the double-stacked suture technique. *(Redrawn with permission from Noyes 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.)*

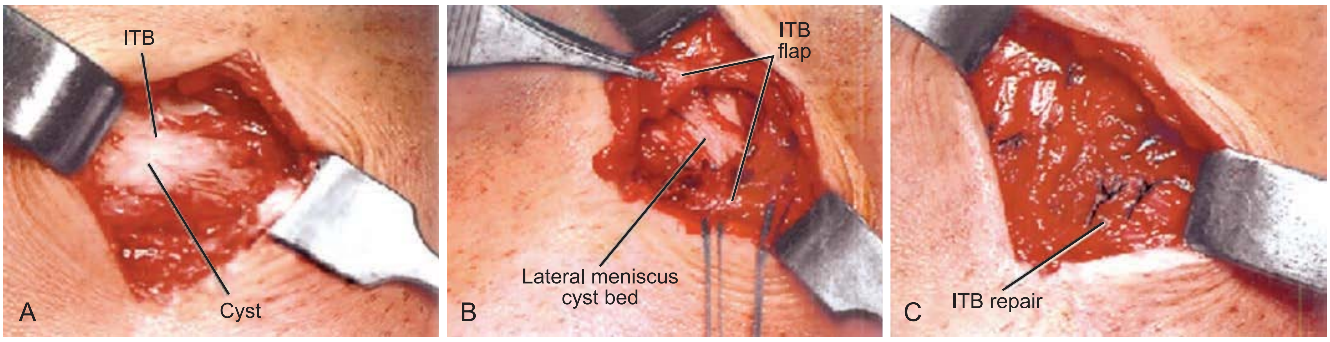

FIGURE 30-7. Demonstration of repair of lateral meniscus horizontal tear with a meniscal cyst. **A,** A 3-cm lateral joint incision placed directly over cyst shows the iliotibial band and an obvious protruding cyst. **B,** Iliotibial band is split in a line of fibers over the cyst and retracted, the 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.)*

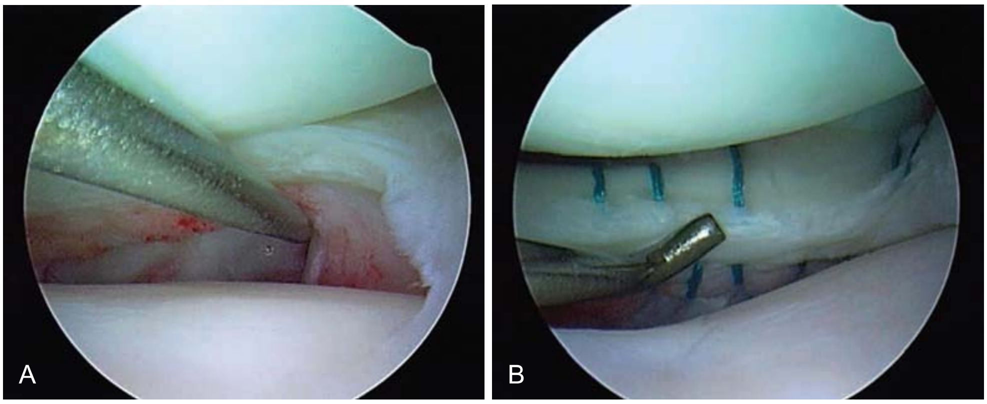

FIGURE 30-8. An athlete who had a prior negative arthroscopic examination and MRI and continued posterolateral joint pain shows a posterior horn popliteomeniscal attachment tear that required suture repair. **A,** Enlarged popliteal hiatus and laxity of the meniscotibial attachments is shown. **B,** 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.)*

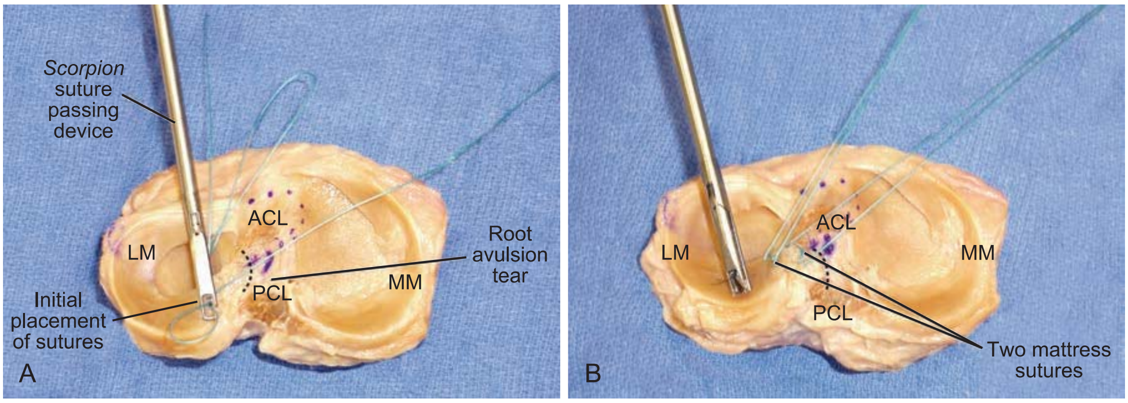

FIGURE 30-9. Posterior meniscus root attachment tear. **A,** Placement of two mattress sutures; the meniscus suture-passing device (Arthrex, Naples, FL) may be passed in and out of the portal to place higher-holding strength mattress sutures over a single suture. **B,** Final placement of sutures brought 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)

REFERENCES

1. Cook JL: The current status of treatment for large meniscal defects. *Clin Orthop Relat Res* 435:88–95, 2005.
2. Sohn DH, Moorman CT: Meniscal debridement: current concepts. *J Knee Surg* 21:145–153, 2008.
3. Baker BE, Peckham AC, Pupparo F, et al: Review of meniscal injury and associated sports. *Am J Sports Med* 13:1–4, 1985.
4. Majewski M, Susanne H, Klaus S: Epidemiology of athletic knee injuries: A 10-year study. *Knee* 13:184–188, 2006.
5. Englund M, Guermazi A, Roemer FW, et al: Meniscal tear in knees without surgery and the development of radiographic osteoarthritis among middle-aged and elderly persons: The Multicenter Osteoarthritis Study. *Arthritis Rheum* 60:831–839, 2009.
6. Fithian DC, Paxton LW, Goltz DH: Fate of the anterior cruciate ligament-injured knee. *Orthop Clin North Am* 33:621–636, v, 2002.
7. Noyes FR, Barber-Westin SD: Repair of complex and avascular meniscal tears and meniscal transplantation. *J Bone Joint Surg Am* 92:1012–1029, 2010.
8. 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.
9. 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.
10. 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.

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

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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.

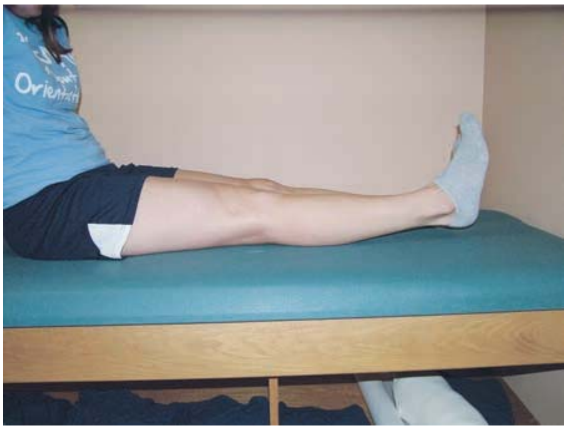


FIGURE 30-13. The active heel lift is performed in a long-sitting position. The patient contracts the quadriceps and dorsiflexes the ankle, elevating the heel above the supporting surface.

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.
  - 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.

FIGURE 30-12. The towel stretch exercise is used to stretch the knee into maximal extension, including 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)

REFERENCES

1. 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.
2. Kornick J, Trefelner E, McCarthy S, et al: Meniscal abnormalities in the asymptomatic population at MR imaging. *Radiology* 177:463–465, 1990.
3. 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.
4. 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.
5. Rimington T, Mallik K, Evans D, et al: A prospective study of the nonoperative treatment of degenerative meniscus tears. *Orthopedics* 32(8):pii, 2009.
6. 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.
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

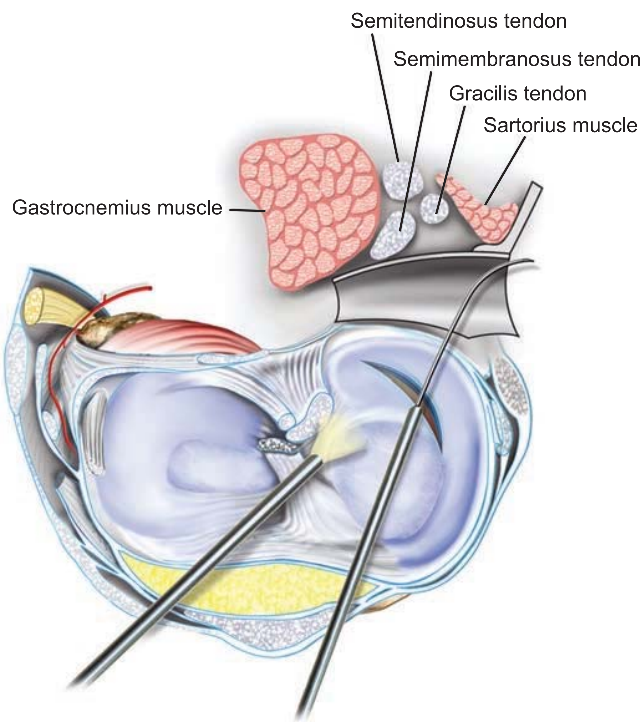


FIGURE 30-16. Cross-section showing popliteal retractor between the posterior capsule and the medial gastrocnemius for a medial meniscus repair. The suture cannula is placed through the lateral or medial portal with care taken to angle the needle away from the neurovascular structures. *(Reprinted with 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.)*

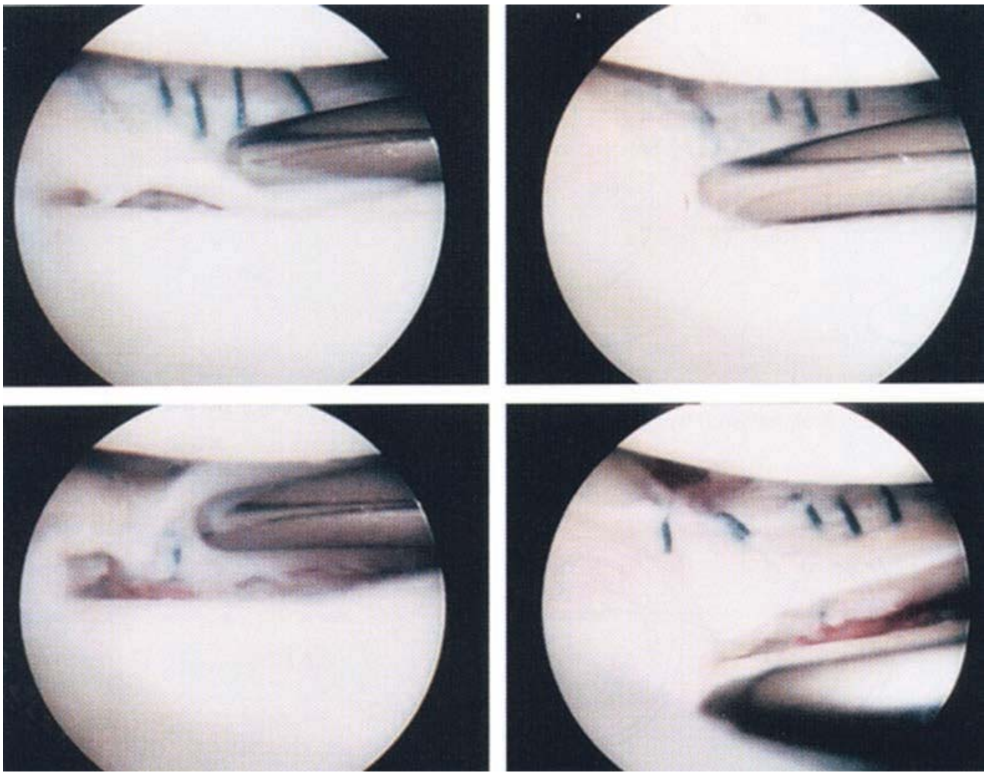


FIGURE 30-17. A longitudinal meniscal tear site demonstrating some fragmentation inferiorly. This tear required multiple superior and inferior vertical divergent sutures to achieve an anatomic reduction. *(Reprinted with permission from Noyes FR, Barber-Westin SD: Arthroscopic repair of meniscal tears 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)

- 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°

PHASE II (weeks 3 to 6)

- 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.

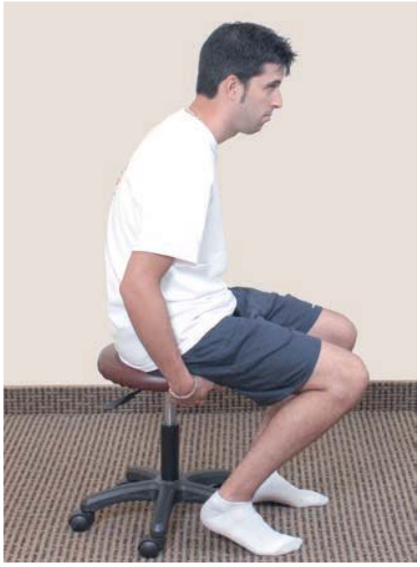


FIGURE 30-19. Rolling stool overpressure exercise for knee flexion. *(Reprinted with permission from Heckmann TP, Noyes FR, Barber-Westin SD: Rehabilitation of primary and revision anterior cruciate ligament reconstructions. In Noyes FR, Barber-Westin SD, editors: Noyes' knee disorders: surgery, rehabilitation, 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

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

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 body-weight 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.*)

- 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)

REFERENCES

1. 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.
2. Heckmann TP, Noyes FR, Barber-Westin SDL: (2009) 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.
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

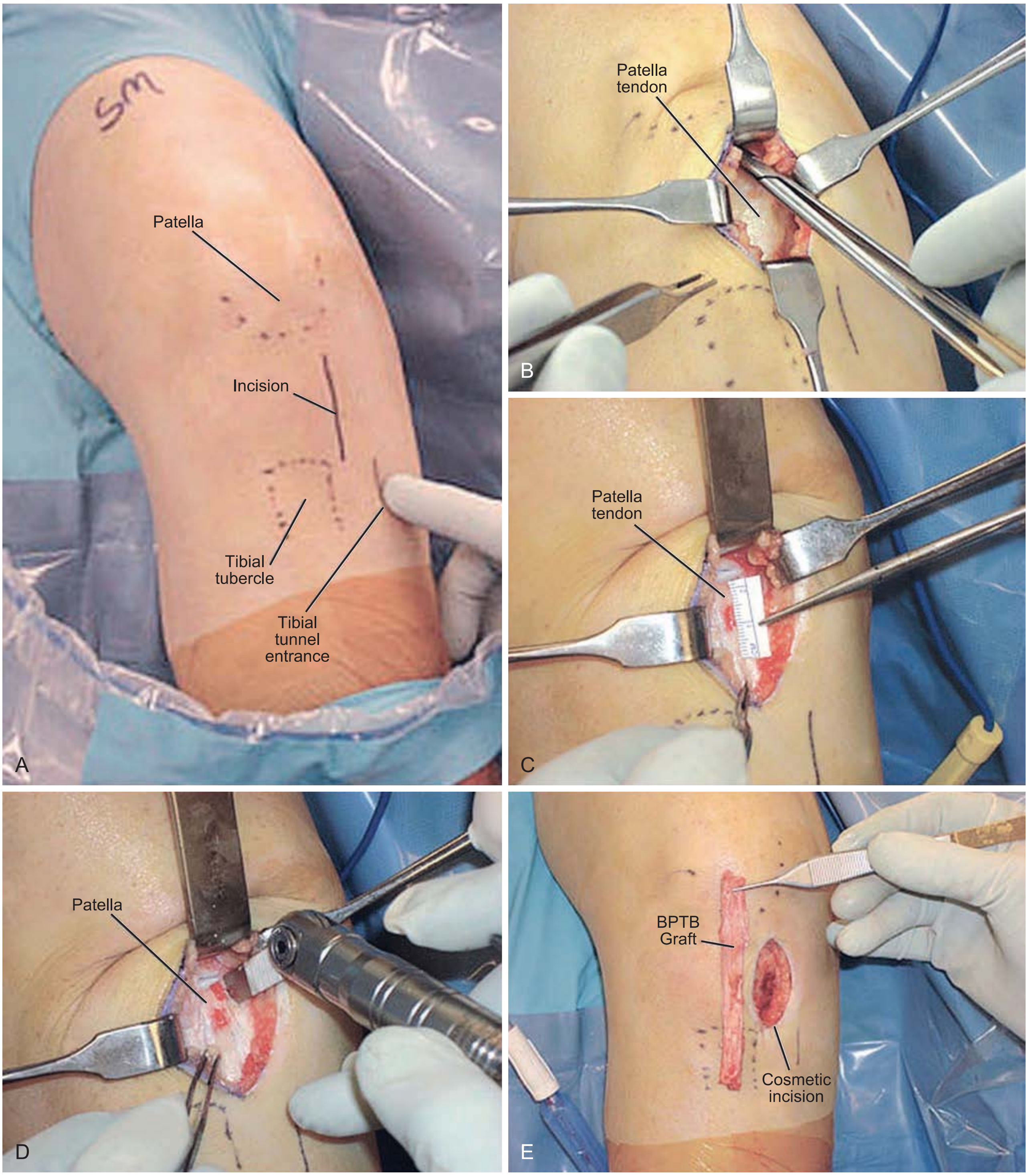


FIGURE 30-22. **A,** A 3- to 4-cm skin incision, just medial to the patellar tendon, is made to avoid the bony prominence of the patella and tibial tubercle. The index finger points to the planned tibial tunnel, which can be reached through this cosmetic incision. **B,** Mobilization of subcutaneous 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.)*

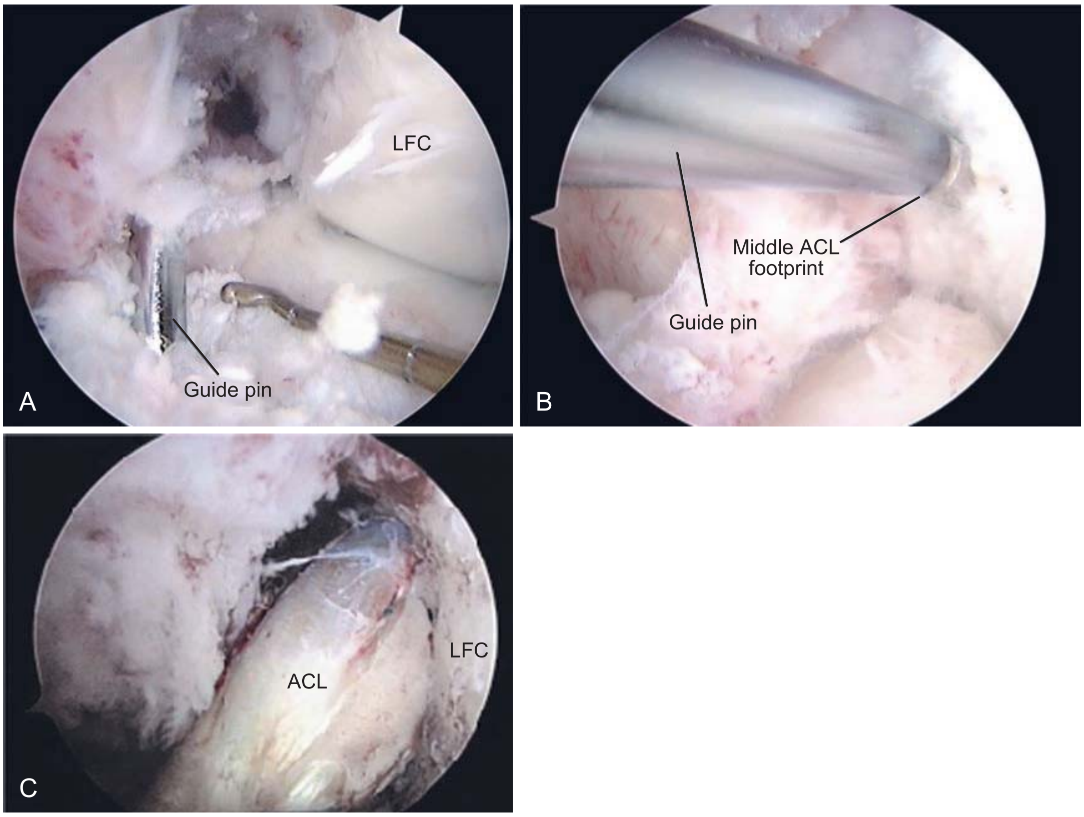


FIGURE 30-23. **A,** Guide pin placement is shown into the center of the ACL tibial attachment and adjacent, but not behind, the lateral meniscus attachment. **B,** ACL femoral central point is reached with knee hyperflexion and anteromedial portal or with a two-incision rear-entry technique. **C,** 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 $\frac{1}{2}$ WB for peripheral meniscus repairs
- Toe-touch to $\frac{1}{4}$ 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
- $\frac{1}{2}$ to $\frac{3}{4}$ BW complex, all-inside meniscus repairs (increase by approximately 25% per week)
- $\frac{1}{4}$ 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

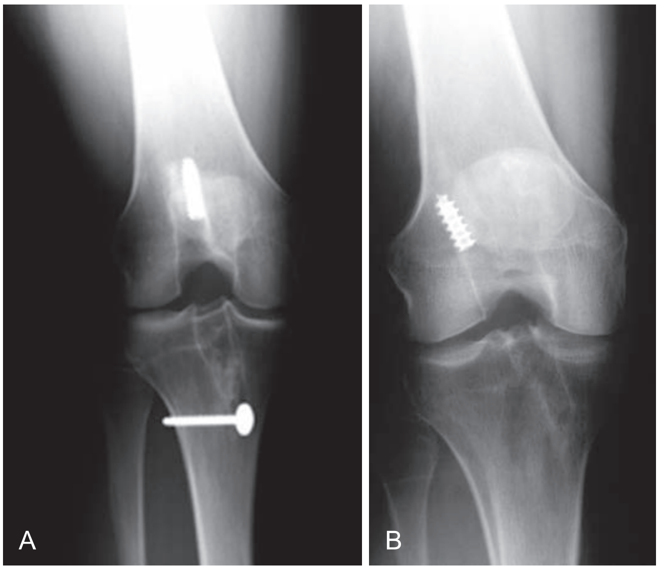


FIGURE 30-24. **A,** Anteroposterior radiograph shows a vertically oriented ACL graft with enlarged tibial and femoral tunnels. This graft placement should be avoided at all times, as it will not be effective in restoring normal ACL function. **B,** Correct ACL graft placement is shown. *(Reprinted with 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)

REFERENCES

1. Noyes FR, Barber-Westin SD: Anterior cruciate ligament primary and revision reconstruction: Diagnosis, operative techniques, and clinical outcomes. In Noyes FR, editor: *Noyes' knee disorders: Surgery, rehabilitation, clinical outcomes*, Philadelphia, 2009, Saunders, pp 140–228.
2. Heckmann TP, Noyes FR, Barber-Westin SD: Rehabilitation of meniscus repair and transplantation procedures. In Noyes FR, editor: *Noyes' knee disorders: Surgery, rehabilitation, clinical outcomes*, Philadelphia, 2009, Saunders, pp 806–817.
3. Barber-Westin SD, Heckmann TP, Noyes FR: Scientific basis of rehabilitation after anterior cruciate ligament autogenous reconstruction. In Noyes FR, editor: *Noyes' knee disorders: Surgery, rehabilitation, clinical outcomes*, Philadelphia, 2009, Saunders, pp 268–305.
4. Heckmann TP, Noyes FR, Barber-Westin SD: Rehabilitation of primary and revision anterior cruciate ligament reconstructions. In Noyes FR, editor: *Noyes' knee disorders: Surgery, rehabilitation, clinical outcomes*, Philadelphia, 2009, Saunders, pp 306–336.
5. Noyes FR, Barber-Westin SD: Prevention and treatment of knee arthrofibrosis. In Noyes FR, editor: *Noyes' knee disorders: Surgery, rehabilitation, clinical outcomes*, Philadelphia, 2009, Saunders, pp 1053–1095.
6. Barber-Westin SD, Noyes FR: Decreasing the risk of anterior cruciate ligament injuries in female athletes. In Noyes FR, editor: *Noyes' knee disorders: Surgery, rehabilitation, clinical outcomes*, Philadelphia, 2009, Saunders, pp 428–463.

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 non-weight bearing for the first 4 to 6 weeks with a post-operative 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

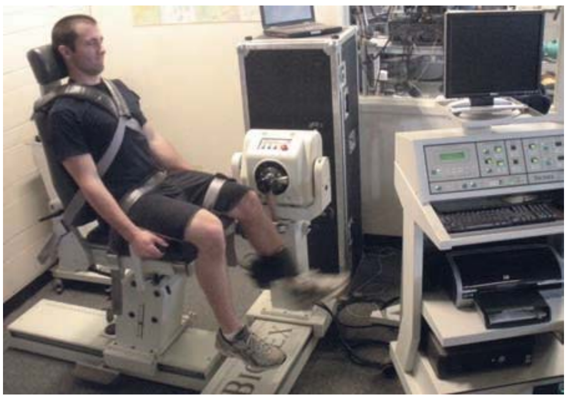


FIGURE 30-36. Biodex Isokinetic.

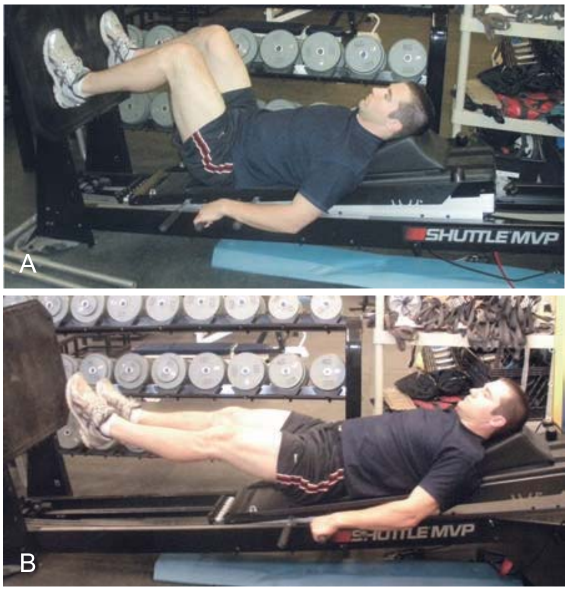


FIGURE 30-37. Shuttle MVP. **A,** Start position. **B,** Jump.

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

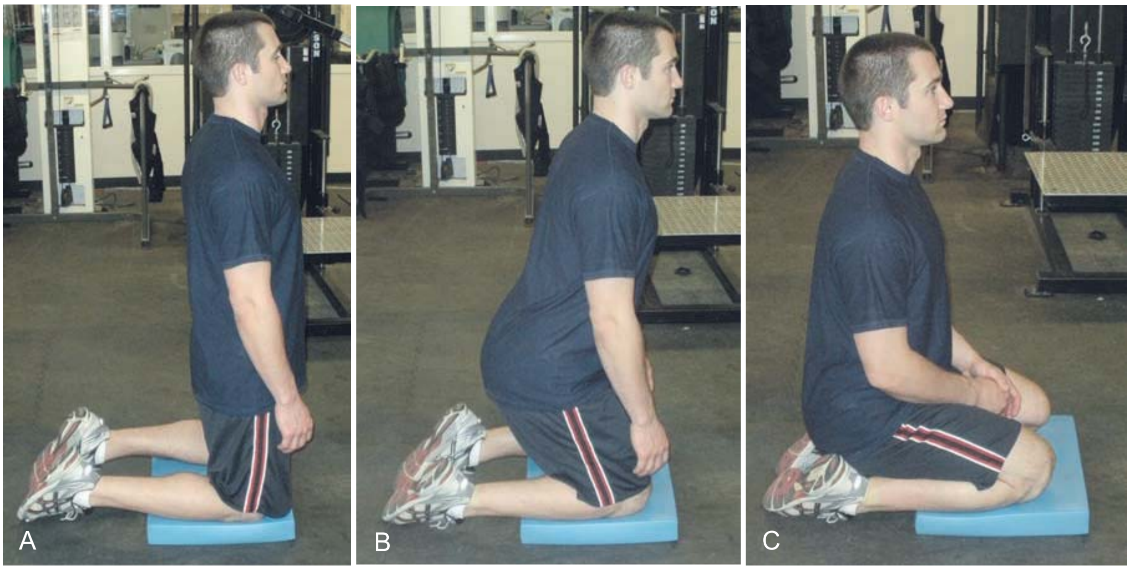


FIGURE 30-38. Kneeling squat. **A,** Start position. **B,** Middle position. **C,** End position.

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

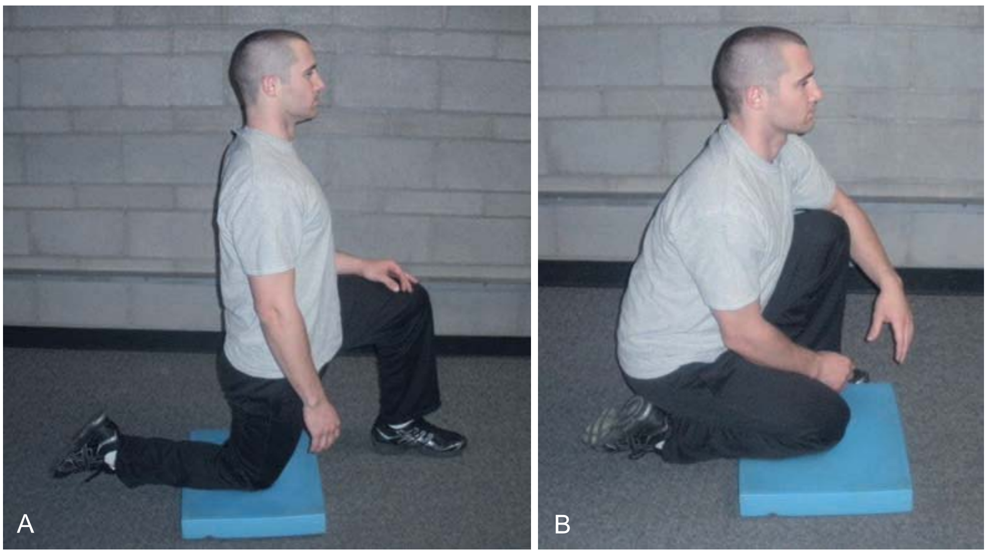


FIGURE 30-39. Half kneeling squat. **A,** Start position. **B,** End position.

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.

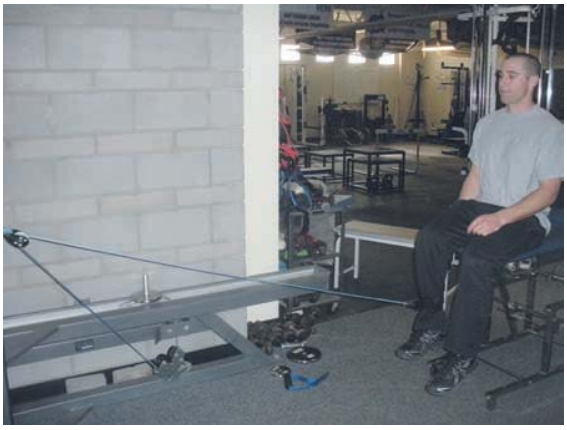


FIGURE 30-41. Impulse inertial training.

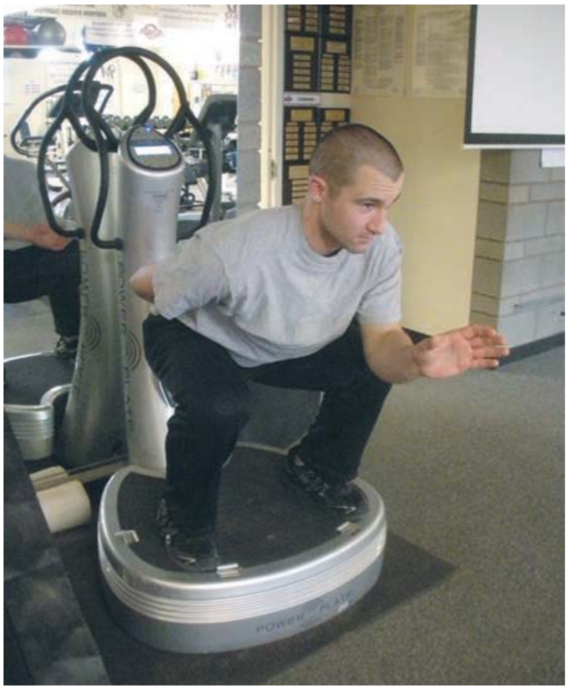


FIGURE 30-42. Power plate.

- 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 Plantarflexion	0°–20° 0°–50°
Knee	Flexion Extension	0°–145° † 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

LOWER EXTREMITY FUNCTIONAL TEST

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: ____________________

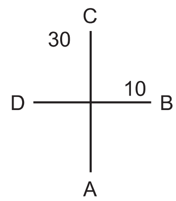
Trial	1	2	3	Avg	%/HT
Both					
RU/I					
LU/I					
Initials					

NORMS

	Female	Male
Both	90% of Ht	100% of Ht
Right	80% of Ht	90% of Ht
Left	80% of Ht	90% of Ht

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.

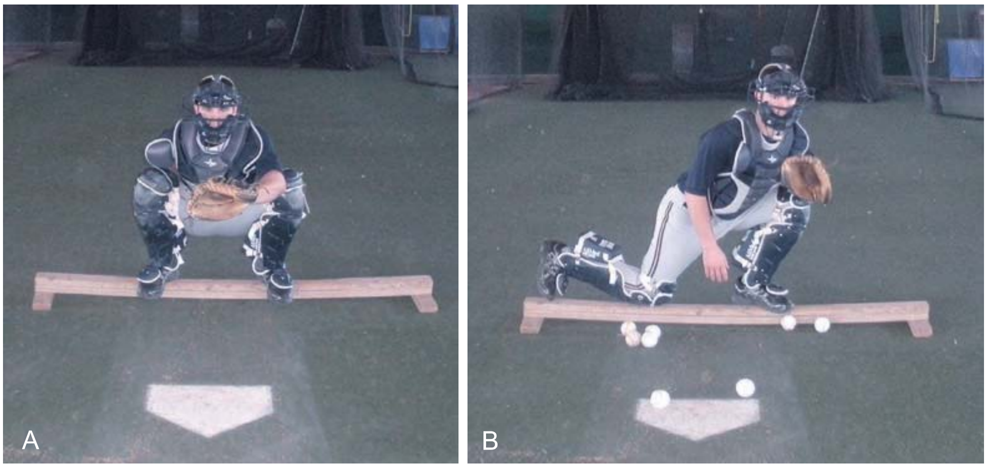


FIGURE 30-45. Balance beam drill. **A,** Receiving stance. **B,** Spread stance.

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.

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).

FIGURE 30-52. Hurdle drills.

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)

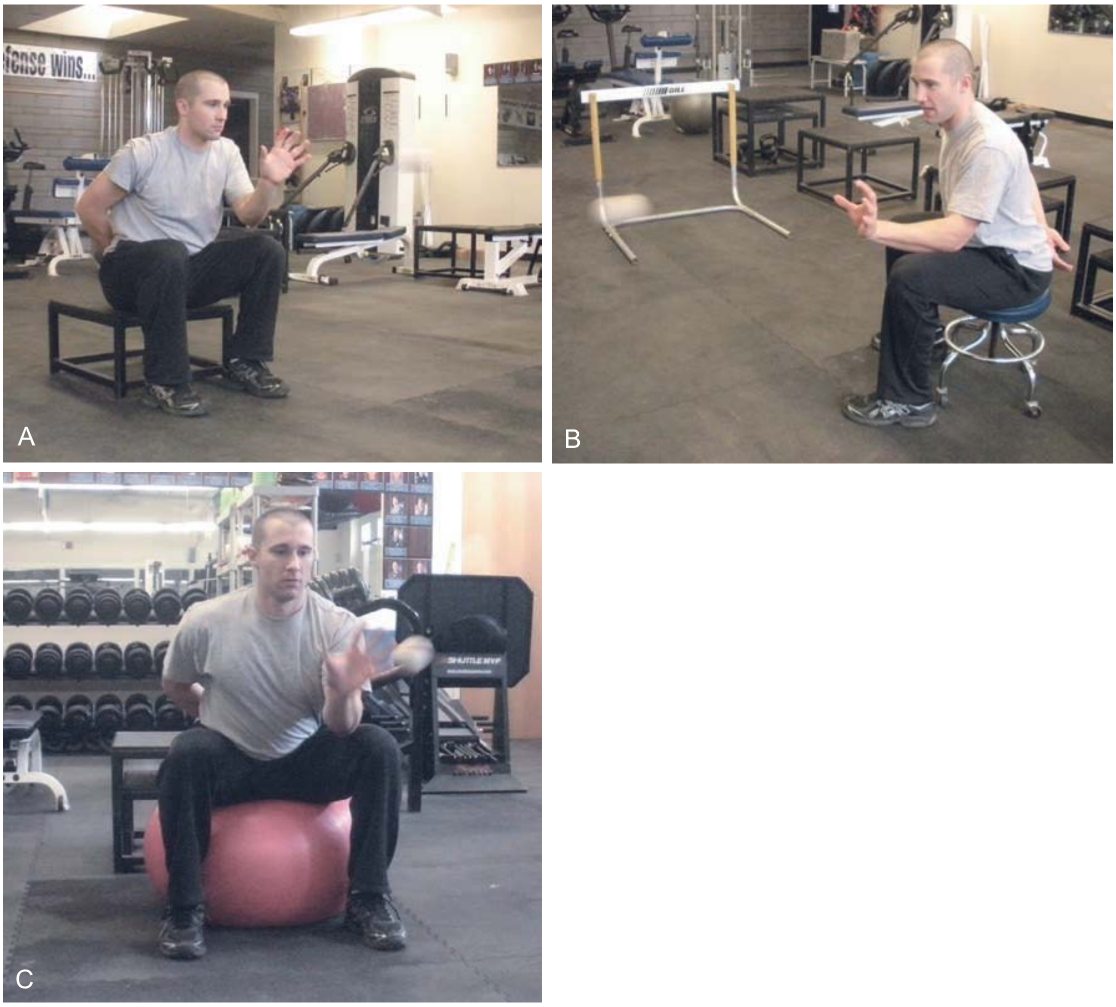


FIGURE 30-53. Supported catching drills. **A,** Plyo Box. **B,** Stool. **C,** Physio Ball.

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.

REFERENCES

1. Aglietti P, Zaccherotti G, De Biase P, et al: A comparison between medial meniscus repair, partial meniscectomy, and normal meniscus in anterior cruciate ligament reconstructed knees. *Clin Orthop Relat Res* 307:165–173, 1994.
2. Barber FA, Stone RG: Meniscal repair. An arthroscopic technique. *J Bone Joint Surg Br* 67:39–41, 1985.
3. Biedert RM: Treatment of intrasubstance meniscal lesions: a randomized prospective study of four different methods. *Knee Surg Sports Traumatol Arthrosc* 8:104–108, 2000.
4. DeHaven KE: Rationale for meniscus repair or excision. *Clin Sports Med* 4:267–273, 1985.
5. Henning CE, Lynch MA: Current concepts of meniscal function and pathology. *Clin Sports Med* 4:259–265, 1985.
6. Newman AP, Daniels AU, Burks RT: Principles and decision making in meniscal surgery. *Arthroscopy* 9:33–51, 1993.
7. Rockborn P, Messner K: Long-term results of meniscus repair and meniscectomy: a 13-year functional and radiographic follow-up study. *Knee Surg Sports Traumatol Arthrosc* 8:2–10, 2000.
8. Rosenberg TD, Metcalf RW, Gurley WD: Arthroscopic meniscectomy. *Inst Course Lecture* 37:203–208, 1988.
9. Sommerlath KG: Results of meniscal repair and partial meniscectomy in stable knees. *Int Orthop* 15:347–350, 1991.
10. Axe MJ, Odgers S: The baseball catcher's special requirements. In Andrews JR, Zarins B, Wilk KE, editors: *Injuries in baseball*, Philadelphia, 1998, Lippincott-Raven.
11. Metcalf MH, Barrett GR: Prospective evaluation of 1485 meniscal tear patterns in patients with stable knees. *Am J Sports Med* 32:675–680, 2004.
12. Mintzer CM, Richmond JC, Taylor J: Meniscal repair in the young athlete. *Am J Sports Med* 26:630–633, 1998.
13. DeHaven KE: Meniscus repair. *Am J Sports Med* 27:242–250, 1999.
14. Schoenfeld AJ, Landis WJ, Kay DB: Tissue-engineered meniscal constructs. *Am J Orthop* 36:614–620, 2007.
15. Gray JC: Neural and vascular anatomy of the menisci of the human knee. *J Orthop Sports Phys Ther* 29:23–30, 1999.
16. Nyland J, Brosky T, Currier D, et al: Review of the afferent neural system of the knee and its contribution to motor learning. *J Orthop Sports Phys Ther* 19:2–11, 1994.

17. Assimakopoulos AP, Katonis PG, Agapitos MV, et al: The innervation of the human meniscus. *Clin Orthop Relat Res* 275:232–236, 1992.
18. Pabian P, Hanney WJ: Functional rehabilitation after medial meniscus repair in a high school football quarterback: A case report. *N Am J Sports Phys Ther* 3:161–169, 2008.
19. Shelbourne KD, Patel DV, Adsit WS, et al: Rehabilitation after meniscal repair. *Clin Sports Med* 15:595–612, 1996.
20. Barber FA: Accelerated rehabilitation for repairs. *Arthroscopy* 10:206–210, 1994.
21. McCarty EC, Marx RG, Wickiewicz TL: Meniscal tears in the athlete. Operative and nonoperative management. *Phys Med Rehabil Clin N Am* 1:867–880, 2000.
22. 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.
23. 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.
24. Irrgang JJ: *Rehabilitation following meniscal repair and transplantation. The ninth Panther Sports Medicine Symposium: Current concepts in knee surgery*, Pittsburgh, 2000, Sports Medicine Institute.
25. McLaughlin J, DeMaio M, Noyes FR, et al: Rehabilitation after meniscus repair. *Orthopedics* 17:463–471, 1994.
26. Brotzman SB, Wilk KE: *Clinical orthopaedic rehabilitation*, Philadelphia, 2003, Mosby.
27. Wilk KE, Brien K, Reinold MM, et al: Rehabilitation of articular lesions in the athlete's knee. *J Orthop Sports Phys Ther* 36:815–827, 2006.
28. 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.
29. Thompson WO, Thaete FL, Fu FH, et al: Tibial meniscal dynamics using three-dimensional reconstruction of magnetic resonance images. *Am J Sports Med* 19:210–215, 1991.
30. Escamilla RF: Knee biomechanics of the dynamic squat exercise. *Med Sci Sports Exerc* 1:127–141, 2001.
31. 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.
32. 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.
33. 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.
34. Axe MJ, Windley TC, Snyder-Mackler L: Data-based interval throwing programs for baseball position players from age 13 to college level. *J Sport Rehabil* 10:267–286, 2001.
35. Axe MJ, Hurd W, Snyder-Mackler L: Data-based interval throwing programs for baseball players. *Sports Health* 2:1–19, 2009.
36. Barrett DD, Burton AW: Throwing patterns used by collegiate baseball players in actual games. *Res Q Exerc Sport* 1:19–27, 2002.
37. Whitely R: Baseball throwing mechanics as they relate to pathology and performance- a review. *J Sports Sci Med* 6:1–20, 2007.
38. Odgers S, Axe MJ: The baseball catcher's special requirements. In Andrews JR, Zarins B, Wilk KE, editors: *Injuries in baseball*, Philadelphia, 1998, Lippincott-Raven, pp 581–585.
39. American College of Sports Medicine position stand: Progression models in resistance training for healthy adults. *Med Sci Sports Exerc* 41(3):687–708, 2009.
40. Wilk K, et al: Anterior cruciate ligament reconstruction rehabilitation: A 12-week follow-up of isokinetic testing in recreational athletes. *Isokinetics Exer Sci* 2:82–91, 1992.
41. Davies GJ, Ellenbecker TS: Application of isokinetics in testing and rehabilitation. In Andrews JR, Harrelson GL, Wilk KE, editors: *Physical rehabilitation of the injured athlete*, ed 2, Philadelphia, 1998, Saunders.
42. Davies GJ: *A compendium of isokinetics in clinical usage and rehabilitation techniques*, ed 4, Onalaska, WI, 1992, S & S Publishers.
43. 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.
44. Birmingham TB, Kramer JF, Inglis JT, et al: Effect of a neoprene sleeve on knee joint position sense during sitting open kinetic chain and supine closed kinetic chain tests. *Am J Sports Med* 26:562–566, 1998.
45. Birmingham TB, Inglis JT, Kramer JF, et al: Effect of a neoprene sleeve on knee joint kinesthesis: Influence of different testing procedures. *Med Sci Sports Exerc* 32:304–308, 2000.
46. McNair PJ, Stanley SN, Strauss GR: Knee bracing: effects of proprioception. *Arch Phys Med Rehabil* 77:287–289, 1996.
47. Impulse Training Systems: Impulse Manual. (Accessed December 29, 2011 at http://www.impulsepower.com/its/index.html)
48. Albert MS, Hillegass E, Spiegel P: Muscle torque changes caused by inertial exercise training. *J Orthop Sports Phys Ther* 5:254–261, 1994.
49. Matheson JW, Kernozek TW, Fater DC, et al: Electromyographic activity and applied load during seated quadriceps exercises. *Med Sci Sports Exerc* 10:1713–1725, 2001.
50. Power Plate: Discover the Difference. Irvine, CA. (Accessed January 24, 2012 at http://www.powerplate.com/us)
51. Delecluse C, Roelants M, Verschueren S: Strength increase after whole-body vibration compared with resistance training. *Med Sci Sports Exerc* 6:1033–1041, 2003.
52. Marín PJ, Rhea MR: Effects of vibration training on muscle strength: a metaanalysis. *J Strength Cond Res* 2:548–556, 2010.
53. Cardinale M, Bosco C: The use of vibration as an exercise intervention. *Exerc Sport Sci Rev* 1:3–7, 2003.
54. Delecluse C, Roelants M, Diels R, et al: Effects of whole body vibration training on muscle strength and sprint performance in sprint-trained athletes. *Int J Sports Med* 8:662–668, 2005.
55. Moezy A, Olyaei G, Hadian M, et al: A comparative study of whole body vibration training and conventional training on knee proprioception and postural stability after anterior cruciate ligament reconstruction. *Br J Sports Med* 5:373–378, 2008.
56. Roelants M, Verschueren SM, Delecluse C, et al: Whole-body-vibration-induced increase in leg muscle activity during different squat exercises. *J Strength Cond Res* 1:124–129, 2006.
57. Lamont HS, Cramer JT, Bemben DA, et al: Effects of adding whole body vibration to squat training on isometric force/time characteristics. *J Strength Cond Res* 1:171–183, 2010.
58. Wathen D: Exercise selection. In Baechle TR, Earl, RW, editors, *Essentials of strength training and conditioning*, ed 3, Champaign, IL, Human Kinetics, 2000.
59. Reiman MP, Lorenz DS: Integration of strength and conditioning principles into a rehabilitation program. *Int J Sports Phys Ther* 3:241–253, 2011.
60. 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* 5:296–303, 2011.
61. Coleman E: Running speed in professional baseball. *J Strength Cond* 29:72–76, 2007.
62. Hosey RG, Puffer JC: Baseball and softball sliding injuries incidence and the effects of technique in collegiate baseball and softball players. *Am J Am Sports Med* 3:360–363, 2000.
63. Corzatt RD, Groppel JL, Pfautsch E, et al: The biomechanics of head-first versus feet-first sliding. *Am J Sports Med* 3:229–232, 1984.
64. Kane SM, House HO, Overgaard KA: Head-first versus feet-first sliding: A comparison of speed from base to base. *Am J Sports Med* 6:834–836, 2002.
65. The Functional Movement Screen: The system for a simple and quantifiable method for evaluating basic movement abilities. (Accessed February 14, 2012, at http://www.performbetter.com)
66. Onate JA, Dewey T, Kollock RO, et al: Real-time intersession and interrater reliability of the functional movement screen. *J Strength Cond Res* 2:408–415, 2012.
67. Minick KI, Kiesel KB, Burton L, et al: Interrater reliability of the functional movement screen. *J Strength Cond Res* 2:479–486, 2010.
68. 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* 3:147–158, 2007.

69. Davies GJ, Zillmer DA: Functional progression of exercise during rehabilitation. In Ellenbecker TS, editor: *Knee ligament rehabilitation*, ed 1, Philadelphia, 2000, Churchill Livingstone, pp 345–360.
70. Reese NB, Bandy WD: *Joint range of motion and muscle length testing*, ed 2, St Louis, 2010, Saunders.

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)