Chapter 24

Muscle Strains about the Hip and Thigh

INTRODUCTION

Timothy F. Tyler, MS, PT, ATC, and Stephen J. Nicholas, MD

Epidemiology

- Ice hockey and soccer players are particularly susceptible to adductor muscle strains.
- In professional ice hockey and soccer players throughout the world, approximately 10% to 11% of all injuries are groin strains.
- The level of experience is related to the incidence of groin strains.
- Athletes of all ages sustain groin strains.
- Older players have a higher incidence than younger ones.
- Goalkeepers have a higher incidence than position players.

Pathophysiology

- The adductor longus is the most commonly injured adductor during sporting activity (Figure 24-1).
- Groin strain injury is defined as any injury to the adductor muscle group that keeps a player out of a practice or a game, or requires the attention of the team physician.
- A groin strain is characterized by pain on palpation of the adductor tendons or the insertion on the pubic bone, or both, and groin pain during adduction against resistance.
- Groin strains are graded as a first degree strain if there is pain but minimal loss of strength and minimal restriction of motion. A second-degree strain is defined as tissue damage that compromises the strength of the muscle, but not including complete loss of strength and function. A third degree strain denotes complete disruption of the muscle tendon unit. It includes complete loss of function of the muscle.

Clinical Presentation

History

- Patient reports a feeling of a tearing in the groin region.
- Pain on push off injured lower extremity or change in direction.
- Decreased stability of the involved lower extremity on single leg stance.
- Inability to kick a ball.
- Inability to take slap shot/load body weight quickly on injured lower extremity.

Physical Examination

Abnormal Findings

- Decreased muscle force of the adductors.
- Pain on contraction of the adductor muscle group.
- Pain to passive abduction motion beyond normal range.
- Pain on palpation of the origin of the adductor longus.
- Inability to single limb stand against perturbation.
- A palpable defect of the muscle belly of the adductor longus.
- Ecchymosis in groin region.
- Swelling in groin region.
- Decreased step length.

Pertinent Normal Findings

- Symmetrical adductor force production of both lower extremities.
- Adductor strength greater than 80% abductor strength within each leg.

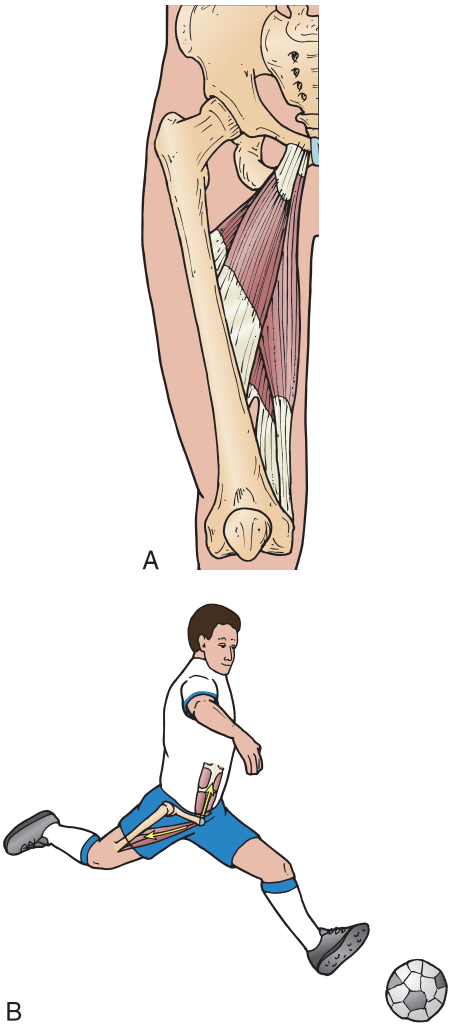

FIGURE 24-1. A, The location of the most frequently injured muscle in a groin strain, the adductor longus. **B,** An Adductor longus strain occurrence in sport.

FIGURE 24-2. An MRI of a grade 3 adductor strain.

Imaging

- X-rays
- CT scan
- MRI (Figure 24-2)

Differential Diagnosis

- Athletic pubalgia: injury to the transversalis fascia leading eventually to incompetency of the posterior inguinal wall. A diagnosis of exclusion
- Osteitis pubis: increased uptake on bone scan or CT scan at the pubic symphysis.
- Hernia: positive inguinal hernia exam.
- Hip-joint osteoarthrosis: hip X-ray revealing avascular necrosis or osteoarthritis of hip.
- Rectal or testicular referred pain: MRI of suspected region.
- A coexisting fracture of the pelvis or the hip: seen on X-ray.
- Hip flexor strain.

Treatment

Nonoperative Management

- Bracing/spica (Figure 24-3)
- Rehabilitation
- Correction of faulty biomechanics
- PRP

Guidelines for Choosing Among Nonoperative Treatments

- No bony avulsion
- No sports hernia

FIGURE 24-3. Example of a hip spica to provide support and protection to the adductors.

Surgical Indications

- Avulsion of the adductor longus
- Sports hernia

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

- The degree of the groin strain.
- Whether a palpable defect is present.

Aspects of Clinical Decision Making When Surgery Is Indicated

- MRI revealing bony involvement.
- Failed greater than 6 months of nonoperative treatment.

Evidence

Arnason A, Sigurdsson SB, Gudmundsson A, et al: Risk factors for injuries in football. *Am J Sports Med* 32(1 Suppl):5S–16S, 2004.

Height, weight, body composition, flexibility, leg extension power, jump height, peak O_2 uptake, joint stability, and history of previous injury were recorded for 306 male football players. Risk factors for a groin strain were a previous groin strain and decreased range of motion in hip abduction. Age and previous injury were identified as the main risk factors for injury among elite football players from Iceland. (Level III evidence).

Feeley BT, Powell JW, Muller MS, et al: Hip injuries and labral tears in the national football league. *Am J Sports Med* 36:2187–2195, 2008.

This descriptive epidemiology study defined the incidence and etiologic factors of intra- and extraarticular hip injuries in the NFL. The NFL Injury Surveillance System was used to define all hip-related injuries from 1997 to 2006. There were a total of 23,806 injuries from 1997 to 2006, of which 738 were hip injuries (3.1%) with an average of 12.3 days lost per injury. Muscle strains were the most common injury. Intraarticular injuries resulted in the most time lost. Contact injuries most likely resulted in a contusion, and noncontact injuries most often resulted in a muscle strain. (Level III evidence).

Hölmich P, Larsen K, Krogsgaard K, et al: Exercise program for prevention of groin pain in football players: a cluster-randomized trial. *Scand J Med Sci Sports* 20:814–821, 2010.

A total of 1211 soccer players were randomized to an exercise program aimed at preventing groin injuries or to a control group. The intervention program consisted of six exercises including strengthening, coordination, and core stability exercises. Twenty-two teams in each group completed the study, represented by 977 players. The risk of a groin injury was reduced by 31%, but this reduction was not significant. An analysis showed that having had a previous groin injury almost doubles the risk of developing a new groin injury and playing at a higher level almost triples the risk of developing a groin injury. (Level II evidence).

Robinson P, Barron DA, Parsons W, et al: Adductor-related groin pain in athletes: correlation of MR imaging with clinical findings. *Skeletal Radiol* 33:451–457, 2004.

The purpose of this study was to evaluate gadolinium-enhanced MR imaging in athletes with chronic groin pain and correlate with the clinical features. MR examinations performed in 52 athletes with chronic groin pain and 6 asymptomatic control athletes were independently reviewed by two radiologists masked to the clinical details. The extent and side of anterior pubis and adductor longus enthesis abnormality on MR imaging significantly and reproducibly correlated with the athletes' current symptoms in chronic adductor-related groin pain. (Level II evidence).

Tyler TF, Campbell R, Nicholas SJ, et al: The association of hip strength and flexibility on the incidence of groin strains in professional ice hockey players. *Am J Sports Med* 29:668–673, 2000.

This prospective study was conducted to determine whether hip muscle strength and flexibility play a role in the incidence of adductor and hip flexor strains in NHL ice hockey team players. Hip flexion, abduction, and adduction strength were measured in 81 players before two consecutive seasons. Preseason hip adduction strength was 18% lower in the players who subsequently sustained an adductor muscle strain compared with that of uninjured players. Adduction strength was 95% of abduction strength in the uninjured players, but only 78% of abduction strength in the injured players. A player was 17 times more likely to sustain an adductor muscle strain if his adductor strength was less than 80% of his abductor strength. (Level I evidence).

Multiple Choice Questions

QUESTION 1. When building an injury prevention program for groin strain, which muscle group should be strengthened?

A. Abductors
B. Adductors
C. Hip flexors
D. Hamstrings

QUESTION 2. What is one of the strongest intrinsic factors that predisposes an athlete to a groin injury/strain?

A. Strength ratio of the adduction to abduction muscle groups
B. Increased preseason practice sessions
C. Previous groin strain
D. A lack of mechanical advantage for the adductor longus

QUESTION 3. In a clinical examination, pertinent normal findings to look for may include:

A. Swelling in the groin region
B. Decreased muscle force of the adductors
C. Pain on contraction of the adductor muscle group
D. Symmetrical adductor force production of both lower extremities

QUESTION 4. A general guideline for choosing a nonsurgical treatment option consist of:

A. Avulsion of the adductor longus
B. Sports hernia
C. No bony avulsion
D. Hip fracture

QUESTION 5. An increased uptake on a bone scan or CT scan may differentiate which of the following from a diagnosis of groin strain?

A. Osteitis pubis
B. Athletic pubalgia
C. Hernia
D. Hip-joint osteoarthrosis

Answer Key

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

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

QUESTION 3. Correct answer: **D** (see Clinical Presentation)

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

QUESTION 5. Correct answer: **A** (see Differential Diagnosis)

NONOPERATIVE REHABILITATION OF ADDUCTOR AND HIP JOINT STRAINS

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GUIDING PRINCIPLES OF NONOPERATIVE REHABILITATION

- Pain
- Range of motion
- Restore the adduction-to-abduction strength ratio of the injured leg
- Function

Phase I (weeks 0 to 3 to 6)

Protection

- Compression shorts or a wrap bandage may be helpful in decreasing swelling and provide support.
- If walking causes pain, limit weight bearing; crutches are considered for the first day or two after the injury.

Management of Pain and Swelling

- RICE (rest, ice, compression, elevation) is the standard protocol for mild to moderate muscle strains for the first 24 to 48 hours.
- Electrical stimulation, cold laser, or ultrasound can be useful in healing.

Techniques for Progressive Increase in Range of Motion

Therapy Techniques

- Gentle pain-free sub maximal contractions within 48 hours. Maintain pain-free available passive range of motion.

TIMELINE 24-1: Nonoperative Rehabilitation of Adductor and Hip Joint Strains

PHASE I (weeks 0 to 4)	PHASE II (weeks 4 to 8)
• RICE (rest, ice, compression and elevation) for first ~48 hours after injury • NSAIDs • Massage • TENS • Ultrasound • Submaximal isometric adduction with knees bent, with knees straight progressing to maximal isometric adduction, pain free • Hip passive range of motion (PROM) in pain-free range • Non weight-bearing hip progressive resistive exercises (PREs) without weight in antigravity position (all except abduction), pain-free, low load, high repetition exercise • Upper body and trunk strengthening • Contralateral LE strengthening • Flexibility program for noninvolved muscles • Bilateral balance board	• Bicycling/swimming • Sumo squats • Single limb stance • Concentric adduction with weight against gravity • Standing with involved foot on sliding board moving in frontal plane • Adduction in standing on cable column or Thera-Band • Seated adduction machine • Bilateral adduction on sliding board moving in frontal plane (i.e., bilateral adduction simultaneously) • Unilateral lunges (sagittal) with reciprocal arm movements • Multiplane trunk tilting • Balance board squats with throwbacks • General flexibility program • Involved lower extremity PROM equal to that of the uninvolved side and involved adductor strength at least 75% that of the ipsilateral abductors.

Soft Tissue Techniques

- Gentle massage to the area with ice to help decrease swelling.

Other Therapeutic Exercises

- Biking for maintaining fitness
- Upper body and trunk strengthening
- Core stability

Activation of Primary Muscles Involved

- Submaximal isometric adduction with knees bent (Figure 24-4), with knees straight progressing (Figure 24-5) to maximal isometric adduction.
- If pain free, progress to side-lying hip adduction against gravity (Figure 24-6).
- Hip passive range of motion (PROM) in pain-free range.

FIGURE 24-4. Submaximal adductor strengthening with short lever arm.

FIGURE 24-5. Submaximal adductor strengthening with long lever arm.

FIGURE 24-6. Side-lying hip adduction against gravity.

Sensorimotor Exercises

- Bilateral balance board
- Single leg stance on stable surface

TIMELINE 24-1: Nonoperative Rehabilitation of Adductor and Hip Joint Strains (Continued)

PHASE III (weeks 8 to 12)	PHASE IV (weeks 12+)
• Phase II exercises with increase in load, intensity, speed and volume • Standing resisted stride lengths on cable column to simulate skating • Slide board • On ice kneeling adductor pull togethers • Lunges (in all planes) • Correct or modify ice skating technique	• Heavy load isolated eccentrics of the adductors • On ice training forward/backwards/crossovers • Skating with without the puck • Skating with puck • Stickhandling, passing, shooting • Scrimmage NO contact • Scrimmage • Game play

Open and Closed Kinetic Chain Exercises

Nonweight-bearing hip progressive resistive exercises (PREs) without weight in antigravity position (all except abduction), pain-free, low load, high repetition exercises.

- Mini squats to full squats

Techniques to Increase Muscle Strength, Power, and Endurance

- Contralateral LE strengthening

Neuromuscular Dynamic Stability Exercises

- Flexibility program for noninvolved muscles

Sport-Specific Exercises

- Hockey: stick-handling while standing with the ball

Milestones for Progression to the Next Phase

- Pain-free passive range of motion
- Minimal swelling as measured by clinical palpation and observation.
- Concentric adduction against gravity without pain.
- Normal gait with full weightbearing

Phase II (weeks 3 to 6 and weeks 6 to 8)

Protection

- Compression shorts
- Hip spica

Management of Pain and Swelling

- Electrical stimulation
- Cold laser
- Ultrasound
- Ice

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Manual resistance to adductors. Providing minimal resistance to the leg proximal then moving more distally towards the ankle. Resistance should always be pain free.

Soft Tissue Techniques

- Graston technique and/or deep tissue massage. Gentle massage to the knee to milk the fluid away from the groin

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Initiate gentle PROM of adductor and hip flexors. Gentle stretching so as not to cause plastic deformation of the muscle.

Other Therapeutic Exercises

- Elliptical
- StairMaster
- Treadmill long stride walking
- Bicycling
- Swimming

Activation of Primary Muscles Involved

- Concentric adduction with weight against gravity. Start with 2 lbs and try to achieve 3 sets of 10, then move to 3 sets of 15 followed by 1 set of 30 at the same weight. If the patient can perform 1 set of 30 with that weight, add 2 lbs and go back to doing 3 sets of 10 repetitions.
- Adduction in standing on cable column or Thera-Band. Start the athlete with yellow Thera-Band and then move to red once they achieve 30 repetitions with perfect form.
- Seated adduction machine. Use a pain free resistance level so the patient can achieve 3 sets of 10.
- General flexibility program. Perform a general flexibility assessment looking for asymmetrical tightness from anterior to posterior or restrictions from involved non-involved sides.

Sensorimotor Exercises

- Single-leg stance standing on the floor, the patient is bare foot, knee slightly bent and eyes open. Perform SLS for 30 seconds. Try and achieve this 3 times. If the patient can perform easily without pain or loss of balance, progress to 1 minute for 3 sets. If patient cannot perform for 30 seconds or 1 minute, decrease time and/or add UE support. This exercise can be progressed by adding an unstable surface (BAPS, Thera-Band, stability pad etc.)
- Quick steps: Quick alternating steps over a line on the floor. Count the number of repetitions.
- Tic tock: Feet shoulder width apart and pass the ball back and forth quickly between feet.
- Lateral band walks (Figure 24-7)
- Balance board tosses: Patient in mini squat position, perform 30 tosses in a row without touching either side of board to the floor. Perform this 3 times. Progress to overhead throw and side chops while maintaining balance.

Open and Closed Kinetic Chain Exercises

- Sumo squats (Figure 24-8): Begin with 3 sets of 10, stand on the floor with pain-free and proper form, add a kettle bell for resistance.

FIGURE 24-7. Lateral band walks.

FIGURE 24-8. Sumo squats.

- Contralateral Thera-Band: Stand on the involved leg and move the noninvolved leg into different planes of motion, for example hip abduction/extension.
- Leg Press: Perform 3 sets of 10 progressing to 3 sets of 12 and 3 sets of 15 with two legs in pain-free resistance. Progress to single leg.

Neuromuscular Dynamic Stability Exercises

- Standing with involved foot on sliding board moving in frontal plane (Figure 24-9)
- Balance board squats with throwbacks: With patient in mini squat position, perform 30 tosses in a row without touching either side of the board to the floor. Perform this 3 times. Progress to overhead throw and side chops while maintaining balance.

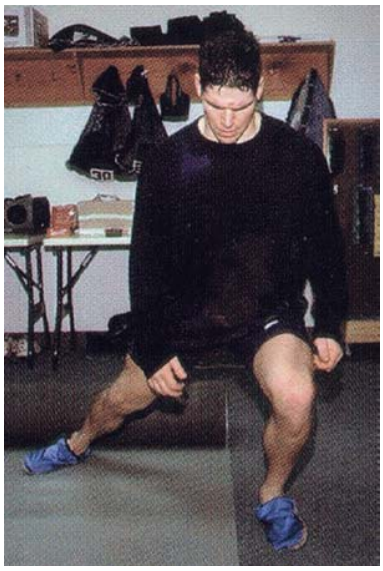


FIGURE 24-9. Standing with involved foot on sliding board moving in frontal plane.

Plyometrics

- Lateral shuffles: Maintain proper alignment in mini squat position (watch for knees diving in) shuffle side to side across the room. Begin at 50% speed pain-free and progress to 75% and then full speed.

Functional Exercises

- Lunges (forward and lateral) with reciprocal arm movements.
- Unweighted spilt jumps: Explosively jump while using the arms to assist as needed. While in mid-air switch the leg position landing softly in lunge position. Progress for maximum height and power.
- Forward/backward running drills: Begin at 50% and progress to 75% to then full speed. Therapist can add in directional changes.

Sport-Specific Exercises

- Bilateral adduction on sliding board moving in frontal plane (i.e., bilateral adduction simultaneously). Standing on sliding board slide both legs together. Perform as many as patient can pain-free.
- Skater strides (Figure 24-10): In skating position, see how many times the patient can go back and forth along the slide board. Increasing the number of reps and speed as they progress within the same timeframe.

Milestones for Progression to the Next Phase

- Involved lower extremity PROM equal to that of the uninvolved side
- Involved adductor strength at least 75% that of the ipsilateral abductors. This is determined by performing a break test using a hand held dynamometer.

FIGURE 24-10. Skater strides.

Phase III (weeks 6 to 8 and weeks 9 to 12)

Protection

- Hip spica

Management of Pain and Swelling

- Biofreeze
- Ice
- Compression wrap

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Manual resistance to adductors

Soft Tissue Techniques

- Graston technique and/or deep tissue massage

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Progressive stretching of the adductors

Other Therapeutic Exercises

- Phase II exercises with increase in load, intensity, speed, and volume
- Core stability with/without stability ball: planks, side planks, double-leg/single-leg bridges. Use a time based approach starting at 30 seconds progressing to one minute.

Activation of Primary Muscles Involved

- Eccentric lengthened state strengthening of the adductors

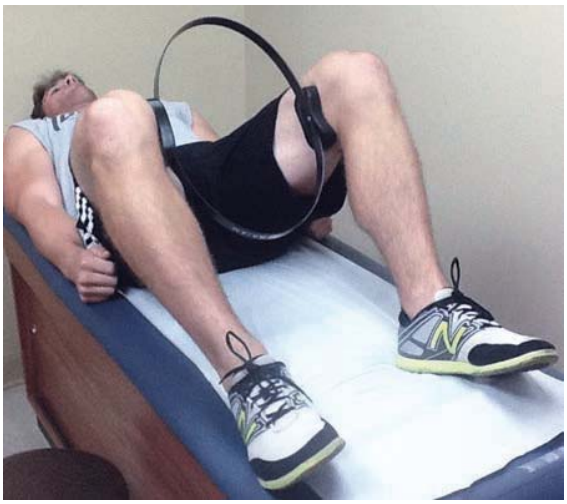


FIGURE 24-11. Ring squeezes.

FIGURE 24-12. Ring squeezes in table top.

- Ring squeezes (Figure 24-11)
- Ring squeezes in table top position (Figure 24-12)
- Hip adductor machine

Sensorimotor Exercises

- Slide board side to side

Open and Closed Kinetic Chain Exercises

Standing resisted stride lengths on cable column to simulate skating

Techniques to Increase Muscle Strength, Power, and Endurance

- Lunges (in all planes)

Neuromuscular Dynamic Stability Exercises

- Single-leg cable column ice skating stride
- Quick kick with Thera-Band
- Perturbation training

Plyometrics

- Bounding side to side

Functional Exercises

- Correct or modify ice skating technique

Sport-Specific Exercises

- On ice kneeling adductor pull togethers

Milestones for Progression to Advanced Sport-Specific Training and Conditioning

- Adduction strength, at least 90% to 100% of the abduction strength. This is determined by performing a break test using a hand held dynamometer.
- Involved adductor muscle strength equal to that of the contralateral side. This is determined by performing a break test using a hand held dynamometer.

Phase IV (weeks 12+)

Protection

- Hip spica
- Compression shorts

Management of Pain and Swelling

- Ice

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Contract-relax

Soft Tissue Techniques

- Massage

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Stretching of the adductors

Other Therapeutic Exercises

- Running
- Squats
- Dead lifts
- Cleans
- Snatches

FIGURE 24-13. Split squats.

Activation of Primary Muscles Involved

- Heavy load eccentrics of adductors and hip flexors

Sensorimotor Exercises

- Ice skating with drill

Open and Closed Kinetic Chain Exercises

- Split squats (Figure 24-13)

Techniques to Increase Muscle Strength, Power, and Endurance

- Timed slide board slides

Neuromuscular Dynamic Stability Exercises

- Ice single-limb stance

Plyometrics

- Box jumps

Milestones to Progress to Sport-Specific Training and Conditioning

- Pain-free range of motion
- Pain-free ice skating
- Symmetrical strength of adductors in shortened, mid range and lengthened state of the muscle. We determine this by performing a break test using a hand held dynamometer. Approximately 10° from the most shortened muscle length and 10° from the longest muscle length.
- No limiting symptoms with full speed functional drills

Criteria for Abandoning Nonoperative Treatment and Proceeding to Surgery or More Intensive Intervention

- No response in returning strength
- Grade 3 tear

Tips and Guidelines for Transitioning to Performance Enhancement

- All motion loaded and unloaded in the frontal sagittal and transverse plane should be pain free.
- During this period there should be no movement deviations or compensations.

Performance Enhancement and Beyond Rehabilitation: Training/Trainer and Optimization of Athletic Performance

- Perturbation training on and off the ice

Specific Criteria for Return to Sports Participation: Tests and Measurements

- Confidence in the lower extremity.
- 100 % recovery. Ask the patient what percent of 100% are they today, and then compare this to the uninjured side.

Evidence

Engebretsen AH, Myklebust G, Holme I, et al: Prevention of injuries among male soccer players: a prospective, randomized intervention study targeting players with previous injuries or reduced function. *Am J Sports Med* 36:1052–1060, 2008.

A total of 508 players were divided into high-risk (HR) (76%) and low-risk (LR) groups. The HR players were randomized individually into an HR intervention group or HR control group. A total of 505 injuries were reported, sustained by 56% of the players. Compliance with the training programs in the HR intervention group was poor, with only 27.5% in the ankle group, 29.2% in the knee group, 21.1% in the hamstring group, and 19.4% in the groin group defined as having carried out the minimum recommended training volume. The players with a significantly increased risk of injury were able to be identified through the use of a questionnaire, but player compliance with the training programs prescribed was low and any effect of the intervention on injury risk could not be detected. Randomized controlled trial. (Level II evidence).

Hölmich P, Uhrskou P, Ulnits L, et al: Effectiveness of active physical training as treatment for long-standing adductor-related groin pain in athletes: randomized trial. *Lancet* 353:439–443, 1999.

This randomized clinical trial compared an active training rehabilitation program (AT) with a passive rehabilitation program (PT) in the treatment of 68 athletes with long-standing groin pain. Twenty-three patients in the AT group returned to sports without groin pain while only four returned in the PT group. AT with a program aimed at improving strength and coordination of the muscles acting on the pelvis, in particular the adductor muscles, is very effective in the treatment of athletes with long-standing adductor-related groin pain. (Level I evidence).

Robinson P, Barron DA, Parsons W, et al: Adductor-related groin pain in athletes: correlation of MR imaging with clinical findings. *Skeletal Radiol* 33:451–457, 2004.

The purpose of this study was to evaluate gadolinium-enhanced MR imaging in athletes with chronic groin pain and correlate with the clinical features. MR examinations performed in 52 athletes with chronic groin pain and 6 asymptomatic control athletes were independently reviewed by two radiologists masked to the clinical details. The extent and side of anterior pubis and adductor longus enthesis abnormality on MR imaging significantly and reproducibly correlates with the athletes' current symptoms in chronic adductor-related groin pain. (Level II evidence).

Schlegel TF, Bushnell BD, Godfrey J, et al: Success of nonoperative management of adductor longus tendon ruptures in National Football League athletes. *Am J Sports Med* 37: 2009.

Adductor tendon ruptures documented by MRI were identified in 19 NFL players. Fourteen players were treated nonoperatively, and 5 players were treated with surgical repair using suture anchors, all players eventually returned to play. Mean time for return to play was 6.1 ± 3.1 weeks (range, 3 to 12 weeks) for the nonoperative group and 12.0 ± 2.5 weeks (range, 10 to 16 weeks) for the operative group ($p = .001$). Nonoperative treatment of proximal adductor tendon rupture results in a statistically significantly faster return to play than does operative treatment in athletes competing in the NFL. (Level III evidence).

Multiple-Choice Questions

QUESTION 1. Which is not an appropriate clinical guideline for progressing from Phase I to Phase II?

A. Pain-free PROM
B. Minimal swelling
C. Abduction strength
D. Pain-free concentric adduction against gravity

QUESTION 2. Which of the following should be avoided in Phase I?

A. Adductor strengthening
B. Submax isometrics
C. Ultrasound
D. Ice

QUESTION 3. What factors have been proven to put athletes at risk for adductor strains?

A. Gender
B. History of ITB friction syndrome
C. Ambient temperature
D. Poor hip adductor to abductor ratio

QUESTION 4. Which of the following is NOT a guiding principle of rehab for an adductor strain?

A. Thigh girth
B. ROM
C. Function
D. Restoring abduction to adduction strength ratio

QUESTION 5. What added protection may a sports clinician give to a player to return to play?

A. Tape
B. Thera-Band
C. Hip spica
D. Underwear

Answer Key

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

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

QUESTION 3. Correct answer: **D** (see Introduction, Evidence)

QUESTION 4. Correct answer: **A** (see Guiding Principles)

QUESTION 5. Correct answer: **C** (see Phase IV)

BEYOND BASIC REHABILITATION: RETURN TO HOCKEY AFTER ADDUCTOR STRAIN

Timothy F. Tyler, MS, PT, ATC, and Stephen J. Nicholas, MD

Introduction

- Groin strains are a prevalent pathology associated with ice hockey and have a high recurrence rate.
- It is particularly challenging to return to the sport because the player needs stability on a single leg on a skate blade, which requires adductor strength.
- The three mechanisms of ice hockey hip and adductor strains are (Figure 24-14*A, B, and C*):
  - Excessive ROM
  - Contact with an opposing player
  - Contact with ice

ASPECTS OF HOCKEY THAT REQUIRE SPECIAL ATTENTION IN REHABILITATION

- Balance
- Agility
- Strength
- Power
- Kinetics
- Anaerobic power
- Speed endurance and training

Phase I: Advanced Strength and Conditioning Programs

Periodization

- Linear
- Microcycles

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- Training continuum
- Flexibility/joint mobility for joint stability
- Training with hockey posture
- Sensorimotor and balance training
- Core training
- Cardiorespiratory training
- Multiplanar training activities
- Training for optimum muscle balance
- Training for optimum muscle functional strength
- Training for optimum muscle functional power
- Neuromuscular dynamic stability exercises
- Training for speed, agility, quickness (SAQ)
- Plyometric training
- Functional training
- Sport-specific training

Olympic Lifts Used in the Training Program

- Snatch
- Clean and jerk
- Power clean

Training Principles Used in the Design of the Program

- Principle of progression
- Principle of overload
- Principle of variation
- Principle of individualization
- Principles of specificity–specific adaptation to imposed demands (SAID)

FIGURE 24-14. The three mechanisms of ice hockey hip and adductor strains. **A**, Excessive ROM. **B**, Contact with an opposing player. **C**, Contact with ice.

Application of Acute Training Variables

- High repetitions
- 5 to 14 sets
- 30 to 60 second rest interval
- Moderate intensity
- Training frequency of TIW
- Training duration of 10 to 20 minutes
- Training volume of 8 to 14 sets
- Specific exercises used in the training are sumo squats, on-ice squeezes, isometric ball squeezes.

TIMELINE 24-2: **Beyond Basic Rehabilitation: Return to Hockey after Adductor Strain**

PHASE I	PHASE II	PHASE III
Warmup	**Advanced Strengthening Program**	**Sport-Specific Training**
• Bike • Adductor stretching • Sumo squats • Side lunges • Kneeling pelvic tilts	• Bilateral adduction on sliding board moving in frontal plane (i.e. bilateral adduction simultaneously) • Unilateral lunges with reciprocal arm movements	• On-ice kneeling adductor pull togethers • Standing resisted stride lengths on cable column to simulate skating • Slide skating • Cable column crossover pulls
Strengthening Program		
• Ball squeezes (legs bent to legs straight) • Different ball sizes • Concentric adduction with weight against gravity • Adduction in standing on cable column or elastic resistance • Seated adduction machine • Standing with involved foot on sliding board moving in sagittal plane		

Phase II: Performance Enhancement Training Techniques

Periodization

- Linear
- Undulating
- Macrocycles
- Mesocycles
- Microcycles

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- Core training
- Cardiorespiratory training
- Multiplanar training activities
- Training for optimum muscle balance
- Training for optimum muscle functional strength
- Training for optimum muscle functional power
- Neuromuscular dynamic stability exercises
- Training for speed, agility, quickness (SAQ)
- Plyometric training
- Functional training on the ice
- Sport-specific training on the slide board

Olympic Lifts used in the Training Program

- Snatch
- Clean and jerk
- Power clean

Training Principles Used in the Design of the Program

- Principle of progression
- Principle of overload
- Principle of variation
- Principle of individualization
- Principles of specificity–specific adaptation to imposed demands (SAID)

Application of Acute Training Variables

- 6 to 12 repetitions
- 8 to 10 sets per body part
- Rest interval of 60 seconds
- High intensity
- Slow repetition tempo
- Training frequency of 48 hours rest for each body part
- Training duration of 6 to 10 weeks
- Training volume of no more than 30 repetitions
- Specific exercises used in the training
  - Split squats (See above: gives some guidelines to the readers regarding volume of training for the different exercises)
  - Squats
  - Lunges
  - Slide board
  - Diagonal PNF
  - Light agility program with on-ice directional changes

Application of Chronic Training Variables

- Repetition to create muscle memory.

Phase III: Sport-Specific Training

Periodization

- Linear
- Macrocycles: full year and will rest after the season is over
- Mesocycles: resistance training to balance adductor to abductor strength ratio.
- Microcycles: individual sport specific eccentric training

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- Training continuum
- Flexibility/joint mobility for joint stability
- Sport-specific on-ice training

Training Principles Used in the Design of the Program

- Principle of progression: The Delorme principle is recommended to progress resistance training.
- Principle of overload: The Oxford training principles are recommended.
- Principle of variation: Perform dry land training 2 times per week during the hockey season.
- Principle of individualization: An example of this is to emphasize the end range strength in goaltenders who are functioning often in their end ROM.

Application of Acute Training Variables

- 2 to 5 repetitions on-ice
- 2 minute rest interval
- Maximum intensity
- Repetition tempo as fast as the athlete can
- Daily training frequency
- 10 to 20 minute training duration
- High training volume
- Specific exercises used in the training
  - Forward skating
  - Backwards skating
  - Clockwise cross overs
  - Counter clockwise cross overs
  - One on ones
  - Two on ones
  - Three on twos
  - Scrimmage no contact
  - Scrimmage with checking
  - Game

Application of Chronic Training Variables

- Applied to the athlete's tolerance.

Sports Performance Testing

General Information

- General history
- Subjective questionnaires
- Medical history
- Sports injury history
- Surgical history
- Chronic conditions/medication
- Impact testing
- Eye exam

Specific Criteria for Progression to the Next Stage to Determine their Readiness for Hockey

Objective Tests

- Physiological assessments. Girth measurements to asses for atrophy.
- Body composition tests BMI, skin-fold testing.
- Movement performance testing to look for ROM and strength deficits forward and backward shuttle runs looking for asymmetrical body movement.
- Sport-specific testing: Timed slide board slides.
- Impact testing for concussion management.
- On-ice testing: Timed circles in both directions to assess single limb stance ability on skates.

Criteria for Determining Readiness for Sport

- Rate of perceived exertion

Specific Criteria for Releasing an Athlete to Unsupervised Complete Participation in Hockey

- Pain-free full ROM and strength throughout the range.
- Symmetrical adduction strength, symmetrical single-leg hop for distance. Hand held dynamometer testing in which the involved hip adductors are 80% of the hip abductors of the involved leg.
- Subjective 100% confidence of patient that they are ready to return.

Recommended Ongoing Exercises

- Standing unilateral elastic resistance, slide board, balance board.

Evidence

Tyler TF, Campbell R, Nicholas SJ, et al: The effectiveness of a preseason exercise program on the prevention of groin strains in professional ice hockey players. *Am J Sports Med* 30:680–683, 2002.

A total of 33 of 58 players from the same NHL team were identified as at risk on the basis of preseason hip adductor strength and participated in an intervention program. The program consisted of 6 weeks of exercises aimed at functional strengthening of the adductor muscles. Adductor strains were reduced by 78% compared to the previous seasons. A therapeutic intervention of strengthening the adductor muscle group appears to be an effective method for preventing adductor strains in professional ice hockey players. (Level I evidence).

Multiple-Choice Questions

QUESTION 1. Where should most sport specific training be done?

A. On ice
B. Gym
C. Training room
D. At night at home

QUESTION 2. What is a good acute training exercise for warming up?

A. Box jumps
B. Isokinetics
C. Sumo squats
D. Ultrasound

QUESTION 3. Repeated sprints should take how long to complete?

A. Each 5 to 6 minutes to complete
B. All day
C. Each takes 4 to 6 seconds
D. Each takes 45 to 60 seconds

QUESTION 4. Why is it particularly challenging to return to hockey after a groin strain?

A. Hockey players have less stability than other athletes
B. Younger people play hockey
C. Most are multisport athletes
D. The player needs stability on a single leg on a skate blade, which requires adductor strength

QUESTION 5. During speed training the training should include how many turns?

A. 4
B. 3
C. 9
D. 1

Answer Key

QUESTION 1. Correct answer: **A** (see Box 24-1)

QUESTION 2. Correct answer: **C** (see Warm-up phase of guidelines)

QUESTION 3. Correct answer: **D** (see Box 24-1)

QUESTION 4. Correct answer: **D** (see Introduction)

QUESTION 5. Correct answer: **D** (see Box 24-1)

BOX 24-1 Advanced Rehabilitation Program: On- and Off-Ice Workouts

On-Ice Workouts

ANAEROBIC POWER TRAINING

- Repeated sprints that each take 45 to 60 seconds to complete. Move goals forward to approximately in line with the end zone face-off spots and have athletes skate 3 laps as fast as they can. Rest period should be 4 to 6 times the sprint time. Players should complete 6 to 8 sets. The rest time can be dictated by how many players are in a group.
- For example, if you want a 5:1 recovery to sprint ratio and you have 18 players, divide the players into 3 groups of 6 with each group stationed at different points around the ice. The first players in each group complete their first set, then the 2nd players go and so on until all 6 players have completed their first set of 3 laps. Then the first 3 players start their 2nd set.
- Direction should be reversed between each set and the goals should be moved to spread the wear on the ice.
- The distance can be fixed by tying a rope between both goals. When the goals are moved, to spread the wear on the ice, make sure the rope remains taught.
- Regardless of how the workout is executed the goal is to have players go all out for 45 to 60 seconds and give them 4 to 6 minutes recovery and repeat 6 to 8 times.
- The distance will depend on the time after injury of the athlete. The shorter the recovery time the slower the subsequent sets.
- The traditional mentality is to have short recovery times so everyone is exhausted for the last couple of sets and crawl over the finish line (no pain no gain mentality). Training adaptations will be better if there is only a small decline in speed from first to last sets.

SPEED ENDURANCE TRAINING

- Repeated sprints that each take 20 to 30 seconds to complete. Figure of 8 sprints performed across the width of the ice, where players start in the middle and have to complete 3 laps (i.e. cross their starting point 6 times).
- The recovery to sprint ratio should be the same or similar to the anaerobic power training i.e. 4:1, 5:1, or 6:1.
- This test is more technically demanding than anaerobic power training because skating ability during turns is critical. Thus this tests a combination of skating ability and fitness.
- The practical issue in doing this test is wear on the ice. Actual distance can be manipulated to match the fitness of the players to stay within the 20 to 30 second time requirements.

SPEED TRAINING

- All out sprint with only 1 turn. The goal is to test instantaneous power.
- For example, start on goal line, sprint to opposite goal line and back to blue line at end where you started (292 foot sprint).
- This should take approximately the same time as the figure of 8 test, but should only be repeated a max of 6 times, with the same 4 to 6:1 recovery:sprint ratio.

Off-Ice Workouts

AEROBIC POWER

- On track 200 meters in 45 second, 200 meters in 90 seconds, repeat 10 to 12 times. This workout is designed for athletes with a VO_2 max of 50 ml/kg/min.
- If you want an accurate measure of their VO_2 max have them run 8 laps (2 miles) and get an accurate time for their max effort. A VO_2 max of 50 ml/kg/min equates to 2 miles in 14 min.

ANAEROBIC POWER

- 30 meter sprint every 30 seconds repeated 6 times, 2 minute recovery, repeat 6 times.
- Players can do alternating 20 sit-ups or pushups during 2 minute recovery.
- In any of these sprint workouts (on-ice or off-ice) it is essential to provide sufficient recovery so that the later sprints are not performed at walking speed.
- Some decrement is expected, but if it is no longer a sprint, that is, they are too fatigued to go fast, then the exercise is not going to be beneficial.
- The key to training the targeted energy systems is quality of the sprint.

Strength workouts

SQUATS*

1. Single-leg split squats with rear leg held back and parallel to ground (2 × 15 or 20)
2. Single-leg split squats with rear leg back and up on bench (approx. 3 feet high) (2 × 15 or 20)
3. Walking split squats; also called lunge walking (20 repetitions)
4. Split squat plyometric jumps; also called lunge jumping (2 × 15 or 20)

JUMPS

1. Lateral jumps: single leg lateral jumps across markings 2 feet apart. Jump for 10 seconds (count repetitions). Do 4 sets each leg, alternating between legs.
2. Skater jumps: lateral jumps across a 5 foot distance (6 feet for adults). Take off on 1 leg and land on the other leg. Do 10 repetitions, rest 1 minute, do 3 sets.

OTHER

Sit-ups and pushups as needed.

*Do numbers 1 and 2 on one day and numbers 3 and 4 on another day

NONOPERATIVE REHABILITATION OF HAMSTRING STRAINS AND CONTUSIONS

Marc Sherry, PT, DPT, LAT, CSCS, PES, Bryan C. Heiderscheit, PT, PhD, and William Clancy, MD, PhD

GUIDING PRINCIPLES OF NONOPERATIVE REHABILITATION

- Excessive or aggressive stretching of the injured hamstrings should be avoided, as this can result in a dense scar formation in the area of injury prohibiting muscle regeneration. However, early mobilization and movement, with pain defining the range of motion limit, is safe and effective for return to sport with minimal chance for injury recurrence.
- Rehabilitation interventions should focus on progressive agility, trunk stabilization, eccentric strengthening and eliminating muscle imbalances.
- Specific evaluation of strength, mobility and apprehension are key indicators for return to sport readiness.

Phase I: Acute (weeks 0 to 4)

Phase I starts as soon as possible after the injury and continues for 5 to 25 days depending on the severity of injury.

Protection

- Crutches may be used in moderate to severe injuries.
- In mild to moderate injuries athletes should be able to shorten their normal stride length to ambulate pain free.

Management of Pain and Swelling

- Modification of activity, particularly avoiding tension on the hamstring during the acute phase
- Compression thigh wraps for moderate to severe injuries to help decrease swelling
- Slight elevation above the heart for moderate to severe injuries to help decrease swelling
  Note: the elevation should not be so great as to stretch the injured hamstrings during this time.
- Cryotherapy
- Use of NSAIDs for this type of injury remains controversial

Therapeutic Exercises

- Stationary biking
- Progressive agility and trunk stabilization (PATS), Phase I
  - Low- to moderate-intensity side stepping, 3 times 1 minute
  - Low- to moderate-intensity grapevine stepping (lateral stepping with the trail leg going over the lead leg and then under the lead leg), both directions, 3 times 1 minute (Figure 24-15)
  - Low- to moderate-intensity steps forward and backward over a tape line while moving sideways, 2 times 1 minute (Figure 24-16)
  - Single-leg stand, progressing from eyes open to eyes closed, 4 times 20 seconds (Figure 24-17)

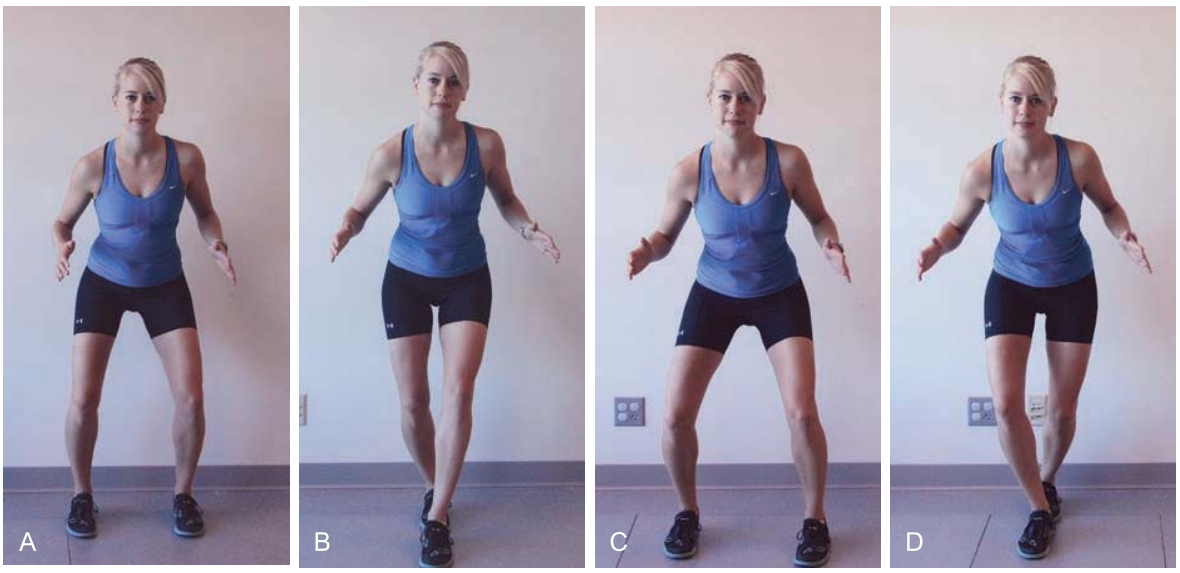


FIGURE 24-15. Grapevine stepping.

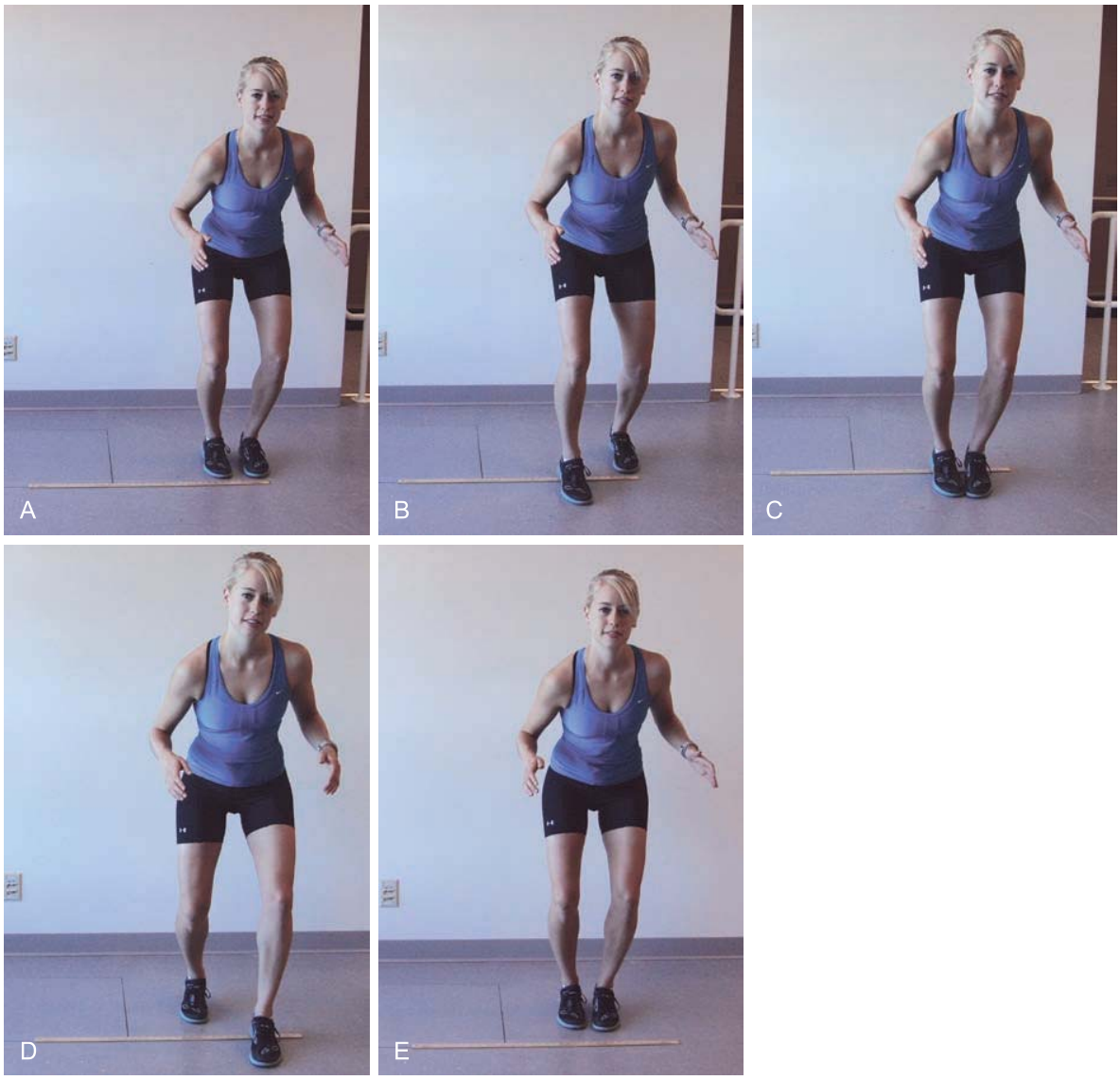


FIGURE 24-16. Forward-backward stepping over a line while moving sideways.

- Prone abdominal body bridge (performed by using abdominal and hip muscles to hold the body in a face down straight plank position with the elbows and feet being the only point of contact), 4 times 20 seconds (Figure 24-18)
- Supine extension bridge (performed by using abdominal and hip muscles to hold the body in a supine hook lying position with the head, upper back, arms and feet being the points of contact), 4 times 20 second (Figure 24-19)
- Side bridge (performed by using abdominal and hip muscles to hold the body in a side-lying plank position with the lower elbow and feet being the only point of contact), four times 20 seconds on each side (Figure 24-20)

Activation of Primary Muscles Involved

- Core muscles of the hip and pelvis, hip abductors and adductors, medial and lateral hamstrings

Sensorimotor Exercises

- Single leg stand, progressing from eyes open to eyes closed

Open and Closed Kinetic Chain Exercises

- Progress agility and trunk stabilization; see above

Techniques to Increase Muscle Strength, Power, and Endurance

- Progress agility and trunk stabilization; see above

Neuromuscular Dynamic Stability Exercises

- Progress agility and trunk stabilization; see above

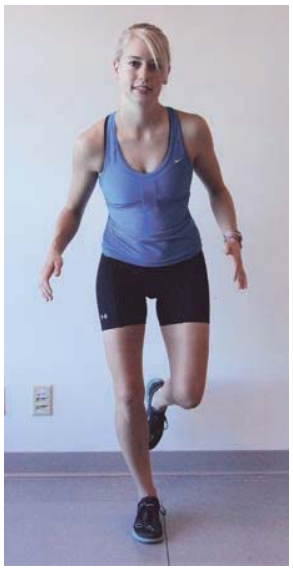


FIGURE 24-17. Single leg standing, progress from eyes open to eyes closed.

Functional Exercises

- Progress agility and trunk stabilization; see above

Milestones for Progression to the Next Phase

- Walk with a normal gait pattern without pain.
- Do a knee to waist height march in place without pain.

FIGURE 24-18. Prone body bridge.

FIGURE 24-19. Supine extension bridge.

TIMELINE 24-3: **Nonoperative Rehabilitation of Hamstring Strains and Contusions**

PHASE I (weeks 0 to 4)	PHASE II (weeks 2 to 8)	PHASE III (starting weeks 4 to 8 postinjury and continuing until return to sport)
Week 1 • Crutches as needed to normalize gait • Begin PATS Phase I • Avoid stretching • Ice and compression wrap to control pain and swelling **Week 2** • Crutches as needed to normalize gait; DC crutches • PATS Phases I–II • Avoid stretching • Ice and compression wrap to control pain and swelling **Week 3** • DC crutches • PATS Phases II–III • Avoid stretching • Neuromobilization techniques • Eccentric strengthening • End-range strengthening • Soft tissue and manual therapy techniques for indirect mobility impairments • Low-velocity sport-specific and functional drills and skills • Ice to control pain and swelling	• PATS Phase III • Allow gentle hamstring stretching if needed • Neuromobilization techniques • Eccentric strengthening • End-range strengthening • Soft tissue and manual therapy techniques for indirect mobility impairments • Medium-to-high velocity sport-specific and functional drills and skills • Cardiovascular conditioning • Ice as needed	• PATS Phase III (cont) • Lower extremity dynamic mobility drills, including A and B skips • Neuromobilization techniques • End-range eccentric strengthening • Soft tissue and manual therapy techniques for indirect mobility impairments • High-velocity sport-specific and functional drills and skills • Single-leg balance exercises and perturbation type exercises • Sport-specific conditioning

FIGURE 24-20. Side bridge.

- Have at least 4+/5 strength with one repetition for prone knee flexion at 90° of flexion without pain.

Phase II: Subacute (weeks 2 to 6)

Phase II starts after Phase I milestones are met and continues for 7 to 28 days depending on the severity of injury.

Management of Pain and Swelling

- Ice as needed for postrehabilitation soreness

Manual Therapy Techniques

- During this time if the individual has indirect joint mobility or flexibility limitations, which may have contributed to their injury or the recovery of it, the appropriate manual therapy interventions should be employed. Examples:
  - Restricted ankle dorsiflexion secondary to decreased posterior talar glide (Figure 24-21)
  - Restricted spinal mobility, such as thoracic spine hypomobility limiting upper body rotation and causing increased lumbar lordosis and anterior pelvic tilt
  - Sacroiliac joint restrictions affecting pelvic mobility (Figure 24-22)

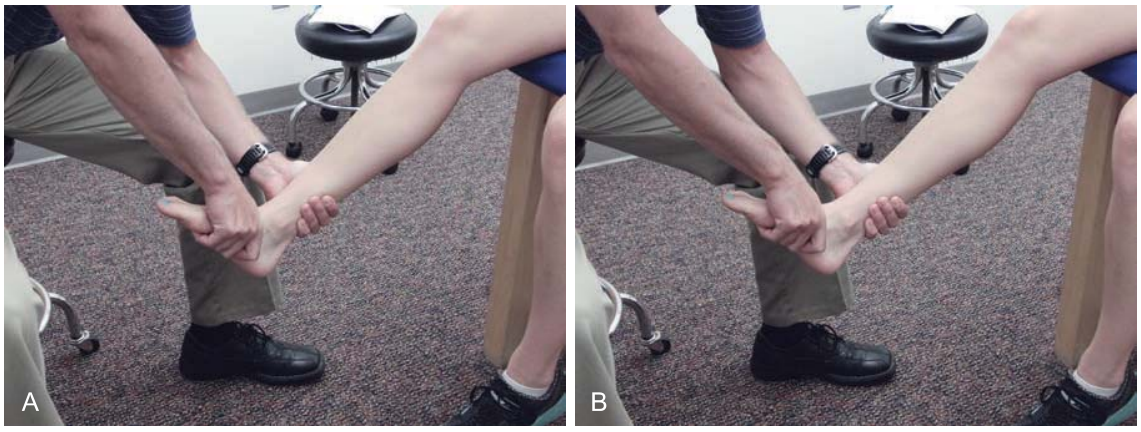


FIGURE 24-21. Talar glide to facilitate ankle dorsiflexion.

FIGURE 24-22. Sacroiliac manipulation.

Soft Tissue Techniques

- Manual or self-directed (the Stick, foam roller, etc.) soft tissue mobilization may be gently initiated in this phase for moderate to severe injuries when there is a concern for excessive scar tissue formation (Figure 24-23).

Stretching and Flexibility Techniques for the Musculotendinous Unit

- During this time, isolated and/or aggressive hamstring stretching should be avoided.
- If the individual has indirect mobility or flexibility limitations, which may have contributed to the injury or the recovery of it, corrective therapeutic interventions should be prescribed.
  - Examples include restricted ankle dorsiflexion, restricted spinal mobility or hip flexor tightness.

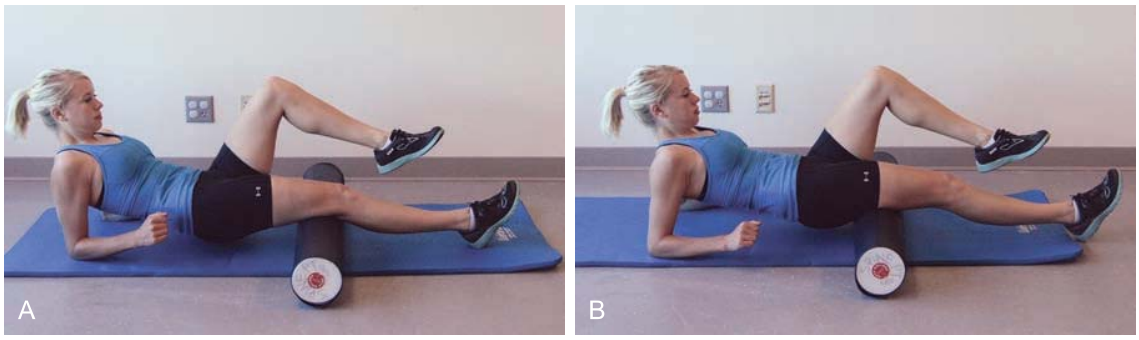


FIGURE 24-23. Foam rolling to hamstrings.

Other Therapeutic Exercises

- Progressive agility and trunk stabilization (PATS), Phase II
  - Moderate to high-intensity side stepping, 3 times 1 minute
  - Moderate– to high-intensity grapevine stepping, 3 times 1 minute
  - Moderate- to high-intensity steps forward and backward while moving sideways, 2 times 1 minute
  - Single leg stand windmill touches (performed by standing on one leg, then rotating the trunk and flexing the hips to bring the hand down in front of the lower leg), 4 times 20 seconds of repetitive alternate hand touches (Figure 24-24)
  - Pushup stabilization with trunk rotation (performed by starting at the top of a full pushup, then maintain this position with one hand while rotating the chest toward the side of the hand that is being lifted to point toward the ceiling, pause and return to the starting position), 2 times 15 reps on each side. (Figure 24-25)
  - Fast feet in place (performed by jogging in place with increasing velocity, picking the foot only a few inches off the ground), 4 times 20 seconds
  - High-to-low and low-to-high wood chops with Thera-Band, 2 × 15 to the right and left of each (Figures 2-26 and 24-27)
- Neuromobilization techniques may be used if the injured athlete demonstrates any sign of adverse lower limb tension as a result of the injury or recovery process. Care should be taken to tension the nerve without overtensioning the injured hamstring, thus limiting the hip flexion component of the neural mobilization techniques (Figure 24-28).

Activation of Primary Muscles Involved

- Core muscles of the hip and pelvis, hip abductors and adductors, medial and lateral hamstrings

Sensorimotor Exercises

- In addition to the balance exercises listed in the PATS program, balance board and unstable surface balance training are appropriate for this phase.

Open and Closed Kinetic Chain Exercises

- See Phase II PATS above.

FIGURE 24-24. Single-leg stand windmill touches.

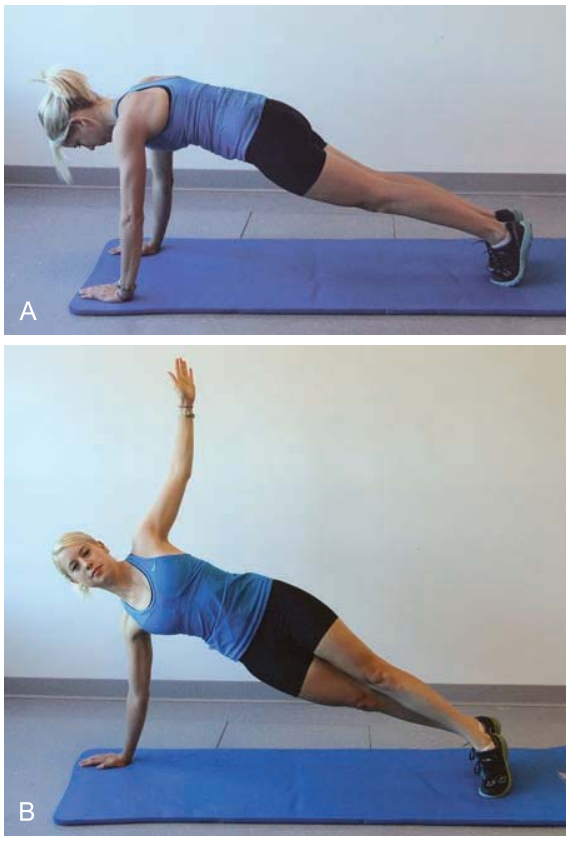


FIGURE 24-25. Pushup stabilization with trunk rotation.

Techniques to Increase Muscle Strength, Power, and Endurance

- Sub-maximal eccentric strengthening exercises near mid-length of the muscle are initiated as part of functional movement patterns rather than through exercises isolating the hamstring.

Neuromuscular Dynamic Stability Exercises

- See Phase II PATS above.

Plyometrics

- Begin initiating plyometric exercises near mid-length of the muscle. These exercises are initiated as part of functional movement patterns rather than through exercises isolating the hamstring.

Functional Exercises

- See Phase II PATS above.

Sport-Specific Exercises

- Symptom-free practice and skill-related drills without high-speed maneuvers.

Milestones for Progression to the Next Phase

- Ability to jog without pain
- Have 5/5 strength for prone knee flexion at 30° of flexion without pain.

Phase III: Early Functional (weeks 4 to 8 and beyond)

Management of Pain and Swelling

- Ice as needed for postrehabilitation or practice soreness

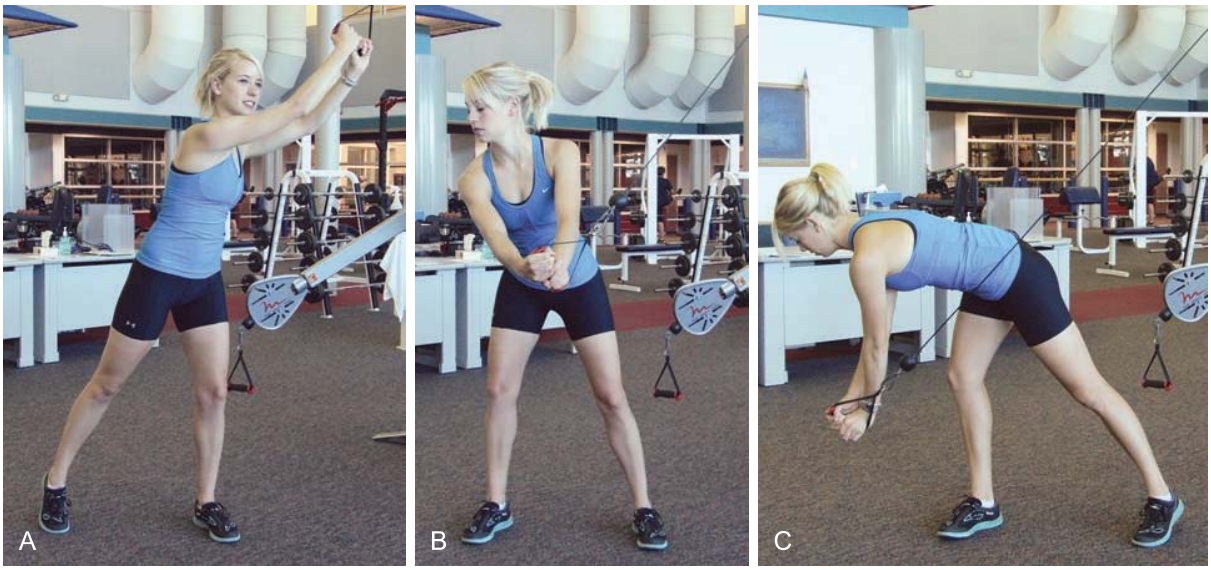


FIGURE 24-26. High to low wood chops.

FIGURE 24-27. Low to high wood chops.

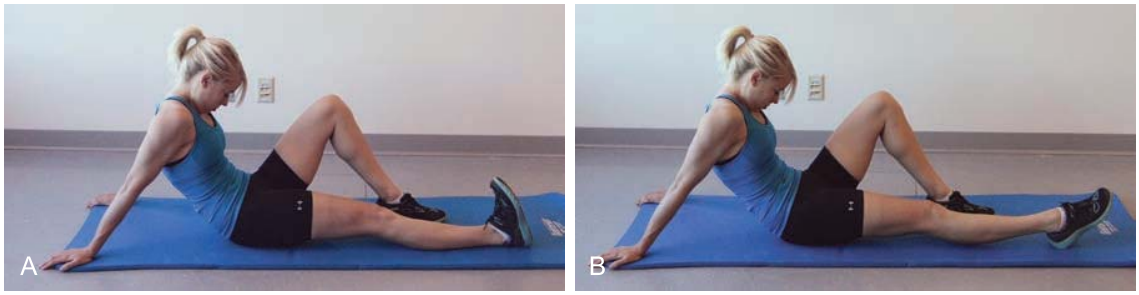


FIGURE 24-28. Neural mobilization.

Manual Therapy Techniques

- Continue during this time working on indirect joint mobility or flexibility limitations, which may have contributed to their injury or the recovery of it, the appropriate manual therapy interventions should be employed. Examples:
  - Restricted ankle dorsiflexion secondary to decreased posterior talar glide
  - Restricted spinal mobility, such as thoracic spine hypomobility limiting upper body rotation and causing increased lumbar lordosis and anterior pelvic tilt.
  - Sacroiliac joint restrictions affecting pelvic mobility

Soft Tissue Techniques

- Manual, augmented (Graston, ASTYM) or self directed (the Stick, foam roller, etc.) soft tissue mobilization may be more aggressively used in this phase for moderate to severe injuries when there is a concern for excessive scar tissue formation.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- During this phase if the athlete has nearly recovered hamstring strength, yet still has limitations in flexibility, then it would be appropriate to include dynamic hamstring stretches.
- The individual should continue to work on indirect flexibility limitations, which may have contributed to the injury or the recovery of it, and they should be given corrective therapeutic interventions.
- Examples would include restricted ankle dorsiflexion, restricted spinal mobility or hip flexor tightness.

Other Therapeutic Exercises

- Dynamic agility drills: Side shuffle, cariocas, boxer shuffles (Figure 24-29), A skips (Figure 24-30) and B skips (Figure 24-31), forward and backward running
- Dynamic core stabilization: Rotating body bridge with dumbbells (Figure 24-32), physioball pushup rotations (Figure 24-33), physio ball bridges with single-leg hold (Figure 24-34)

Activation of Primary Muscles Involved

- Working toward maximal eccentric strengthening exercises near end-length of the muscle are included as part of functional movement patterns. Functional exercises begin to focus on power by being more explosive and reactive.

Sensorimotor Exercises

- This phase should include single-leg balance exercises, especially those involving core control and hamstring activation in a lengthened position. Examples include

FIGURE 24-29. Boxer shuffles.

FIGURE 24-30. A skips.

single-leg deadlifts, single-leg dumbbell hang cleans, single-leg windmill touches with dumbbells, and repetitive hop for distance.

Open and Closed Kinetic Chain Exercises

- The transition from open to closed chain movement is important in this phase. Specific exercises that can work on this include B skips, repetitive hopping, alternating leg windmill touches with dumbbell reach and alternating short arc bridge curl on a physio ball.

Techniques to Increase Muscle Strength, Power, and Endurance

- Olympic Lifts
- Snatches
  - Clean and jerk
  - Power clean

Neuromuscular Dynamic Stability Exercises

- Single-leg balance exercises, especially those involving core control and hamstring activation in a lengthened position.
- Examples include the following:
  - Single-leg deadlifts
  - Single-leg dumbbell hang cleans
  - Single-leg windmill touches with dumbbells
  - Repetitive hop for distance

Plyometrics

- Plyometrics are used in this phase to help increase power; focus should be in single-leg activities to prevent overcompensating with the uninvolved leg.

Functional Exercises

- See exercises above.

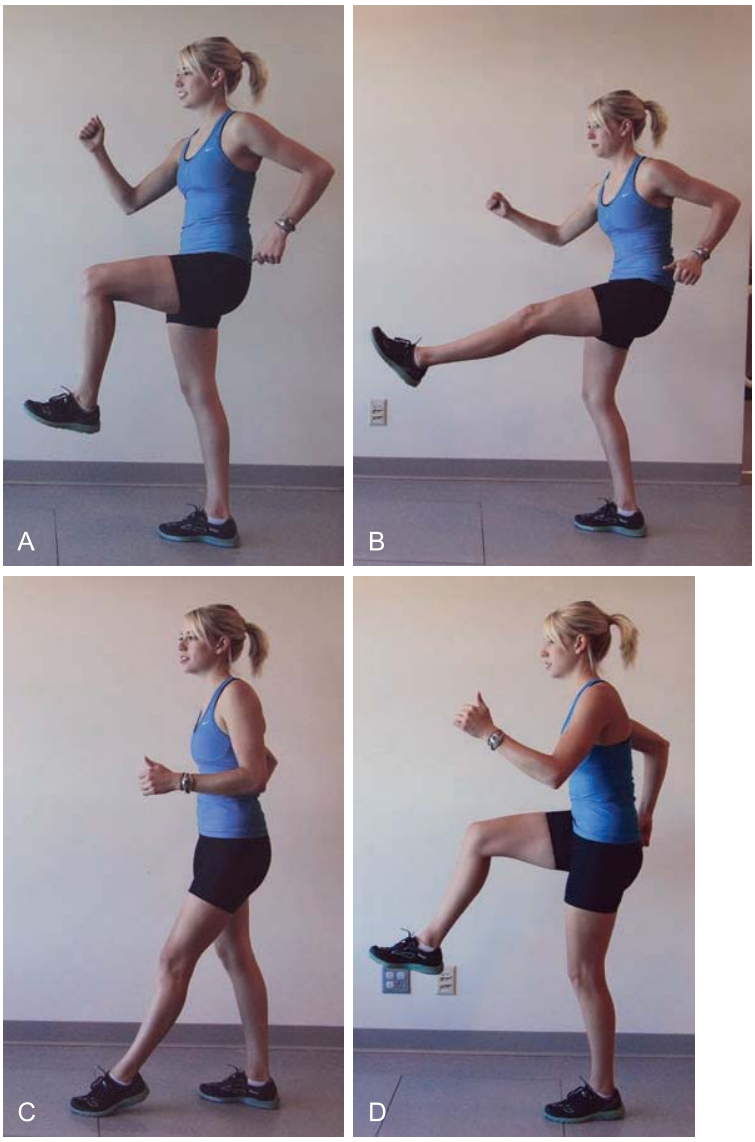


FIGURE 24-31. B skips.

Sport-Specific Exercises

- Symptom-free practice and skill-related drills building up to high-speed maneuvers.
- Running drills that incorporate change of direction as well as change of head and body position are potentially very important during this phase.
- These drills will challenge core control and also train the hamstring activation patterns in various positions and lengths.

Milestones for Progression to Return to Sport

- No apprehension or fear by the athlete. This can be measured and compared to the other side with Asking's active hamstring test.
- Full strength:
  - 5/5 strength on manual muscle testing of the hamstrings in prone at 15° of knee flexion. This should be done with 4 consecutive repetitions with the tibia in external rotation, neutral and internal rotation and then compared with the other side.
  - Less than 5% bilateral deficit in eccentric hamstrings (30°/second): concentric quadriceps (240°/second) ratio during isokinetic testing.
  - Bilateral symmetry in knee flexion angle of peak isokinetic concentric knee flexion torque at 60°/second
- Good control of dynamic single-leg balance and support movements.
- Replication of sport-specific movements near maximal speed without pain or apprehension (e.g., incremental sprint test for running athletes)
- If patient is not making consistent improvement in strength or progression toward the milestones listed above by 12 to 14 weeks, they should be reevaluated by the physician. There are not standard surgical options or time-frames for this injury but adjuncts to rehabilitation, such as PRP or dry needling, may be considered.

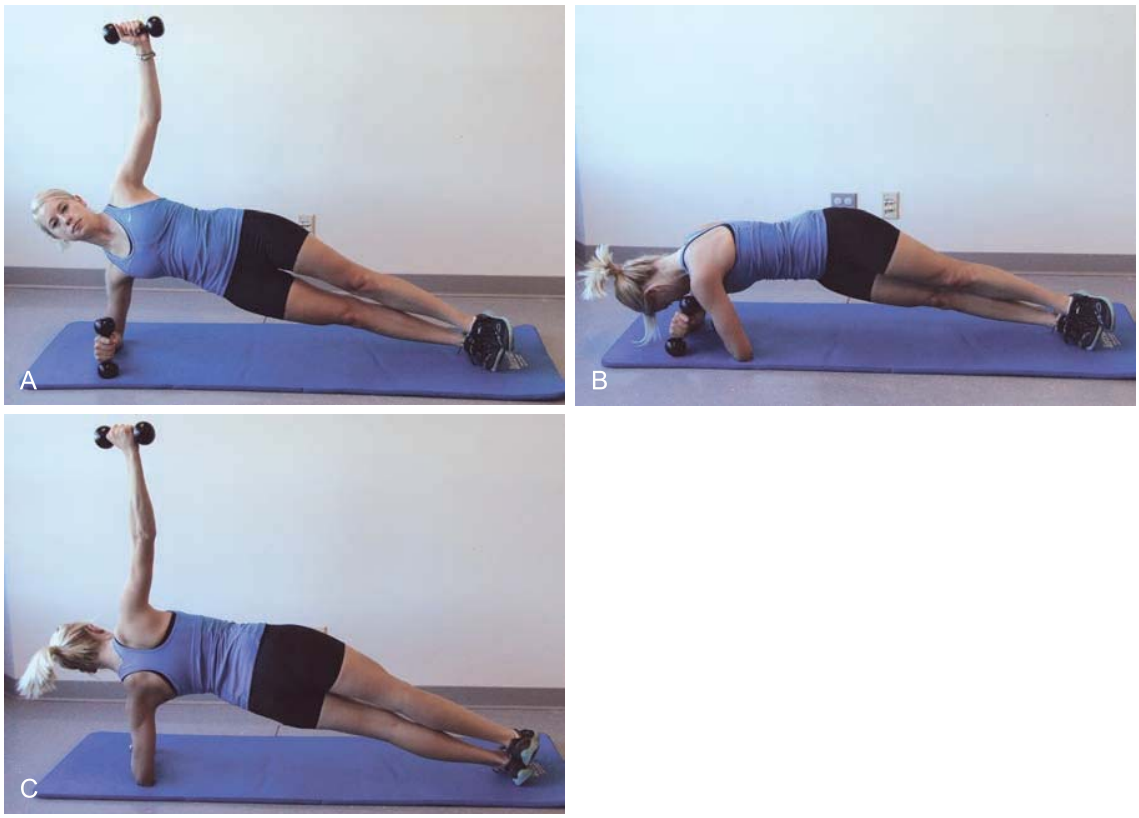


FIGURE 24-32. Rotating body bridge with dumbbells.

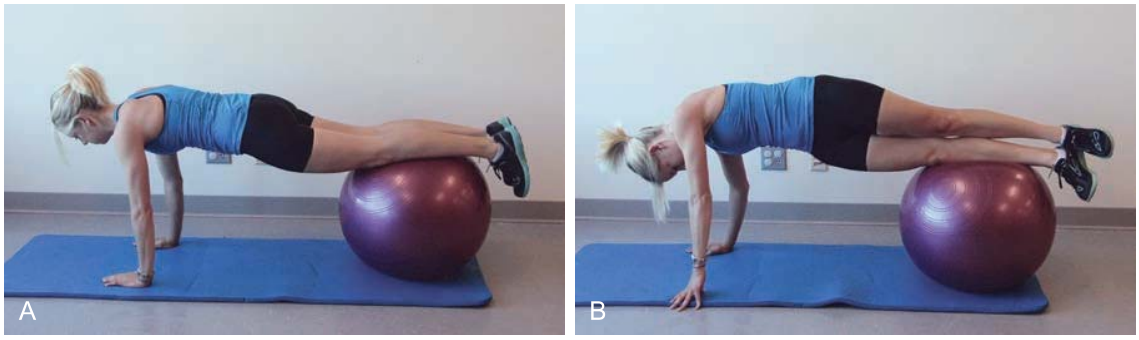


FIGURE 24-33. Physio ball pushup rotations.

FIGURE 24-34. Physio ball bridges with single-leg hold.

Performance Enhancement and Prevention of Reinjury

- Once the athlete has met milestones for return to sport, it is suggested they continue a program for performance enhancement and prevention of reinjury for the rest of that season and following off-season. The physician or physical therapist should reevaluate after the season and prior to the next season to screen for potential muscle imbalances, compensations, or weaknesses that have developed and subsequently make that athlete at higher risk for reinjury.

- Program components should include:
  - Single-leg balance exercises and perturbation type exercises
  - Dynamic agility drills
  - Eccentric hamstring strengthening, especially in a lengthened position
  - Core and trunk stabilization exercises

Specific Criteria for Return to Sports Participation: Tests and Measurements

- Pain free to palpation over the site of muscle strain
- Full concentric and eccentric strength of the hamstrings (as compared to the uninjured side) tested in a lengthened position. This can be done with an isokinetic dynometer, a mobile force sensor, or estimated with manual muscle testing.
- Full concentric and eccentric muscular endurance of the hamstrings (as compared to the uninjured side) tested in a lengthened position. This can be done with an isokinetic dynometer, a mobile force sensor, or estimated with repetition manual muscle testing.
- No fear or kiniesophobia, as measured by the hamstring active test (H Test) or modified hamstring active test.
- No pain or fear with a progressive sprint test of at least 30 yards (70% to 80% to 90% to 95% speed intervals).

Evidence

Askling CM, Nilsson J, Thorstensson A: A new hamstring test to complement the common clinical examination before return to sport after injury. *Knee Surg Sports Traumatol Arthrosc* 18:1798–1803, 2010.

Eleven healthy subjects (average age, 28 years) were tested on repeated occasions, and 11 athletes (average age, 21 years) with MRI-verified acute hamstring strain were tested when common clinical examination revealed no signs of remaining injury. Flexibility (highest range of motion of three consecutive trials) was calculated during active ballistic hip flexions and conventional passive slow hip-flexions in a supine position. A VAS-scale (0-100) was used to estimate experience of insecurity during active tests. No significant test-retest differences were observed. Active flexibility was greater (23%) than passive flexibility. In the athletes, the injured leg showed smaller (8%) active, but not passive, flexibility than the uninjured leg. Average insecurity estimation was 52 (range 28-98) for the injured and 0 for the uninjured leg, respectively. The authors report that in their own clinical experience they have used the feeling of insecurity as a guide for return to play, and in doing so they have not experienced reinjuries during the first 4 weeks. Therefore, they recommend that if an athlete has insecurity, the test should be repeated in 2 weeks, and return to sport should not be allowed until no insecurity is present. (Level III and Level V evidence).

Cameron ML, Adams RD, Maher CG, et al: Effect of the Ham-Sprint Drills training programme on lower limb neuromuscular control in Australian football players. *J Sci Med Sport* 12:24–30, 2007.

This randomized controlled trial of 29 footballers from one professional Australian Football League club compared drills specific to the improvement of running technique, coordination, and hamstring function to normal training. The training group showed significant improvement in lower limb neuromuscular control with movements similar to the late-swing, early stance phase of running. (Level I evidence).

Chumanov ES, Heiderscheit BC, Thelen DG: The effect of speed and influence of individual muscles on hamstring mechanics during the swing phase of sprinting. *J Biomech* 40:3555–3562, 2007.

The purpose of this study was to characterize the effect of speed and influence of individual muscles on hamstring stretch, loading, and work during the swing phase of sprinting at speeds ranging from 80% to 100% of maximum speed. Swing phase simulations were used to characterize the effects of speed on the peak stretch, maximum force, and negative work of the biceps femoris long head (BF), the most often injured hamstring muscle. Perturbations of the double float simulations were used to assess the influence of individual muscles on BF stretch. Peak hamstring musculotendon stretch occurred at approximately 90% of the gait cycle (late swing) and was independent of speed. Peak hamstring force and negative musculotendon work increased significantly with speed ($p<0.05$). Muscles in the lumbo-pelvic region had greater influence on hamstring stretch than muscles acting about the knee and ankle, with the hip flexors were found to induce the most hamstring stretch in the opposite limb. They concluded that hamstring strain injury during sprinting may be related to the performance of large amounts of negative work over repeated strides and/or resulting from a perturbation in pelvic muscle coordination that induces excessive hamstring stretch in a single stride. (Level II evidence).

Croisier JL, Ganteaume S, Binet J, et al: Strength imbalances and prevention of hamstring injury in professional soccer players: a prospective study. *Am J Sports Med* 36:1469–1475, 2008.

This prospective cohort study of professional soccer players determined whether strength variables could be predictors of subsequent hamstring strain and if normalization of strength imbalances could reduce the incidence of hamstring injury. The rate of muscle injury was significantly increased in subjects with untreated strength imbalances; normalizing the isokinetic parameters reduced the risk factor for injury to that observed in players without imbalances. (Level II evidence).

Kraemer R, Knobloch K: A soccer-specific balance training program for hamstring muscle and patellar and achilles tendon injuries: an intervention study in premier league female soccer. *Am J Sports Med* 37:1384–1393, 2009.

This prospective cohort study of 24 elite female soccer players determined whether proprioceptive training can reduce the incidence of hamstring muscle injuries. Soccer-specific balance training reduced noncontact hamstring injuries with a dose-effect relationship between duration of balance training and injury incidence present. (Level III evidence).

Sherry MA, Best TM: A comparison of two rehabilitation programs in the treatment of acute hamstring strains. *J Phys Ther Orthop Sports* 34:116–125, 2004.

This randomized controlled trial of 24 athletes with an acute hamstring strain compared rehabilitation programs

comprised of static stretching and isolated progressive hamstring resistance exercises or progressive agility and trunk stabilization exercises. Seventy percent (70%) of the athletes who completed the hamstring stretching and strengthening program, as compared to only 7.7% of the athletes who completed the progressive agility and trunk stabilization program, suffered a recurrent hamstring strain during a 1-year period. (Level I evidence).

Sole G, Milosavljevic S, Nicholson HD, et al: Selective strength loss and decreased muscle activity in hamstring injury. *J Orthop Sports Phys Ther* 41:354–363, 2011.

This cross-sectional laboratory study compared muscle isokinetic torque patterns and EMG activity in 15 individuals without hamstring injury and 15 individuals who had sustained a hamstring injury within the past year but had returned to at least partial sports training. Eccentric flexor torque was significantly less in the lengthened range of in the hamstring injured limb in comparison to the uninjured limb, despite no significant differences in absolute peak torque throughout the range. Differences were also found between groups in EMG amplitudes during eccentric flexor contractions, indicating neurophysiological factors may contribute to the changes in torque. (Level II evidence).

Sole G, Milosavljevic S, Nicholson H, et al: Altered muscle activation following hamstring injuries. *Br J Sports Med* 46:118–123, 2012.

In this study, 16 participants with a hamstring injury and 18 control participants participated. The EMG activity of gluteal, quadriceps, and hamstring muscles was recorded during a movement from double- to single-leg movement using surface electrodes. The EMG onsets of biceps femoris and medial hamstrings were significantly earlier for the HG injured and the uninjured sides in preparation for single-leg standing when compared with the CG average. There were no differences in onsets for the gluteal and quadriceps muscles when comparing the injured or uninjured legs of the HG to the bilateral average of the CG. This earlier onset of the injured and the uninjured hamstrings in preparation for single-leg stance of the HG in comparison with the CG suggests an alteration in the motor control of these muscles and thus neuromuscular control following a hamstring injury may be an important consideration in the rehabilitation of hamstring injuries. (Level II evidence).

Gabbe BJ, Bennell KL, Finch CF, et al: Predictors of hamstring injury at the elite level of Australian football. *Scand J Med Sci Sports* 16:7–13, 2006.

A prospective cohort of 222 players underwent baseline measurement in the form of a self-report questionnaire and a musculo-skeletal screen during the preseason period of the 2002 Australian football season. Injury surveillance and exposure data were collected for the full season. Logistic regression analyses were used to identify independent predictors of hamstring injury in this group of players. A total of 31 players sustained a hamstring injury. A past history (previous 12 months) of hamstring injury and increasing age were found to be independent predictors of hamstring injury. Restricted ankle dorsiflexion range of movement showed trends toward predicting injury and thus also warrants consideration in the development of prevention programs for hamstring injury. (Level I evidence).

Warren P, Gabbe BJ, Schneider-Kolsky M, et al: Clinical predictors of time to return to competition and of recurrence following hamstring strain in elite Australian footballers. *Br J Sports Med* 44:415–419, 2010.

A total of 59 Aussie football players who suffered a hamstring strain underwent a clinical assessment by a physiotherapist and questionnaire. This study found players taking more than 1 day to walk pain free were significantly more likely (p=0.018) to take longer than 3 weeks to return to competition (adjusted odds ratio 4.0; 95% CI 1.3 to 12.6). Nine players (15.2%) experienced an injury recurrence, all involving the biceps femoris. Recurrence was more likely in players who reported a hamstring injury in the past 12 months (adjusted odds ratio 19.6; 95% CI 1.5 to 261.0; p=0.025). Time to walk pain free and previous hamstring injury are predictors of time to return to competition and recurrence, respectively. (Level III evidence).

Multiple-Choice Questions

QUESTION 1. Which of the following should be avoided in Phase I of the hamstring injury rehabilitation program?

A. Core stabilization
B. Agility drills
C. Aggressive stretching
D. Icing

QUESTION 2. Which statement most accurately describes the hamstring active test?

A. It is more sensitive when done in standing instead of supine
B. The injured leg shows smaller passive, but not active, flexibility than the uninjured leg
C. This test should only be used after the athlete has returned to sport.
D. Apprehension or insecurity is the most important clinical measure from the test in regards to return to sport.

QUESTION 3. Which factor is important to incorporate in to hamstring rehabilitation?

A. Eccentric strengthening
B. Neuromuscular control
C. End-range hamstring strengthening
D. Core strengthening
E. All of the above

QUESTION 4. Which best describes the progression of agility exercises in the PATS program

A. Start with slow, small movements in the frontal plane progressing to faster, then bigger, then transverse and sagittal plane movements.
B. Start with slow, large movements in the frontal plane progressing to faster, then smaller, then transverse and sagittal plane movements.
C. Start with slow, small movements in the sagittal plane progressing to faster, then bigger, then transverse and frontal plane movements.
D. Start with fast, small movements in the frontal plane progressing to slower heavier resistance in the transverse and sagittal plane movements.

QUESTION 5. The most appropriate criteria for return to sport includes:

A. More passive than active motion in the injured leg on the hamstring active test, 5/5 end range strength on repeated hamstring manual muscle testing, confidence with sport-specific movements
B. No insecurity on the hamstring active test, 5/5 end range strength on repeated hamstring manual muscle testing, confidence with sport-specific movements
C. More active than passive motion in the injured leg on the hamstring active test, 5/5 end range strength on repeated hamstring manual muscle testing, confidence with sport-specific movements
D. No insecurity on the hamstring active test, 5/5 strength on hamstring manual muscle testing at 90° knee flexion, confidence with sport-specific movements

Answer Key

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

QUESTION 2. Correct answer: **D** (see Askling, 2010).

QUESTION 3. Correct answer: **E** (see Annotated Evidence).

QUESTION 4. Correct answer: **A** (see Sherry, 2004).

QUESTION 5. Correct answer: **B** (see Phase III).

BEYOND BASIC REHABILITATION: RETURN TO SPRINTING ACTIVITIES AFTER HAMSTRING STRAIN

Bryan Heiderscheit, PT, PhD, Marc Sherry, PT, DPT, LAT, CSCS, and William Clancy, MD

Introduction

ASPECTS OF SPRINTING THAT REQUIRE SPECIAL ATTENTION IN REHABILITATION

- During the terminal swing phase of running, the hamstring muscles are active while elongating, resulting in substantial eccentric loading.
- The mechanical energy absorbed by the hamstrings during this eccentric loading exponentially increases with running speed.
- Hamstring injury during running is most likely to occur during the terminal swing phase.

Hamstring injuries are very common during high-speed running, particularly sprinting. This injury remains challenging as up to 30% of individuals will experience an injury recurrence upon returning to sport despite completing a formalized rehabilitation program.

The return to running program is given in Box 24-2.

Literature

- Persistent strength deficits, in particular eccentric hamstring strength, have been found to increase the risk of running-related reinjury to the hamstring muscles.[1]
- In addition, inaccuracies in perceiving running-like leg movements have been associated with an increased risk for hamstring strain injury.[2]
- Finally, individuals with a prior hamstring strain often show altered recruitment of the hamstring muscles, potentially affecting the neuromuscular coordination needed to sprint safely.[3]

Advanced Strength and Conditioning Programs

Periodization

- The program is progressed in a linear manner over time.

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- Training continuum
- Flexibility/joint mobility for joint stability
- Training with optimum posture
- Sensorimotor and balance training
- Core training
- Cardiorespiratory training
- Multiplanar training activities
- Training for optimum muscle balance
- Training for optimum muscle functional strength
- Training for optimum muscle functional power
- Neuromuscular dynamic stability exercises
- Training for speed, agility, quickness (SAQ)
- Plyometric training
- Functional training
- Sport-specific training

BOX 24-2 Return to Sprinting Program

This program is designed for individuals who have recently completed rehabilitation for a hamstring strain injury and are now returning to a sport that involves sprinting. Because the greatest risk for reinjury is present during the initial 2 weeks of returning to sport, it is important that this transition be made gradually and progressively. As such, the program is divided into 3 phases, each lasting 2 weeks:

- The initial 2 weeks are focused on the persistent neuromuscular deficits that may remain such as reduced hamstring recruitment, endurance, and ease of movement. The exercises are a continuation of those performed during rehabilitation but with greater speed and intensity.
- During weeks 3 and 4, sport-specific movements with challenging body posture are initiated as are aggressive eccentric training of the hamstrings.
- Finally, weeks 5 and 6 are designed to simulate competition but in a slightly more controlled manner. These exercises are designed to be performed as a stand-alone program. If the individual is also participating in an organized practice or training program, the volume involved with this program should be reduced to avoid overtraining.
- In addition, the strength training aspects should be performed after practice as the gains from eccentric training are better when the muscle is fatigued.

Weeks 1 to 2

GOALS:

1. Promote residual healing
2. Promote full range ease of movement
3. Facilitate hamstring muscle recruitment
4. Promote neuromuscular endurance

EXERCISES/DRILLS:

Dynamic warmup

1. Leg cycling drill, 3 × 10 each leg
2. High knee marching, 3 × 30 meters, jog back to start between repetitions
3. Heel kicks, 3 × 30 meters, jog back to start between repetitions
4. Quick carioca, 2 × 30 meters each direction
5. Cross-over skip, 2 × 30 meters each direction
6. A and B skips, 3 × 30 meters, jog back to start between repetitions A and B skips are a hurdle drill to work on the drive of the lead leg up to the hurdle. The A consists of the initial drive up and the B consists of the extension when the height of the hurdle trajectory is reached.
7. Forward-backward accelerations (20 meters), 3 × 1 minute

Running

8. Falling starts, 3 × 40 meters, walk back to start between repetitions
9. 3-point start, 3 × 40 meters, walk back to start between repetitions
10. Sprinting (70% to 90% intensity), 4 × 60 meters, walk back to start between repetitions

Strength and endurance

11. Rotating body bridge with dumbbells, 5 second hold each side, 2 × 15
12. Supine single-limb chair-bridge, 3 × 15, fast speed
13. Single-limb balance windmill touches with dumbbells, 4 × 10 per arm each leg
14. Prone hip extension off the edge of bed or table for full ROM with ankle weight, start at the top then drop and catch the leg, 2 × 20
15. Lunge walk with trunk rotation, opposite hand dumbbell toe touch and T-lift, 2 × 15 steps per limb (Figure 24-35)

Weeks 3 to 4

GOALS:

1. Promote residual healing
2. Facilitate hamstring muscle hypertrophy with eccentric focus
3. Facilitate symmetrical sprinting mechanics

EXERCISES/DRILLS:

Dynamic warmup

1. Leg cycling drill, 3 × 10 each leg, jog back to start between repetitions
2. High knee marching, 3 × 30 meters, jog back to start between repetitions
3. Heel kicks, 3 × 30 meters, jog back to start between repetitions
4. Quick carioca, 2 × 30 meters each direction
5. Cross-over skip, 2 × 30 meters each direction
6. A and B skips, 3 × 30 meters, jog back to start between repetitions
7. Forward-backward accelerations (20 meters), 3 × 1 minute

BOX 24-2 Return to Sprinting Program *(Continued)*

FIGURE 24-35. Lunge walk with trunk rotation, opposite hand dumbbell toe touch, and T-lift.

Running
8. 3-point start, 3 × 40 meters, walk back to start between repetitions
9. Squat jump and go, 3 × 40 meters, walk back to start between repetitions
10. Sprinting (80% to 95% intensity), 4 × 80 meters, walk back to start between repetitions
11. Sports-specific movements with changing body posture and head positions

Strength
12. Nordic hamstring drop-curl progression (Figures 24-36 and 24-37)
    a. 3 × 8–12, drop and return
    b. Can initially use physio ball to reduce range of motion and bands/cables to reduce load
13. Rotating body bridge with dumbbells, 5 second hold each side, 2 × 15
14. Backward weight throw standing on 2 legs, 2 × 15 (Figure 24-38)

Weeks 5 to 6

GOALS:

1. Facilitate hamstring muscle hypertrophy with eccentric focus and end-range strength
2. Facilitate symmetrical sprinting mechanics

EXERCISES/DRILLS:

Dynamic warmup
1. Leg cycling drill, 3 × 10 meters each leg, jog back to start between repetitions
2. High knee marching, 3 × 30 meters, jog back to start between repetitions
3. Heel kicks, 3 × 30 meters, jog back to start between repetitions
4. Quick carioca, 2 × 30 meters each direction
5. Cross-over skip, 2 × 30 meters each direction
6. A and B skips, 3 × 30 meters, jog back to start between repetitions
7. Forward-backward accelerations (20 meters), 3 × 1 minute

Continued on following page

BOX 24-2 Return to Sprinting Program *(Continued)*

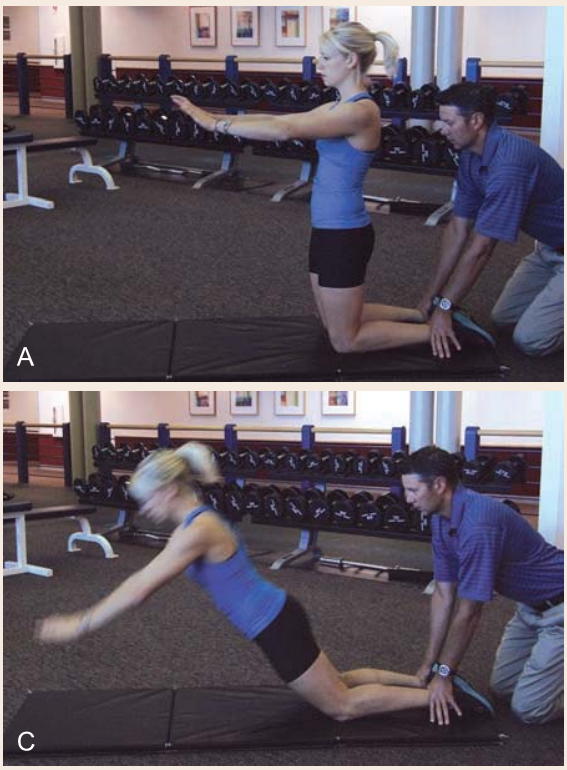


FIGURE 24-36. Nordic hamstring curls.

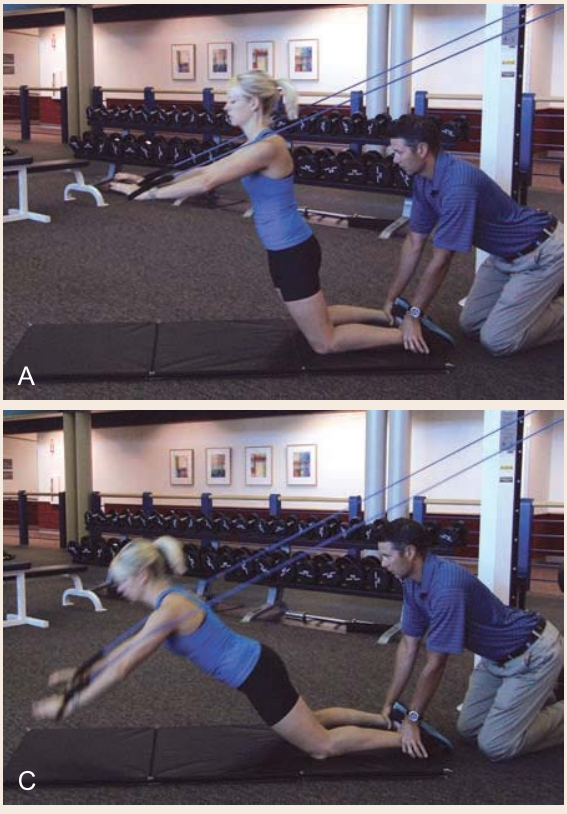
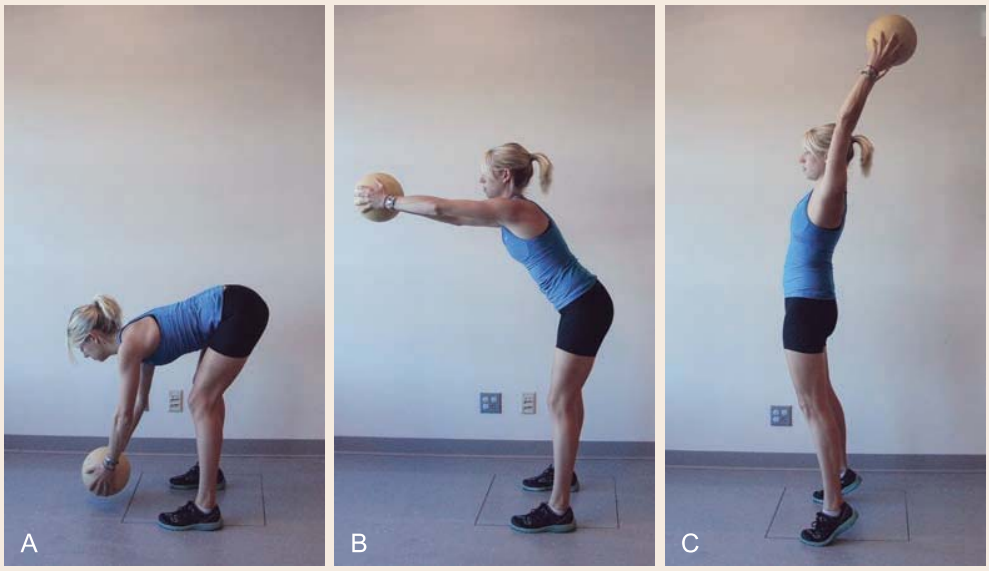


FIGURE 24-37. Nordic hamstring curls with elastic band assistance.

BOX 24-2 Return to Sprinting Program *(Continued)*



Running

8. Squat jump and go, 3 × 40 meters, walk back to start between repetitions
9. Straight leg running, 3 × 20 meters, walk back to start between repetitions
10. Sprinting (85% to 100% intensity), 4 × 100 meters, walk back to start between repetitions
11. Sports-specific movements with changing body posture

Strength

12. Nordic hamstring drop-curl progression
    a. 3 × 12 reps drop and return with increased drop speed
13. Rotating body bridge with dumbbells, 5 second hold each side, 2 × 15
14. Backward weight throw standing on 1 leg, 2 × 15

TIMELINE 24-4: **Beyond Basic Rehabilitation: Return to Sprinting Activities After Hamstring Strain**

PHASE I (weeks 1 to 2)	PHASE II (weeks 3 to 4)	PHASE III (weeks 5 to 6)
• Leg cycling drill • High knee marching • Heel kicks • Quick carioca • Cross-over skip • A and B skips • Forward-backward accelerations • Falling starts • Three-point start • Sprinting (70%–90%) • Rotating body bridge with dumbbells • Supine single-limb chair-bridge • Single-limb balance windmill touches with dumbbells • Prone hip extension off the edge of bed or table for full ROM with ankle weight • Lunge walk with trunk rotation, opposite hand dumbbell toe touch and T-lift	• Leg cycling drill • High knee marching • Heel kicks • Quick carioca • Cross-over skip • A and B skips • Forward-backward accelerations • Three-point start • Squat jump and go • Sprinting (80%–95%) • Sports-specific movements with changing body posture • Nordic hamstring drop-curl progression • Rotating body bridge with dumbbells • Backward weight throw standing on two legs	• Leg cycling drill • High knee marching • Heel kicks • Quick carioca • Cross-over skip • A and B skips • Forward-backward accelerations • Squat jump and go • Straight leg running • Sprinting (85%–100%) • Sports-specific movements with changing body posture • Nordic hamstring drop-curl progression • Rotating body bridge with dumbbells • Backward weight throw standing on one leg

Training Principles Used in the Design of the Program

- Principle of progression
- Principle of overload
- Principle of variation
- Principle of individualization
- Principles of specificity; specific adaptation to imposed demands (SAID)

Sports Performance Testing

General Information

- General history
- Medical history
- Sports injury history
- Surgical history
- Chronic conditions/medication

Subjective Questions

- Perceived ease of movement throughout full hip/knee range of motion
- Minimal self-reported insecurity of movement with active straight leg raise

Objective Tests

- Dynamic muscle performance testing
  - Isokinetic testing performed at time of return to sport and 6 weeks later
    - Concentric strength of the quadriceps and hamstrings at 60°/second and 240°/second
    - Eccentric strength of the hamstrings at 0°/second
    - Less than 5% bilateral asymmetry in hamstring to quadriceps peak torque ratio (H_{ECC30}: Q_{CON240})
- Movement performance testing
  - Nordic drops (assessing during each training session)
    - assessing depth of drop and ability to return
- Sport-specific testing
  - Straight line sprinting (assessing during each training session)
    - Bilateral symmetry in heel height during swing phase
    - Bilateral symmetry in foot-ground contact pattern
  - Sprinting with changing body posture specific to sport
    - Appropriate pelvic motion but not excessive
    - Able to bend forward at hips without excessive lumbar motion

Specific Criteria for Progression to the Next Stage to Determine Readiness for Sprinting

- Time criteria only, as the player is no longer injured and is back to sport

Recommended Ongoing Exercises

- The program should be repeated as part of each year's preseason training.
- The core stabilization exercises should be completed indefinitely.

Evidence

Askling C, Karlsson J, Thorstensson A: Hamstring injury occurrence in elite soccer players after preseason strength training with eccentric overload. *Scand J Med Sci Sport* 13:244–250, 2003.

This randomized controlled trial of 30 premier-league soccer players compared preseason strength training with emphasis on eccentric overload to a normal preseason training. The training group showed a decreased incidence of hamstring strain injuries over the subsequent 10 months with an increase in strength and speed. (Level I evidence).

Brooks JH, Fuller CW, Kemp SP, et al: Incidence, risk, and prevention of hamstring muscle injuries in professional rugby union. *Am J Sports Med* 34:1297–1306, 2006.

This prospective cohort study defined the incidence, severity, and risk factors associated with hamstring strain injuries in professional rugby, as well as whether hamstring strengthening and stretching exercises reduce the incidence and severity of these injuries. Running accounted for the majority of hamstring injuries but kicking resulted in the most severe. Nordic hamstring exercises reduced the incidence and severity of injury during practice and competition. (Level III evidence).

Cameron ML, Adams RD, Maher CG, et al: Effect of the Ham-Sprint Drills training programme on lower limb neuromuscular control in Australian football players. *J Sci Med Sport* 12:24–30, 2007.

This randomized controlled trial of 29 footballers from one professional Australian Football League club compared drills specific to the improvement of running technique, coordination and hamstring function to normal training. The training group showed significant improvement in lower limb neuromuscular control with movements similar to the late-swing, early stance phase of running. (Level 1 evidence).

Croisier JL, Ganteaume S, Binet J, et al: Strength imbalances and prevention of hamstring injury in professional soccer players: a prospective study. *Am J Sports Med* 36:1469–1475, 2008.

This prospective cohort study of professional soccer players determined whether strength variables could be predictors of subsequent hamstring strain and if normalization of strength imbalances could reduce the incidence of hamstring injury. The rate of muscle injury was significantly increased in subjects with untreated strength imbalances; normalizing the isokinetic parameters reduced the risk factor for injury to that observed in players without imbalances. (Level I evidence).

Engebretsen AH, Myklebust G, Holme I, et al: Intrinsic risk factors for hamstring injuries among male soccer players: a prospective cohort study. *Am J Sports Med* 38:1147–1153, 2010.

This cohort study of 508 players from 31 amateur teams determined whether previous hamstring injuries, reduced function scores, abnormalities on a clinical examination, high maximum sprint speed, poor hamstring strength, or low hamstring/quadriceps ratio can predict increased risk of new hamstring injuries. Previous acute hamstring injury was found to be the most important risk factor for new injury, with previously injured players having more than twice as high a risk of sustaining a new hamstring injury. (Level II evidence).

Kraemer R, Knobloch K: A soccer-specific balance training program for hamstring muscle and patellar and achilles tendon

injuries: an intervention study in premier league female soccer. *Am J Sports Med* 37:1384–1393, 2009.

This prospective cohort study of 24 elite female soccer players determined whether proprioceptive training can reduce the incidence of hamstring muscle injuries. Soccer-specific balance training reduced noncontact hamstring injuries with a dose-effect relationship between duration of balance training and injury incidence present. (Level III evidence).

Sherry MA, Best TM: A comparison of 2 rehabilitation programs in the treatment of acute hamstring strains. *J Orthop Sports Phys Ther* 34:116–125, 2004.

This randomized controlled trial of 24 athletes with an acute hamstring strain compared rehabilitation programs comprised of static stretching and isolated progressive hamstring resistance exercises or progressive agility and trunk stabilization exercises. Seventy percent (70%) of the athletes who completed the hamstring stretching and strengthening program, as compared to only 7.7% of the athletes who completed the progressive agility and trunk stabilization program, suffered a recurrent hamstring strain during a 1-year period. (Level I evidence).

Verrall GM, Slavotinek JP, Barnes PG: The effect of sports-specific training on reducing the incidence of hamstring injuries in professional Australian Rules football players. *Br J Sports Med* 39:363–368, 2005.

This prospective cohort study of one team of Australian Rule football players assessed the effect of a sport-specific intervention program on the incidence and consequence of hamstring strain injuries. During the 2 years with the intervention, a decreased incidence of hamstring injuries was observed, as well as fewer games missed caused by this injury. (Level III evidence).

REFERENCES

1. Croisier JL, Ganteaume S, Binet J, et al: Strength imbalances and prevention of hamstring injury in professional soccer players: a prospective study. *Am J Sports Med* 36:1469–1475, 2008.
2. Cameron ML, Adams RD, Maher CG, et al: Effect of the HamSprint Drills training programme on lower limb neuromuscular control in Australian football players. *J Sci Med Sport* 12:24–30, 2007.
3. Sole G, Milosavljevic S, Nicholson HD, et al: Selective strength loss and decreased muscle activity in hamstring injury. *J Orthop Sports Phys Ther* 41:354–363, 2011.

Multiple-Choice Questions

Question 1. During sprinting, the hamstring muscles are at the great risk for reinjury at:

A. Midstance
B. Push-off
C. Initial swing
D. Terminal swing

Question 2. After returning to sport following a hamstring strain injury, what neuromuscular deficit has not been identified?

A. Muscle weakness
B. Altered proprioception
C. Increased stiffness
D. Altered recruitment

Question 3. Because of the residual evidence of muscle injury that is common at the time of return to sport, what type of exercise is delayed until week 3?

A. High-speed running/sprinting
B. Eccentric strength training
C. Progressive agility
D. Trunk stabilization

Question 4. Which of the following is not part of the sports performance testing for return to sprinting activities following a hamstring strain injury?

A. Isokinetic strength testing
B. Sprinting mechanics
C. Nordic drops
D. Passive straight leg raise

Question 5. Based on the Engebretsen et al. (2010) study, what is the single biggest risk factor for incurring another hamstring strain injury?

A. A previous hamstring injury
B. Straight leg raise less than 60°
C. Hamstring strength bilateral difference of 15%
D. Athlete perception of reduced performance

Answer Key

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

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

QUESTION 3. Correct answer: **B** (see Box 24-2).

QUESTION 4. Correct answer: **D** (see Sports Performance Testing).

QUESTION 5. Correct answer: **A** (see Evidence).

POSTOPERATIVE REHABILITATION AFTER REPAIR OF PROXIMAL HAMSTRING AVULSION

Matthew Joseph Salzler, MD, Steve Brian Behrens, MD, and James P. Bradley, MD

Indications for Surgical Treatment

- All three hamstring origins avulsed
- Sciatic nerve symptoms secondary to hamstring avulsion
- Two hamstring origins avulsed with >2 cm of retraction
- One or two hamstring origin chronic avulsion with <2 cm of retraction with persistent pain, despite adequate nonoperative management

Brief Summary of Surgical Treatment

Major Surgical Steps

- General anesthesia with patient in prone position and table flexed ~30° at the waist (Figure 24-39)
- Transverse infragluteal incision, retract gluteus maximus proximally (Figure 24-40)
- Protect sciatic nerve
- Longitudinally incise hamstring fascia, mobilize hamstring origins
- Prepare ischial tuberosity and proximal hamstrings (Figure 24-41)
- Place five 2.8 to 3.0 mm PLDLA/calcium phosphate suture anchors loaded with high-strength nonabsorbable sutures in an X configuration (Figure 24-42)
- Pass sutures through tendons in horizontal mattress fashion and tie down securely (Figure 24-43); we prefer horizontal mattress sutures through the tendon over a whipstitch to prevent tendon bunching
- Careful multilayered wound closure covered with a waterproof dressing
- Postop precautions: Touchdown weight bearing with knee immobilizer locked at 40°
- Complications: Wound dehiscence, sitting discomfort, posterior thigh/foot numbness

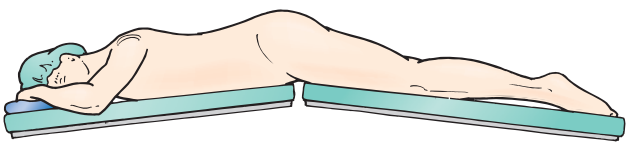


FIGURE 24-39. Illustration of flexed operative table (approximately 20°) for hamstring repair. *(Reproduced with permission from Pombo M, Bradley JP. Proximal hamstring avulsion injuries: A technique note on surgical repairs. Sports Health 1:261–264, 2009.)*

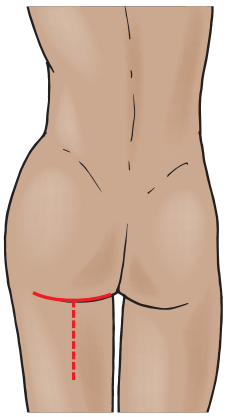


FIGURE 24-40. Illustration of transverse infragluteal incision. *(Reproduced with permission from Pombo M, Bradley JP. Proximal hamstring avulsion injuries: A technique note on surgical repairs. Sports Health 1:261–264, 2009.)*

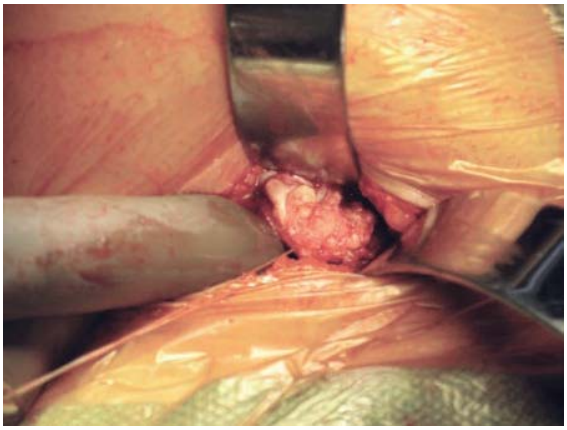


FIGURE 24-41. Intraoperative photograph of mobilized and debrided proximal hamstring tendon. *(Reproduced with permission from Pombo M, Bradley JP. Proximal hamstring avulsion injuries: A technique note on surgical repairs. Sports Health 1:261–264, 2009.)*

Factors that may Affect Rehabilitation

Anesthetic

- Avoid regional and spinal anesthesia; impairs assessment of sciatic nerve postoperatively

Surgical

- Number of hamstring tendons repaired, chronicity, and amount of retraction
  - Greater number of tendons avulsed, more retraction, and longer time of retraction all potentially increase tension on the repair. If concerned for strength of repair or tension on repair, consider a slower and more conservative protocol.

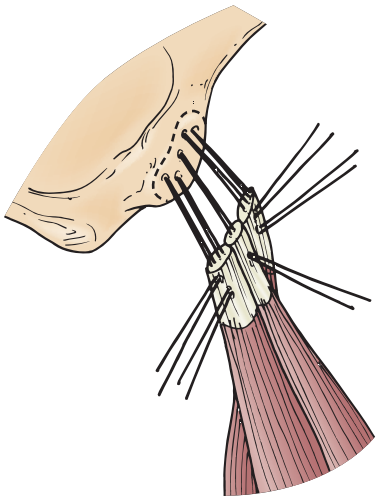


FIGURE 24-42. Illustration of suture anchors in an X configuration with sutures through the proximal tendon in a horizontal mattress fashion. *(Reproduced with permission from Pombo M, Bradley JP. Proximal hamstring avulsion injuries: A technique note on surgical repairs. Sports Health 1:261–264, 2009.)*

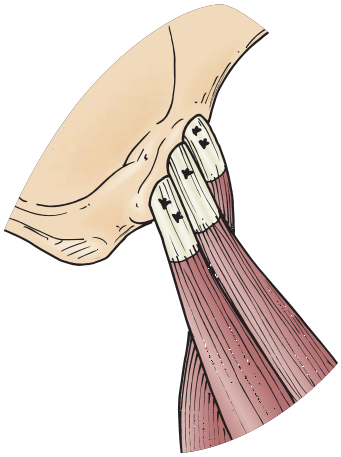


FIGURE 24-43. Illustration of repaired tendon after tying of sutures. *(Reproduced with permission from Pombo M, Bradley JP. Proximal hamstring avulsion injuries: A technique note on surgical repairs. Sports Health 1:261–264, 2009.)*

Before Surgery: Overview of Goals, Milestones, and Guidelines

GUIDING PRINCIPLES OF POSTOPERATIVE REHABILITATION

- Understand the anatomic structures involved and their rate of healing
- Understand position and activities that stress the repair
- Proper selection of therapy and ROM at the appropriate phase of healing

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

CLINICAL PEARLS

If there are concerns about the strength of the repair, tension on the repair, or the patient's compliance, consider a more conservative rehabilitation protocol. This would involve utilizing a hip abduction brace instead of a hinged knee brace and potentially delaying the phases of rehab by 1 to 2 weeks.

Goals

- Allow for wound healing; dehiscence is a disastrous complication
- Protect the repaired structures
- Minimize the effects of immobilization
- Decrease pain and inflammation

Protection

- Toe-touch weight bearing on crutches at all times
- Avoid the "7" position (hips flexed and knees extended straight (Figure 24-44)
- Hinged knee brace locked at 40° to be removed briefly only for bathing/dressing and minimize hip flexion when out of brace (Figure 24-45.)
- Hip flexion brace locked in full extension if concerned about the strength of the repair or about patient compliance (Figure 24-46)

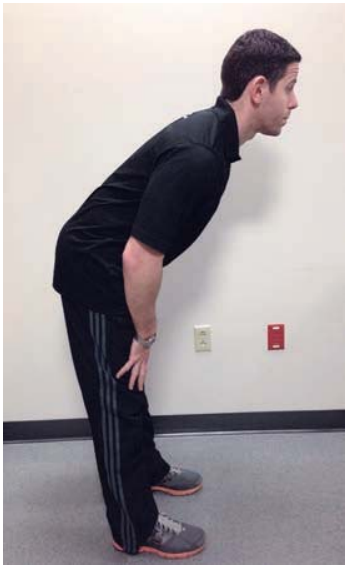


FIGURE 24-44. Photograph of the "7" position (hips flexed and knees extended straight) to be avoided.

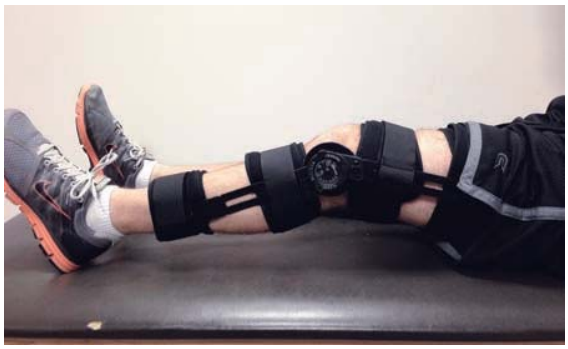


FIGURE 24-45. Photograph of a hinged knee brace locked at 40°.

FIGURE 24-46. Photograph of a hip flexion brace locked in full extension.

Management of Pain and Swelling

- Oral pain medications
- Therapeutic modalities for pain and inflammation to include TENS, E-Stim, and ice/continuous cryotherapy
- Patient education: Find a "position of comfort" that relaxes the repair with the hips extended and knee flexed
- Light desensitization massage of the incision may reduce the occurrence of hypersensitivity

Techniques for Progressive Increase in Range of Motion

- Ankle ROM only

Other Therapeutic Exercises

- Ankle pumps should be performed 20 to 30 times per hour
- Quad sets should be performed for 10 to 15 minutes, 3 times a day
- Any additional therapeutic exercises should be avoided to prevent stressing the repair

Milestones for Progression to the Next Phase

- Adequate wound healing
- No evidence of failure of repair (palpable gap at repair site)

Phase II (weeks 3 to 6)

Goals

- Protect the repaired structures
- Minimize the effects of immobilization
- No marked pain at area of repair
- Progress towards normal gait pattern

Protection

- Continue with crutches for 6 weeks postop
- Continue with knee brace locked at 40 degrees for full 4 weeks; okay to remove for PT

TIMELINE 24-5: **Postoperative Rehabilitation After Repair of Proximal Hamstring Avulsion**

PHASE I (weeks 0 to 2)	PHASE II (weeks 3 to 6)	PHASE III (weeks 6 to 10)
• Hinged knee brace locked at 40° (or hip flexion brace locked in full extension) • PT modalities • TDWB on crutches • Ankle ROM only • Ankle pumps and quad sets	• Hinged knee brace locked at 40° (or hip flexion brace locked in full extension) • PT modalities • TDWB on crutches: increase WB by 25% body weight every week • PROM – knee flexion in prone position • Wk 4 – PROM of hip extension • Wk 4 – gentle AROM/AAROM avoiding hip flexion & terminal knee extension • Ankle pumps and quad sets	• DC hinged knee brace • Wean off crutches when normal gait pattern established • PT modalities as needed • PROM – avoid combined hip flexion/knee extension • TBS/TAS activities as recommended & tolerated • TLS – gluteus medius/maximus PREs • OKC standing hamstring curls • CKC quarter depth squats and heel raises

- At 4 weeks, brace can be unlocked as tolerated
- Begin partial weight bearing at 25% of body weight increasing by 25% every week over next 4 weeks

Management of Pain and Swelling

- Continue with oral pain medications
- Continue therapeutic modalities including TENS, E-Stim, and cryotherapy
- Continue with cryotherapy as needed

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Avoid hip flexion and 40° of terminal knee extension up to 4 weeks
- At 2 weeks, PROM flexion of the knee in the prone position should be initiated to prevent knee stiffness
- Ankle and lumbar spine ROM is encouraged

Soft Tissue Techniques

- Scar mobilization to surgical incision once closed.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- At 4 weeks, PROM of hip extension and knee flexion is initiated with cessation of ROM with any discomfort

Other Therapeutic Exercises

- Continue with ankle pumps and quad sets
- Persistent limitation of activity beyond ADLs to protect repair for 4 to 6 weeks

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Initiate gentle isotonic AAROM/AROM at week 4 with avoidance of hip flexion and terminal knee extension

Milestones for Progression to the Next Phase

- No evidence of failure of repair
- Pain tolerable with limited PROM

Phase III (weeks 6 to 10)

Clinical Pearl

Flexibility exercises remain contraindicated at this point to protect the repair. Tightness and/or cramping is not uncommon, and, if experienced, gentle stretching with hip and knee flexion as tolerated can be initiated (Figure 24-47)

FIGURE 24-47. Photograph of "knee-to-chest" stretch with hip and knee flexion.

Goals

- Protect repaired structures
- Normal gait pattern
- Return of pain-free ADLs at home
- Limited pain with gentle strengthening

TIMELINE 24-5: Postoperative Rehabilitation After Repair of Proximal Hamstring Avulsion (Continued)

PHASE IV (weeks 10 to 14)	PHASE V (weeks 14 to 24)	PHASE VI (weeks 24 to 52)
• PT modalities as needed • PROM – avoid combined hip flexion/knee extension • TBS/TAS activities as recommended & tolerated • TLS – gluteus medius/maximus PREs • OKC standing hamstring curls • CKC half-depth squats and heel raises • CKC leg press PREs • NMS half-depth multidirectional step lunges • Double leg Swiss ball curls	• PT modalities as needed • PROM – full as tolerated (limited goals relative to contralateral side) • TBS/TAS/TLS activities as recommended and tolerated • OKC standing hamstring curls • CKC full depth squats and heel raises • CKC leg press, Romanian dead lifts—PREs • NMS full depth multidirectional step lunges • Plyometrics jumping rope • Single leg Swiss ball curls	• PROM – full as tolerated (limited goals relative to contralateral side) • TBS/TAS/TLS activities as recommended & tolerated • OKC standing hamstring curls • CKC full-depth squats and heel raises • CKC leg press, Romanian dead lifts – PREs • NMS single-leg stance, movement on unstable surfaces • Plyometrics sport-specific high intensity exercises • Plyometrics agility drills, side to side and box jumps • Single-leg Swiss ball curls • Sport-specific exercises initiated and progressed

Protection

- Crutches can be weaned off once a normal gait pattern is reestablished
- Knee brace discontinued

Management of Pain and Swelling

- Oral analgesic use is continued as needed
- NSAID therapy may be prescribed for persistent pain
- TENS and E-Stim for pain control PRN
- Cryotherapy is used posttherapy to mitigate postexercise inflammation and soreness

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- ROM Precautions: Avoid combined hip flexion/knee extension
- Knee PROM: techniques used to improve knee flexion and extension within limits of comfort

Soft Tissue Techniques

- Light desensitization massage to surgical incision and posterior hip.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Gentle isolated knee stretches within limits of comfort
- Avoid combined hip flexion/knee extension stretches

Other Therapeutic Exercises

- Cardiovascular: aquatic walking and an upper body ergometer with gel seat cushioning may be initiated with resistance as tolerated.
- Upper body strengthening is initiated with closed and open chain exercises.
- Initiate core pelvic strength training with avoidance of hip flexion.
- Gluteus maximus strength exercises begin and progress from the prone to supine position
- Gluteus medius strengthening is initiated in the side lying position and progresses to the upright position

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Increasing resistance in isotonics in limited range-of-motion; continued avoidance of terminal range of knee extension

Sensorimotor Exercises

- Gait training without crutches is continued
- Step-down exercises are initiated using progressively higher steps

Open and Closed Kinetic Chain Exercises

- Emphasis of CKC isotonics with initiation of OKC exercises

FIGURE 24-48. Photograph of standing hamstring curl.

- CKC: Quarter-depth squats and heel raises progress from bilateral to unilateral status
- OKC: Standing hamstring curls are initiated with hip joint held in neutral and lower leg moving against gravity in pain free arc. Resistance is increased a pound at a time as tolerated with emphasis on high reps and frequency (Figure 24-48)
- Initiate unilateral leg press activities with light resistance and increase as the operative leg tolerates. (Starting hip position should be below 90° and pain free)

Techniques to Increase Muscle Strength, Power, and Endurance

- Machine hamstring curls initiated with 8 to 10 lb at high reps once a full and pain-free knee flexion arc is obtained.

Milestones for Progression to the Next Phase

- Restoration of normal gait pattern
- Return to complete home ADLs without pain

Phase IV (weeks 10 to 14)

Clinical Pearl

Patients may have discomfort while sitting during ADLs and seated exercises. Upright exercises may avoid the sensitive area and a gel seat pad with/without an incision protecting cutout can mitigate the discomfort.

Goals

- Return to unrestricted pain free ADLs at home and at work (excluding heavy labor)
- Performance of nonimpact cardiovascular exercise
- Transition hamstring strengthening from machines to exercises combining strength and balance

Management of Pain and Swelling

- Oral NSAIDs may be continued. If pain continues to be a limiting factor to progression, the patient should return to the surgeon for reassessment.
- TENS, E-Stim, and cryotherapy for pain control PRN
- Cryotherapy is used posttherapy to mitigate postexercise inflammation and soreness

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- ROM precautions: Avoid combined hip flexion/knee extension
- Knee PROM: Techniques used to improve knee flexion and extension within limits of comfort
- Hip PROM: Techniques used to improve hip flexion and extension within limits of comfort

Soft Tissue Techniques

- Light desensitization massage to surgical incision and posterior hip

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Gentle hip and knee stretches within limits of comfort
- Avoid combined hip flexion/knee extension stretches

Other Therapeutic Exercises

- Cardiovascular: Progression to three to five nonimpact aerobic sessions weekly lasting 30 minutes including upper body ergometer, aquatic walking, elliptical, or stationary cycling.
- Continuation of core pelvic and upper body strengthening
- Continued focus on strengthening the hip stabilizers including the gluteus medius and maximus

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Increasing resistance in isotonics with progression to full range of motion

Sensorimotor Exercises

- Continuation of step-down exercises

Open and Closed Kinetic Chain Exercises

- Continuation of CKC and OKC exercises
- CKC: Unilateral half-depth squats and heel raises progress
- CKC: Leg press activities with increasing resistance, reps, and frequency
- OKC: Continued standing hamstring curls with increasing resistance, reps, and frequency

Techniques to Increase Muscle Strength, Power, and Endurance

- Machine hamstring curls with increasing resistance

Neuromuscular Dynamic Stability Exercises

- Half-depth squats with progression to half depth walking lunges is initiated
- Progression to half-depth multidirectional step lunges

Functional Exercises

- Initiation of double leg Swiss ball curl (Figure 24-49 *A*,*B*)

Milestones for Progression to the Next Phase

- Pain free participation in ADLs at home and at work (excluding heavy labor)
- Performance of nonimpact cardiovascular exercise
- Tolerance of strength and balance exercises

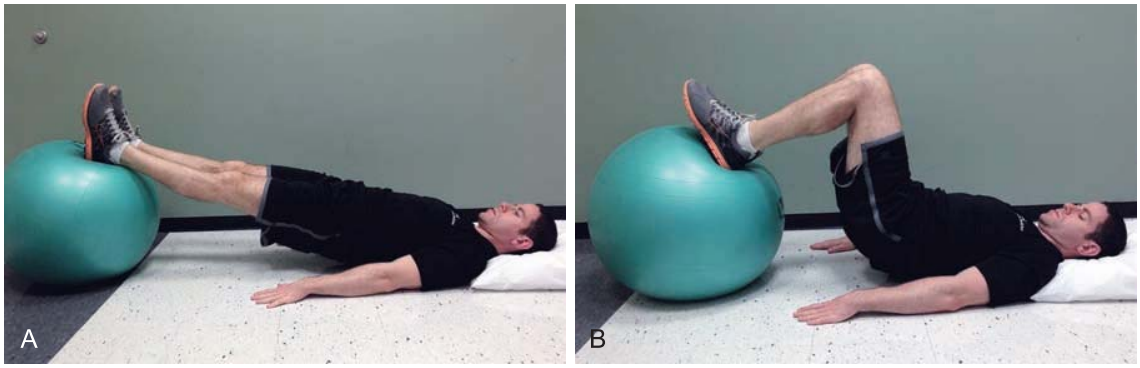


FIGURE 24-49. Photographs of a double-leg Swiss ball curl.

Phase V (weeks 14 to 24)

Clinical Pearl

Hamstring flexibility exercises are initiated in this Phase. The goal of hamstring flexibility is **not** to match the contralateral side; the goal is to alleviate cramping and allow enough flexibility for return to sport.

Goals

- Complete return to work, including heavy labor
- Hamstring strength 75% of contralateral side
- Successful initiation of light jogging

Management of Pain and Swelling

- Oral NSAIDs may be continued. If pain continues to be a limiting factor to progression, the patient should return to the surgeon for reassessment.
- TENS, E-Stim, and cryotherapy for pain control PRN
- Cryotherapy is used posttherapy to mitigate postexercise inflammation and soreness

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- ROM precautions: Within limits of comfort
- PROM: Gentle initiation of hip flexion/knee extension stretching may be initiated; flexibility should remain limited relative to the contralateral side.

Soft Tissue Techniques

- Desensitization massage to surgical incision and posterior hip

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Initiation of gentle combined hip flexion/knee extension stretches within limits of comfort

Other Therapeutic Exercises

- Cardiovascular: Continuation of prior aerobic exercise with the slow introduction of jogging on soft surfaces with avoidance of a treadmill.
- Continuation of core pelvic and upper body strengthening
- Continued focus on strengthening the hip stabilizers including the gluteus medius and maximus

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Increasing resistance in isotonics with progression to full range of motion

Sensorimotor Exercises

- Continuation of step-down exercises

Open and Closed Kinetic Chain Exercises

- CKC: Unilateral full depth squats and heel raises progress
- CKC: Leg press activities with increasing resistance, reps, and frequency
- CKC: Initiation of Romanian dead lifts
- OKC: Continued standing hamstring curls with increasing resistance, reps, and frequency
- OKC: Initiation of resisted inclined hip extensions

Techniques to Increase Muscle Strength, Power, and Endurance

- Machine hamstring curls with increasing resistance

Neuromuscular Dynamic Stability Exercises

- Progression from half- to full-depth squats
- Progression from half- to full-depth multidirectional step lunges

Plyometrics

- Jumping rope
- Multidirectional step lunges at increasing speeds
- Walking lunges at full depth

Functional Exercises

- Progression from double to single leg Swiss ball curls
- Knee pushups with hip extensions (Figure 24-50)

Milestones for Progression to the Next Phase

- Complete return to all home and work activities
- Successful initiation of jogging and light plyometrics
- Hamstring strength 75% of the contralateral side

FIGURE 24-50. Photograph of knee pushup with hip extension.

Phase VI (weeks 24 to 52)

Clinical Pearl

Cramping and activity-related discomfort are common as the intensity of the workouts increase.

Goals

- Ability to tolerate exercise with higher impact, resistance, agility, and speed
- Hamstring strength 90% of contralateral side
- Complete return to sport

Management of Pain and Swelling

- Cryotherapy is used posttherapy to mitigate postexercise inflammation and soreness

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- ROM precautions: Within limits of comfort
- PROM: Gentle hip flexion/knee extension stretching may be continued; flexibility should remain limited relative to the contralateral side.

Soft Tissue Techniques

- Desensitization massage to surgical incision and posterior hip PRN

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Continuation of gentle combined hip flexion/knee extension stretches within limits of comfort. The goal is to maintain and not increase ROM.

Other Therapeutic Exercises

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

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

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

Sensorimotor Exercises

- Ball toss exercises while standing
- Medicine balls
- Progression to slosh balls
- Rapid repositioning drills and reaction movement drills

Open and Closed Kinetic Chain Exercises

- Advancing the previous exercises in accordance with sport-specific demands
- Examples of progression may include kettlebell swings

Techniques to Increase Muscle Strength, Power, and Endurance

- Machine hamstring curls with increasing resistance
- Utilizing isolation and combination exercises as appropriate for the athlete's desired sport

Neuromuscular Dynamic Stability Exercises

- Single leg stance and movement on unstable surfaces as necessary to replicate anticipated performance demands

Plyometrics

- Focus on high intensity activities that simulate the athlete's desired sport
- Examples include side to side jumps, box jumps, and agility drills (tires, ropes, etc.)

Functional Exercises

- Progression from double- to single-leg Swiss ball curls
- Knee pushups with hip extensions

Sport-Specific Exercises

- Return to light sport-specific training can begin as early as 24 weeks
- Light jogging can progress to running with slow build-up of speed
- After tolerating full speed running, then explosive activity, speedwork, and agility drills can be added as tolerated

Milestones for Progression to the Next Phase

- Hamstring strength 90% of the contralateral side on isokinetic testing
- Patient has subjective sense of return to baseline

Criteria for Return to Sport

- Hamstring strength 90% of contralateral side on isokinetic testing
- Single leg lop distance 90% of contralateral side
- Ability to complete activities associated with the sport without pain
- For sports requiring rapid deceleration, acceleration, and direction change (football, basketball, track, rugby, soccer, etc.) there should be symmetric lower extremity motion during sprinting and agility drills that persists despite fatigue.

After Return to Sport

Continuing Fitness or Rehabilitation Exercises

- Continued lower body and whole body strengthening exercises

Exercises and Other Techniques for Prevention of Recurrent Injury

- Limitation of bilateral hamstring stretching beyond what is required for the athlete's desired sport
- Ensure appropriate dynamic neuromuscular control (strength, mobility, kinesthetic awareness, and proprioception of the hamstrings, core muscles, and ipsilateral hip and lower extremity musculature).
- Avoidance or limitation of activities (as appropriate) that cause eccentric loading of the hamstring with concomitant hip flexion and knee extension (e.g., water skiing)

Evidence

Cohen S, Bradley J: Acute proximal hamstring rupture. *J Am Acad Orthop Surg* 15:350–355, 2007.

A review article focusing on indications, surgical technique, and treatment outcomes in proximal hamstring injuries with a review of available evidence. (Level V evidence).

Cohen SB, Rangavajjula A, Vyas D, et al: Functional results and outcomes after repair of proximal hamstring avulsions. *Am J Sports Med* 40:2092–2098, 2012.

Fifty two patients undergoing chronic or acute proximal hamstring repairs had successful outcomes as determined by LEFS, Marx, and custom proximal hamstring questionnaires. (Level IV evidence).

Hamersly S, Schrader M: Postoperative rehabilitation of proximal hamstring tears. *Oper Tech Sports Med* 17:219–224, 2009.

Overview of the authors' rehabilitation protocol with comparison to other protocols. (Level V evidence).

Lefevre N, Bohu Y, Naouri JF, et al: Returning to sports after surgical repair of acute proximal hamstring ruptures. *Knee Surg Sports Traumatol Arthrosc* 21:534–539, 2013.

Prospective observational study of thirty four patients that underwent proximal hamstring repair with good results determined by activity level on UCLA and Tegner scores. (Level III evidence).

Pombo M, Bradley JP: Proximal hamstring avulsion injuries: a technique note on surgical repairs. *Sports Health* 1:261–264, 2009.

A technical guide for surgical repair of proximal hamstring injuries. (Level V evidence).

Multiple Choice Questions

QUESTION 1. Which of the statements below is true regarding ROM goals for the repaired hamstring?

A. Preventing postoperative stiffness is a key guiding principle in postoperative rehabilitation of proximal hamstring repairs
B. ROM exercises emphasizing combined hip flexion and knee extension should be started when the patient notes postoperative tightness and cramping.
C. The final goal for ROM is to have functional ROM, but not to match the contralateral side.
D. The final goal for ROM is to have an equal ROM of the operative and contralateral sides.

QUESTION 2. When is it safe to initiate gentle combined hip flexion and knee extension exercises?

A. 0 to 6 weeks
B. 6 to 10 weeks
C. 10 to 14 weeks
D. 14 to 24 weeks

QUESTION 3. When is it safe to begin gentle isotonic AAROM/AROM with avoidance of terminal knee extension?

A. 0 weeks
B. 2 weeks
C. 4 weeks
D. 6 weeks

Answer Key

QUESTION 1. Correct answer: **C** (see Clinical Pearl week 14–24)

QUESTION 2. Correct answer: **D** (see Phase V)

QUESTION 3. Correct answer: **C** (see Phase II)

BEYOND BASIC REHABILITATION: RETURN TO RUGBY AFTER REPAIR OF HAMSTRING AVULSION

James R. Ross, MD, Michael J. Keating, MS, ATC, CSCS, and Bruce S. Miller, MD

Introduction

ASPECTS OF RUGBY THAT REQUIRE SPECIAL ATTENTION IN REHABILITATION

- Improved agility and quickness to allow quick changes in direction, starting and stopping, and sprinting.
- Good joint mobility and muscle flexibility, especially with muscular balance between the quadriceps and hamstrings to be able to better handle explosives, isometric contractions during contact such as tackling, rucking, lineouts and scrimmaging (Figure 24-51).
- Optimal core and back strength to control the body's movements, especially in highly variable conditions such as scrums and lineouts.
- Ability to control the lower extremity during kicking

Literature

- Lefevre et al.[1] demonstrated return to sport at a mean of 5.7 months after surgical repair of proximal hamstring ruptures. Approximately 80% of patients were able to participate at the same level as before the injury. Although the level of activity according the UCLA scale was good (8.7), it was slightly lower than the preoperative score (9.1).
- Cohen and Bradley[2] similarly demonstrated return to sport at a mean of 6.6 months after surgical repair. Besides waterskiing, approximately 94% were able to return to the sport in which they injured their hamstrings.

Phase I: Advanced Strength and Conditioning Programs

A perioperative rehabilitation program is given in Box 24-3. Specific exercises are shown in Figures 24-52 to 24-57).

Periodization

- Linear
- Undulating
- Macrocycles
- Mesocycles
- Microcycles

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- After the initial phases of traditional rehabilitation have been completed and the athlete has restored basic mobility and strength, it is imperative the athlete is integrated back into physical training to bridge the gap from patient to athlete. This will encompass total body training including cardiovascular, strength, power and agility.

FIGURE 24-51. Good joint mobility and muscle flexibility, especially with muscular balance between the quadriceps and hamstrings, is necessary to better handle explosive movements and isometric contractions during contact such as tackling, rucking, lineouts, and scrimmaging.

BOX 24-3 Perioperative Rehabilitation: Preparation for Return to Sport

Preoperative Period

GOALS:

- Decrease pain
- Diminish effusion
- Maintain quad strength
- Patient education

GENERAL OUTLINE:

- Adequate patient education including explaining the surgical procedure, early postoperative care, and the anticipated rehabilitation program
- Crutches for weight-bearing as needed
- Avoidance of any strengthening and stretching exercises of the injured hamstring muscle to minimize muscular and tendinous retraction
- Isometric contractions of the quadriceps and gluteal muscles to minimize muscular atrophy
- Ankle pumps to minimize the risk of deep vein thrombosis

Week 1: "Protection Phase"

- Goal: maintain the hamstring muscle in a shortened and relaxed position, thus avoiding traction on the tendon repair. A brace is typically not needed with acute (< 2 weeks) repairs so long as the leg can be maintained in a neutral position.
- Avoid sitting and direct pressure on the affected ischial tuberosity, except when using an elevated toilet seat
- Toe-touch weight bearing is permitted with crutch-assistance
- Exercises: four times daily with 3 sets of 10 repetitions
  - Isometric quadriceps and gluteal muscle contractions
  - Ankle pumps
  - Supine heel slides up to 30° to 45° of knee flexion

Week 2: Initiation of formal physical therapy (1 to 2 supervised sessions per week)

- Full weight bearing (with crutches) is allowed when patient is able to perform a straight leg raise to 30° of hip flexion
  - Short strides, 10 times daily for 20 minute intervals
- Patient allowed single leg stance to perform minor knee flexion/extension exercises from 0° to 20° of knee flexion.
  - Four times daily, 3 sets of 10 repetitions
- "Safe" isometric hamstring contractions for 6 seconds
  - Supine with 30° of knee flexion
  - Two times daily, 3 sets of 10 repetitions
- Prone, passive knee flexion/extension exercises
  - Three times daily, 3 sets of 10 repetitions

Week 3

- Continue exercises from week 2
- Standing anti-gravity knee flexion curls with ankle in plantar flexion
  - Once daily, 3 sets of 3 repetitions
- Stationary slow walking on a thick pad
  - Twice daily, 3 sets, 30 seconds per set
- Calf strengthening in standing position with straight leg

Week 4

- Continue exercises from week 2 and 3
- If good posture and balance control, discontinue crutch use indoors, continue when outdoors
- Initiate pool therapy if wound is healed
  - Forward/backward and side-to-side walking
  - Two times weekly, 20 minutes per session
- Stationary bicycle with seat in high position when patient is able to perform 70° of hip flexion with the knee flexed 90°

Week 5: Hamstring strengthening initiated

- Discontinue exercises from weeks 1 to 3; continue with week 4 exercises
- Static or isometric leg curls in the seated position on the edge of chair
  - Press the heel of the operative leg against the toe of the non-operated leg (6 second holds)
  - Two times daily, 2 sets of 10 repetitions
- Standing single-leg catches with a cable or a Thera-Band
  - Three times weekly, 3 sets of 10 repetitions on each leg

BOX 24-3 Perioperative Rehabilitation: Preparation for Return to Sport *(Continued)*

- Single leg balance training
  - Start on floor and progress with eyes open and progress to eyes closed
  - Two times daily
- Core stability exercises
  - Supine pelvic thrusts or bridges (Figure 24-57), initially with the majority of body weight on the nonoperative limb. Progressively increase body weight onto the operative leg in a pain-free manner
  - Three times weekly, 3 sets of 10 repetitions

Week 6

- Gait should be normal; discontinue all crutch weight bearing
- Continue exercises from weeks 4 and 5
- Muscle flexibility training: supine, active knee extension exercises with the hip joint held at 90° of flexion with grasped hands under thigh
  - Two times daily, 3 sets of 10 repetitions
- Lunge walking: start with minimal stride length and gradually increase stride
  - Three times weekly, 3 sets of 10 strides
- Step ups on stair or stool
  - Two times daily, 3 sets of 10
- Gluteus medius strengthening—lateral resisted walking with Thera-Band
  - Two times daily, 20 yards, 4 times
- Single leg balance
  - Progress to mini-trampoline and other devices as able
  - Two times daily
- Leg curls in prone position with resistance: 6 seconds for contraction and 6 seconds for relaxation
  - Three times weekly, 3 sets of 10 repetitions

Week 7 and beyond: initiation of eccentric hamstrings training

- Ensure 2 days of rest per week for recovery
- 2 to 4 hamstring exercises at each training session
- Cautious forward and backward jogging with short strides, including acceleration and decelerations
- Stationary jogging with high knee lifts at increasing intensity over time
  - Four times weekly, 3 sets, 20 seconds per set
- Single-leg supine pelvic thrust
  - Progress by moving the heel away from the hip
  - Three times weekly, 3 sets of 8 repetitions
- Combine complex exercises such as lunges, squats, and jumping
- Dynamic leg curls in both the prone and sitting positions
  - Three times weekly, 3 sets of 10 to 15 repetitions

Return to Sport

- Aggressive, sport-specific activities allowing full unrestricted range of motion
- Outdoor training, slope training
- Can return to preinjury level when functional abilities such as jumping, running, and cutting can be performed without pain, stiffness or a feeling of insecurity
- Active hamstring flexibility test without any pain or feeling of insecurity
- 5 consecutive pain-free repetitions of maximal effort in both prone and supine positions
- May take up to 1 year to regain equal strength

Modified from Askling CM, Koulouris G, Saartok T, Werner S, Best TM: Total proximal hamstrings ruptures: clinical and MRI aspects including guidelines for postoperative rehabilitation. Knee Surg Sports Traumatol Arthrosc 21: 515–533, 2013.

- The rugby athlete requires both aerobic and anaerobic conditioning and both should be addressed during this phase—beginning with attaining an aerobic base.
- In regards to strength training, the athlete is now able to begin traditional strength training including all upper body, core and reintroducing lower extremity exercises such as squats and dead lifts. As muscular strength improves and normalizes compared to the uninvolved side, we look to convert this strength to power.

Olympic Lifts Used in the Training Program

- None at this phase, it typically can begin 16 weeks postoperatively

Training Principles Used in the Design of the Program

- Principle of progression
- Principle of overload
- Principle of variation

FIGURE 24-52. Lunge with medicine ball and truck rotation.

FIGURE 24-53. Single-leg Romanian dead lift on balance disk.

FIGURE 24-54. Russian hamstring curl with partner.

FIGURE 24-55. Single-leg hamstring curl with Swiss ball.

- Principle of individualization
- Principles of specificity—specific adaptation to imposed demands (SAID)

Application of Acute Training Variables

- The basic concept of this phase is to build strength and mass that has likely decreased during the injury and subsequent surgery and recovery.
- Moderate resistance combined with higher reps and sets are preferred. As a strength base is developed, the overload principle should be applied which uses heavier resistance in conjunction with fewer sets and reps. Here are some examples of specific exercises:
  - Back squat
  - Single leg lunge
  - Dead lifts

TIMELINE 24-6: **Beyond Basic Rehabilitation: Return to Rugby after Repair of Hamstring Avulsion**

Weeks 0 to 2	Weeks 3 to 4	Weeks 5
• Crutches with toe touch only • PT modalities • Soft tissue massage (STM) • Gentle PROM of knee/ankle • Isometrics of quads and glutes	• Crutches with progressive weight bearing—discharge at wk 4 indoors, but use outdoors • PT modalities • STM • Gait training • Pool therapy—walking forward, backward and lateral • Begin stationary bike at wk 4 with a high seat	• Crutches only as needed outdoors • PT modalities as needed • Progress hamstring flexibility • Single leg balance • Core strength progression • Hamstring isometrics

FIGURE 24-56. High bench step-up with medicine ball.

- RDL (Romanian dead lift)
- Eccentric hamstring curl
- Step-ups
- Split squats

Phase II: Performance Enhancement Training Techniques

Periodization

- Linear
- Undulating
- Macrocycles
- Mesocycles
- Microcycles

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- During the Return to Sport phase, we begin to transfer the strength that has been established into power and speed.

FIGURE 24-57. Double-leg bridge with Swiss ball.

- This will include review of proper running mechanics (sprint), deceleration and agility with change of direction.
- Addition of a plyometric program is critical during this phase.
- It is important that drills are selected that best represent the demands of the athlete based on the position they play. As an example, a back in rugby will require more agility and a forward will require more explosive power.

Olympic Lifts Used in the Training Program

- Snatch
- Clean and jerk
- Power clean

Training Principles Used in the Design of the Program

- Principle of progression
- Principle of overload
- Principle of variation
- Principle of individualization
- Principles of specificity—specific adaptation to imposed demands (SAID)

Application of Acute Training Variables

- This phase will focus on technique—especially with proper running mechanics. Proper forward lean, knee drive, foot position and arm mechanics are critical to maximize performance and avoid future injury.

TIMELINE 24-6: Beyond Basic Rehabilitation: Return to Rugby after Repair of Hamstring Avulsion (Continued)

Weeks 6 to 10	Weeks 11 to 16	Weeks 17+
• Crutches DC • Normal gait • PT modalities as needed • PROM and flexibility progressing • Closed kinetic chain exercises • Step-ups • Lunges • Single-leg balance • Core strengthening • Glut strengthening • Add dynamic warm-up	• ROM and flexibility without limits • STM as needed • Continue strengthening per above • Single-leg hamstring strengthening • Hamstring eccentric strengthening • Begin return to run progression • Double-leg jumping	• Full motion • Begin strength training program with team • Begin agility training with change of direction • Add deceleration drills • Single leg jumping/plyometric drills • Sport-specific training

- Over-striding and heel strike during sprint mechanics are common causes of recurrent hamstring injury.
- Additionally, as most hamstring injuries occur during the eccentric phase, it is important to select training drills that challenge the hamstring eccentrically. This will include change of direction drills and jump and land drills.
- Specific exercises used in the training
  - Running mechanic instruction—plus drills
  - Sprint progression
  - Sprint with deceleration
  - Agility ladder drills
  - Depth drops
  - Single-leg exploding Harvards

Phase III: Sport-Specific Training

Periodization

- Linear
- Undulating
- Macrocycles
- Mesocycles
- Microcycles

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- During this phase it is critical to identify the specific needs of the rugby athlete—specific to their position. For example, a back in rugby will need to have amazing agility and also kicking skills. A forward needs to have explosive and sustained power for scrimmaging and lineouts.
- Analyzing the needs and selecting sport specific exercises is vital for successful return to play.

Olympic Lifts Used in the Training Program

- Snatch
- Clean and jerk
- Power clean

Training Principles Used in the Design of the Program

- Principle of progression
- Principle of overload
- Principle of variation
- Principle of individualization
- Principles of specificity—specific adaptation to imposed demands (SAID)

Application of Acute Training Variables

- During this phase, replication of match play intervals is critical.
- Specific exercises used in the training
  - Kicking drills—conversion/penalty kicks and punting (backs)
  - Lineout and lifting drills (forwards)
  - Scrimmaging drills (forwards)
  - Tackling and rucking drills (all)
  - Passing drills (all)

Sports Performance Testing

General Information

- General history
- Subjective questionnaires
- Medical history
- Sports injury history
- Surgical history
- Chronic conditions/medication

Specific Objective Tests

- Physiological assessments—VO_2 max,
- Body composition tests—Body fat/lean mass assessment, height, weight
- Static/dynamic postural assessments—Functional movement screen, biomechanical movement analysis
- Dynamic muscle performance testing
- Movement performance testing—Functional movement screen
- Sport-specific testing
- Others
  - Yo-Yo Interval Recovery Test (YIRT)
  - Vertical jump
  - Standing broad jump
  - 5–10–5 proagility shuttle
  - 40 m sprint
  - 10 m sprint—with and without ball

Specific Criteria for Progression to the Next Stage to Determine Readiness for Rugby

- Athlete should be demonstrating increases in strength and power and meeting goals of each stage without disability.

Specific Criteria for Release to Unsupervised Complete Participation in Rugby

- Functional testing that demonstrates 90% or better as compared to the uninvolved extremity.
- Functional testing might include: single leg lateral hop in 20 to 30 seconds for max repetitions, single leg triple hop, single leg excursion tests

Recommended Ongoing Exercises

- The athlete should continue to incorporate both hamstring flexibility/mobility exercises along with a regular hamstring eccentric strengthening program.

Evidence

Birmingham P, Muller M, Wickiewicz T, et al: Functional outcome after repair of proximal hamstrings avulsions. *J Bone Joint Surg* 93:1819–1826, 2011.

This retrospective review of 30 patients who were noted to have a complete rupture of the proximal origin of the hamstrings underwent surgical repair and were evaluated. At a mean follow-up of 43.3 months, 91% of patients returned to activity at an average of 95% of their preinjury level. (Level IV evidence).

Chahal J, Bush-Joseph CA, Chow A, et al: Clinical and magnetic resonance imaging outcomes after surgical repair of complete proximal hamstrings ruptures: Does the tendon heal? *Am J Sports Med* 40:2325–2330, 2012.

This retrospective review of 15 consecutive patients that underwent surgical repair of complete proximal hamstrings tears were evaluated with postoperative MRI. The MRI was performed at a mean of 36 months after repair. 100% of the patients had healed the hamstrings repair, with signs of tendinopathy and mild atrophy in 25% of patients. (Level IV evidence).

Cohen SB, Rangavajjula A, Vyas D, et al: Functional results and outcomes after repair of proximal hamstrings avulsions. *Am J Sports Medicine* 40:2092–2098, 2012.

This retrospective review of 52 patients that underwent proximal hamstrings repair with a mean follow-up of 33 months demonstrated improved clinical outcomes (LEFS, Marx, and proximal hamstrings scores). Acute repairs, however, had higher functional and hamstrings scores, as well as estimated hamstring strength. (Level IV evidence).

Lefevre N, Bohu Y, Naouri JF, et al: Returning to sports after surgical repair of acute proximal hamstrings ruptures. *Knee Surg Sports Traumatol Arthrosc* 21:534–539, 2013.

This prospective observational study of 34 patients with a mean follow-up of 27.2 months demonstrated a return to sport at a mean of 5.7 months, with 79.4% of patients reaching the same level of activity. (Level IV evidence).

REFERENCES

1. Lefevre N, Bohu Y, Naouri JF, et al: Returning to sports after surgical repair of acute proximal hamstrings ruptures. *Knee Surg Sports Traumatol Arthrosc* 21:534–539, 2013.
2. Cohen SB, Rangavajjula A, Vyas D, et al: Functional results and outcomes after repair of proximal hamstrings avulsions. *Am J Sports Medicine* 40:2092–2098, 2012.

Multiple Choice Questions

QUESTION 1. The most common lower extremity injury in rugby players is:

A. Anterior cruciate ligament tear
B. Patellar tendon rupture
C. Proximal hamstring rupture
D. Achilles tendon rupture

QUESTION 2. The expected return to play after surgical repair of a proximal hamstrings tear is approximately:

A. 6 weeks
B. 3 months
C. 6 months
D. 9 months

Answer Key

QUESTION 1. Correct answer: **C** (see Introduction)

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