Rehabilitation of Acute Hamstring Strain Injuries

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KEYWORDS

• Muscle • Injury • Myotendinous • Physical therapy

KEY POINTS

- A previous hamstring strain injury is one of the most cited risks for future injury, with as many as one-third of athletes experiencing a reinjury within 2 weeks of returning to sport activity.
- A comprehensive patient evaluation assists in coming to an accurate diagnosis, providing a reasonable prognosis for time to return to sport, and helping define the rehabilitation options necessary for full recovery.
- Upon return to sport, athletes often exhibit a persistent strength deficit compared with the contralateral limb, highlighting the importance of comprehensive rehabilitation and adequate testing to determine readiness to return to sport for reducing risk of recurrent hamstring strains.

INTRODUCTION

Acute hamstring injuries are one of the most common injuries resulting in loss of time for athletes at all levels of competition.[1–8] Those involved in sports that require high sprinting speeds, such as track, football, and rugby, are especially prone to injury.[9,10] Previous literature has indicated that nearly 1 in 3 hamstring injuries will recur and that many of these would happen within the first 2 weeks on return to sport.[1,2] This high rate of recurrence may be due to a combination of ineffective rehabilitation and inadequate return to sport criteria.

Two specific injury mechanisms have been defined that seem to influence the injury location and rehabilitation requirement, high-speed running and excessive

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stretching. During high-speed running, the terminal swing phase has been identified as the time of hamstring injury occurrence, most often involving biceps femoris long head.[11,12] During this phase of the gait cycle, the hamstring muscles are active while lengthening (eccentric contraction) to absorb energy to slow the advancing limb in preparation for foot contact.[13–15] These injuries typically involve the intramuscular tendon, or aponeurosis, and the surrounding tissues.[16] The second defined injury mechanism involves an overstretch, which more commonly injures the proximal free tendon of the semimembranosus.[17,18] These injuries are common to dancing and kicking activities, in which a combined hip flexion with knee extension movement occurs. Current evidence indicates that athletes with injuries involving the proximal free tendon take longer to recover, such that return to sport may be prolonged.[18] Despite the differences in mechanism, structures involved, and healing rates, current rehabilitation approaches do not differ greatly when treating high-speed running versus overstretch injuries. This topic is an area for future research and investigation.

The goals of rehabilitation for hamstring injuries are to return the athlete to sport, return to prior level of performance, and return to participation with minimal risk for reinjury.[19] As such, deficits experienced as a direct result of the injury (eg, pain, swelling, weakness, reduced range of motion) must be addressed throughout the rehabilitation process. In addition to treating the muscle injury, underlying mechanical imbalances may be corrected to reduce the risk of recurrent injuries. Previous research has identified risk factors for initial hamstring injury. Of these, modifiable risk factors include hamstring weakness, fatigue, reduced flexibility,[20–23] imbalances in hamstring eccentric and quadriceps concentric strength,[24–26] decreased quadriceps flexibility,[27] and strength and coordination deficits of the pelvis and trunk musculature.[2,28] It can be speculated that addressing these issues after hamstring injury would also likely decrease reinjury risk.

PATIENT EVALUATION OVERVIEW

Determining the exact source of injury is critical in determining the most appropriate treatment and expediting safe return to play. Considering the potential causes of posterior thigh pain, the differential diagnosis for acute hamstring muscle strain injury includes hamstring tendon avulsion, ischial apophyseal avulsion, adductor muscle strain injury, proximal hamstring tendinopathy, and referred posterior thigh pain.

Differential diagnosis

- Complete or partial tendon avulsion
  - Mechanism: Forceful overpressure with combined knee extension and hip flexion, such as failed water ski starts, slipping into the splits, or getting tackled with overpressure[29,30]
  - Demographics: Middle- to old-aged adults, men more than women
  - Common subjective findings: Athlete may report hearing a loud pop and experience significant pain and immediate loss of function
  - Common objective findings: Extensive ecchymosis, palpable defect (after hematoma has resolved), positive result of bowstring test, inability or significant difficulty performing a prone leg curl, positive findings on magnetic resonance imaging (MRI) for tendon avulsion with or without retraction[31–33]
- Hamstring muscle/aponeurosis injury
  - Mechanism: Eccentric contraction injury, likely during terminal swing phase of high-speed running

- Demographics: Athletes involved in sprint and agility sports
- Common subjective findings: Possible audible pop; complaint of sudden onset of sharp, stabbing, or twingelike pain that is well defined; usually unable to continue inciting activity[34]
- Common objective findings: Difficulty walking or running, possible bruising, pain and substantial decrease in strength with resistive testing (more severe injuries are weak in shortened and lengthened ranges, whereas less severe ones are weak only in lengthened ranges), pain and limitation in movement with active and passive knee extension testing[19,35,36]

- Hamstring proximal free tendon injury
  - Mechanism: Lengthening overstretch injury involving excessive hip flexion combined with knee extension
  - Demographics: Athletes involved in kicking sports and dance
  - Common subjective findings: Possible audible pop, complaint of sudden onset of sharp, stabbing, or twingelike pain that is very proximal[37,38]
  - Common objective findings: Difficulty walking or running, possible bruising, pain and substantial decrease in strength with resistive testing, pain and limitation in movement with active and passive knee extension testing[18]
- Ischial tuberosity/apophyseal injury
  - Mechanism: Forceful low-velocity overstretch, often with combined hip flexion and knee extension, common in dance and kicking[39,40]
  - Demographics: Young athletes with open growth plates[39]
  - Common subjective findings: Possible audible pop, deep achy pain, discomfort with sitting[39]
  - Common objective findings: Pain and weakness with strength testing, pain and potentially increased motion on active and passive knee extension testing
- High hamstring tendinopathy
  - Mechanism: No specific incident, gradual onset of pain that can vary in intensity
  - Demographics: More common in middle-aged athletes and endurance athletes[41,42]
  - Common subjective findings: Feelings of tightness or cramping, pain that is very near or at the ischial tuberosity
  - Common objective findings: Pain with minimal, if any, weakness on resistive testing; pain with minimal, if any, limitation in flexibility;[43,44] positive result in neuromobility examination, such as slump test or lower limb tension test; positive results in bent knee stretch test and Puranen-Orava test[44]
- Adductor muscle strain injury
  - Mechanism: Quick acceleration or change of direction, typically with extreme hip abduction and external rotation[45]
  - Demographics: Athletes participating in sprint or agility sports, especially those with frontal plane movements, such as soccer and hockey
  - Common subjective findings: Sudden onset of pain in the medial thigh
  - Common objective findings: Tenderness to palpation of adductor tendons because they insert on the pubic ramus, pain with resisted hip adduction, positive findings on MRI for adductor muscle/tendon injury[46]
- Referred pain to the posterior thigh
  - Mechanism: No specific incident, gradual onset of pain that can vary in intensity
  - Demographics: Generally older athletes, may have preexisting spinal conditions

- Common subjective findings: Feelings of tightness or cramping[47,48]
- Common objective findings: Symptoms likely to be more position, posture, or movement specific (especially prolonged postures or movements); positive result of neuromobility examination, such as slump test

Prognosis

- The mechanism of injury can provide insight into the duration of recovery
  - Athletes with high-speed running injuries recover quicker, with return to prior level of competition in an average of 16 weeks, than those with overstretch injuries, which can take up to 50 weeks[16,18]
- Certain characteristics of the injury are important prognostic indicators and indicate longer time to recovery
  - More proximal injury, measured as point of maximal palpation pain in centimeters distal to the ischial tuberosity, especially if it involves the free tendon[18]
  - Larger lesion as visualized with MRI[49]
  - Greater reduction in active range of motion on examination correlates to longer time to return to sport[35]
  - Time to walk: More than 1 day before walking pain-free indicates greater than 3 weeks before return to sport, when compared with less than 3 weeks for those who were able to walk without pain less than 24 hours postinjury[36]

The management of acute hamstring strain injuries is described in the following sections. However, the authors thought it useful to include some general recommendations for care related to each of the sources considered during the differential diagnosis process. These recommendations are not intended to be exhaustive but rather to provide the reader with an initial direction for management.

- Complete tendon avulsion
  - Surgical considerations for open repair of the avulsed tendon, followed by lengthy rehabilitation[33]
- Ischial tuberosity/apophyseal injury
  - Surgical management for avulsion with more than 2 cm retraction[39]
  - Conservative therapy similar to progressive agility and core stabilization (PATS) program if minimal or no tendon retraction is present
- Adductor muscle injury
  - Conservative management consisting of rehabilitation and pain management[50]
- Referred pain to the posterior thigh
  - Treatment is variable and can be composed of surgical, nonsurgical, and pharmaceutical interventions that depend on the source of pain

PHARMACOLOGIC TREATMENT OPTIONS

Nonsteroidal anti-inflammatory medications (NSAIDs) may be used during the acute phase of recovery, although evidence indicates that they are of little benefit[51] and may have a negative effect on the muscle's ability to fully recovery.[52] As a result, their use has become controversial and other analgesics, such as acetaminophen, have been suggested instead. For athletes who experience prolonged pain, a corticosteroid injection[53] may be used to reduce the acute inflammation and reduce pain. Although these options are available, many athletes are able to modulate their pain with activity modification and ice alone.

NONPHARMACOLOGIC TREATMENT OPTIONS

The primary goals of rehabilitation are to return the athlete to sport at prior level of function with a minimal risk of recurrent injury. Without adequate rehabilitation athletes may still experience altered neuromuscular control, persistent weakness, or reduced extensibility of the musculotendon unit,[4,23,54–56] which is due, in part, to residual scar tissue and adaptive changes in the biomechanics and motor patterns of sport movements after injury and return to play.[1,4,57] In addition to addressing these potential deficits, a rehabilitation program should also correct modifiable factors that may have contributed to the original injury through the application of therapeutic exercises and manual techniques, such as joint mobilizations and soft tissue mobilization.

It has been proposed that many athletes will experience a change in the force-length relationship of their hamstrings after injury. After remodeling and repair, the hamstring muscle achieves peak force at shorter lengths, which may predispose the muscle to further injury when functioning at a lengthened position.[4,58,59] Eccentric exercise can shift the peak force production to longer muscle lengths.[60] This shift in force production may help to restore optimal musculotendon length for tension production to reduce risk of injury. In addition, previously injured hamstrings display altered firing patterns,[54] with decreased peak torque production[61] and decreased eccentric strength.[23]

Although strengthening the injured hamstring muscle is commonly the focus of rehabilitation programs, a few incorporate training to address adjacent tissues.[20,22] Neuromuscular control of the lumbopelvic region has been indicated as an important component for hamstring function during sporting activities[62] and should be an integral part to a comprehensive rehabilitation program. Sherry and Best[2] demonstrated a significant decrease in hamstring injury recurrence by using PATS exercises compared with stretching and strengthening at 2 weeks and 1 year after return to sport. Indeed, athletes who performed the PATS exercises were able to return to sport sooner and had a reinjury rate less than 10%.

Neuromobilization techniques have been recommended as part of the treatment program if a positive result of slump test is found on examination.[63] For those diagnosed with grade I injury with mild disruption of muscle fibers, slump stretching has been shown to reduce time away from sport,[64] although no information is available for more severe injuries.

With the above-mentioned considerations in mind, the rehabilitation guide discussed below is proposed for treatment of grade I and II hamstring strain injuries involving the intramuscular tendon.[2,19,49] The focus for phase I is minimization of pain and edema, restoration of normal neuromuscular control at slow speed, and prevention of excessive scar formation while protecting the healing fibers from excessive lengthening. Phase II allows for increased intensity of exercise, neuromuscular training at faster speed and larger amplitudes, and the initiation of eccentric resistance training. Phase III progresses to high-speed neuromuscular training and eccentric resistance training in a lengthened position in preparation for return to sport.

PHASE I (0–4 WEEKS)

Protection

- Direct stretching of the injured hamstring should be avoided
- Crutches may be used in moderate to severe injuries
- In mild to moderate injuries, athletes should shorten their stride length to ambulate pain free

Management of pain and swelling
- Modification of activity to avoid 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
- Cryotherapy
- Use of acetaminophen for pain relief as needed, avoiding NSAIDs

Therapeutic exercises
- Stationary biking for easy motion, working toward full knee extension
- Progressive agility and trunk stabilization
  - Low- to moderate-intensity side stepping
  - 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 (Fig. 1)
  - Low- to moderate-intensity steps forward and backward over a tape line while moving sideways
  - Single-leg stand, progressing from eyes open to eyes closed
  - Prone abdominal body bridge (performed by using abdominal and hip muscles to hold body in a face down straight plank position with the elbows and feet being the only points of contact)
  - 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)
  - 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 points of contact)

Criteria for progression to the next phase
- Normal walking stride without pain
- Very-low-speed jogging without pain
- Pain-free isometric contraction against submaximal (50%–70%) resistance during prone knee flexion (90°) manual muscle test

PHASE II (2–6 WEEKS)

Protection
- Avoiding end range lengthening of hamstring while hamstring weakness is present

Management of pain and swelling
- Ice as needed for postrehabilitation soreness

Manual therapy techniques[65]
- Utilizing manual therapy to normalize indirect joint mobility or flexibility limitations
  - Normalizing ankle dorsiflexion range of motion
  - Addressing spinal mobility limitations
  - Assessing sacroiliac joint restrictions affecting pelvic mobility
  - Using soft tissue techniques (manual or self directed) to limit excessive scar tissue formation
  - Continuing to avoid direct hamstring stretches to allow fiber repair

Fig. 1. Low- to moderate-intensity grapevine stepping (lateral stepping with repeated cycles of A. The trail leg going over the lead leg, B. lateral step with lead leg, and C. trail leg going under the lead leg).

Therapeutic exercises

- Progressive agility and trunk stabilization
  - Moderate- to high-intensity side stepping

- Moderate- to high-intensity grapevine stepping
- Moderate- to high-intensity steps forward and backward while moving sideways
- Single-leg stand windmill touches (performed by standing on 1 leg, then rotating the trunk and flexing the hips to bring the hand down in front of the lower leg)
- Supine bent knee bridge walk out (Fig. 2)

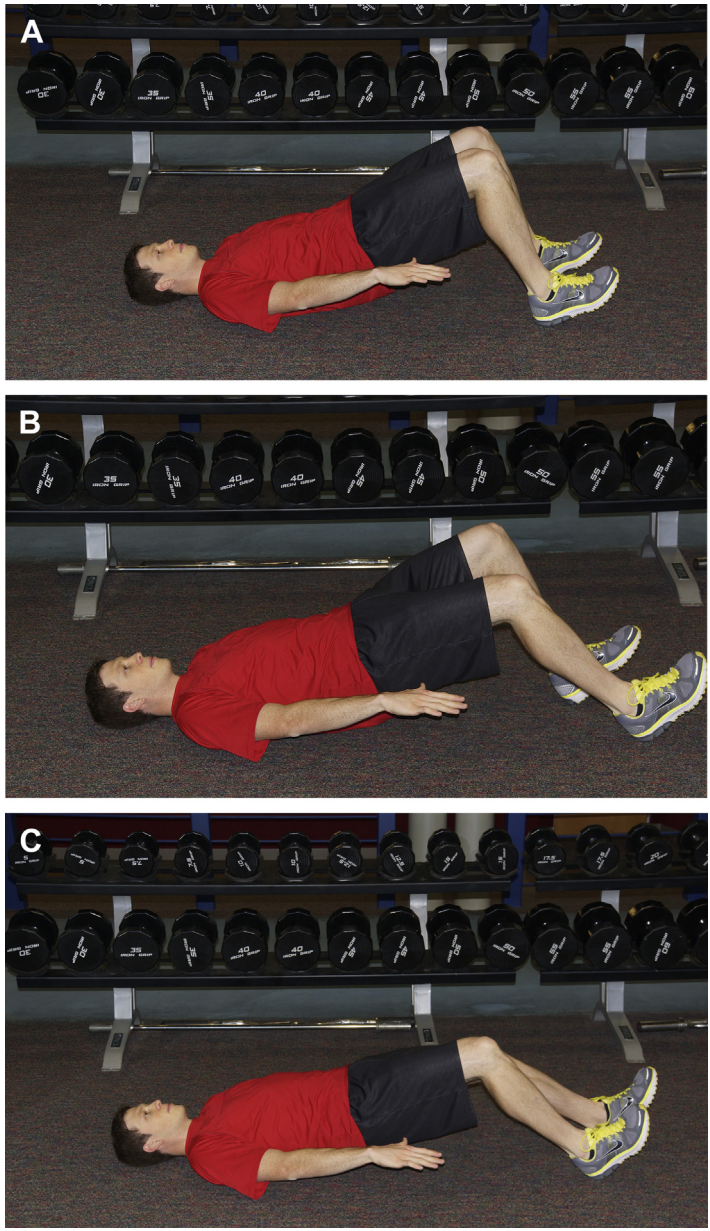

Fig. 2. Supine bent knee bridge walk out. Start in (*A*) supine bridge position and (*B* and *C*) perform a gradual movement of feet away from hips, while maintaining bridge position.

- Pushup stabilization with trunk rotation (performed by starting at the top of a full pushup, then maintaining this position with 1 hand while rotating the chest toward the side of the hand that is being lifted to point toward the ceiling, and then pausing and returning to the starting position)
- Side plank stabilization with trunk rotation (performed by starting in an extended arm side plank support with the top arm reaching up toward the ceiling, then while maintaining the hip height rotate through the trunk and neck to reach the top arm under and through, pause and then return to the start position) (Fig. 3)
- Fast feet in place (performed by jogging in place with increasing velocity, picking the foot only a few inches off the ground)
- High to low (Fig. 4) and low to high (Fig. 5) wood chops
- Neuromobilization[64] techniques if the patient displays adverse limb tension[63]
- Progressive balance training with balance board and unstable surface

- Eccentric resistance training
  - The Diver (Fig. 6) as described by Askling[66]
  - The Glider (Fig. 7)as described by Askling[66]

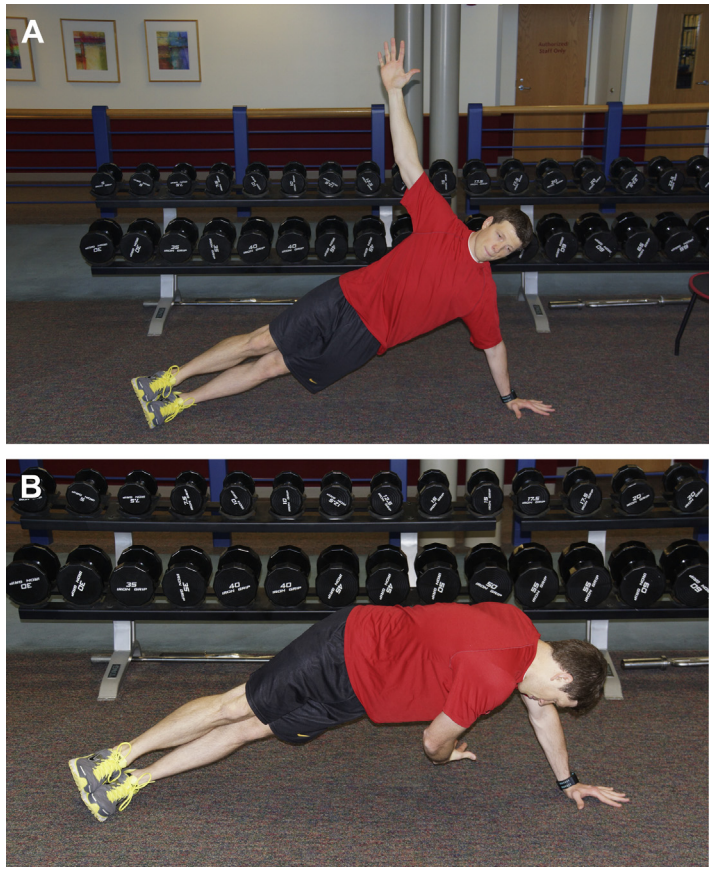

Fig. 3. Side plank stabilization with trunk rotation (performed by (*A*) starting in an extended arm side plank support with the top arm reaching up toward the ceiling, then (*B*) while maintaining the hip height rotate through the trunk and neck to reach the top arm under and through, pause and then return to the start position).

Fig. 4. High to low wood chops. Using resistance cable or elastic tubing, begin with (*A*) trunk extended and arms over one shoulder, then (*B*) rotate and flex trunk toward opposite side.

Criteria for progression to the next phase

- Full strength without pain during 1 repetition maximum isometric contraction in prone position with knee flexed to 30°
- Forward and backward jogging at 50% speed with no pain

PHASE III (4–8 WEEKS AND BEYOND)

Protection

- Avoiding full intensity if pain/tightness/stiffness is present

Fig. 5. Low to high wood chops. Using resistance cable or elastic tubing, begin with (*A*) trunk flexed and rotated to one side, then (*B*) rotate and extend trunk toward opposite shoulder.

Management of pain and swelling

- Use of ice as needed for postrehabilitation or practice soreness

Manual therapy techniques

- Continuing to address indirect limitations in mobility
- Manual, instrumented, or self-directed soft tissue mobilization may be more aggressively used if there is concern for excessive scar tissue formation
- No longer limited in range of motion, so stretching and flexibility for the musculotendinous unit should be initiated

Therapeutic exercises

- Progressive agility and trunk stabilization; sport-specific and agility drills should be emphasized, with a focus on quick direction changes and technique training
  - Dynamic agility drills
    - Side shuffle

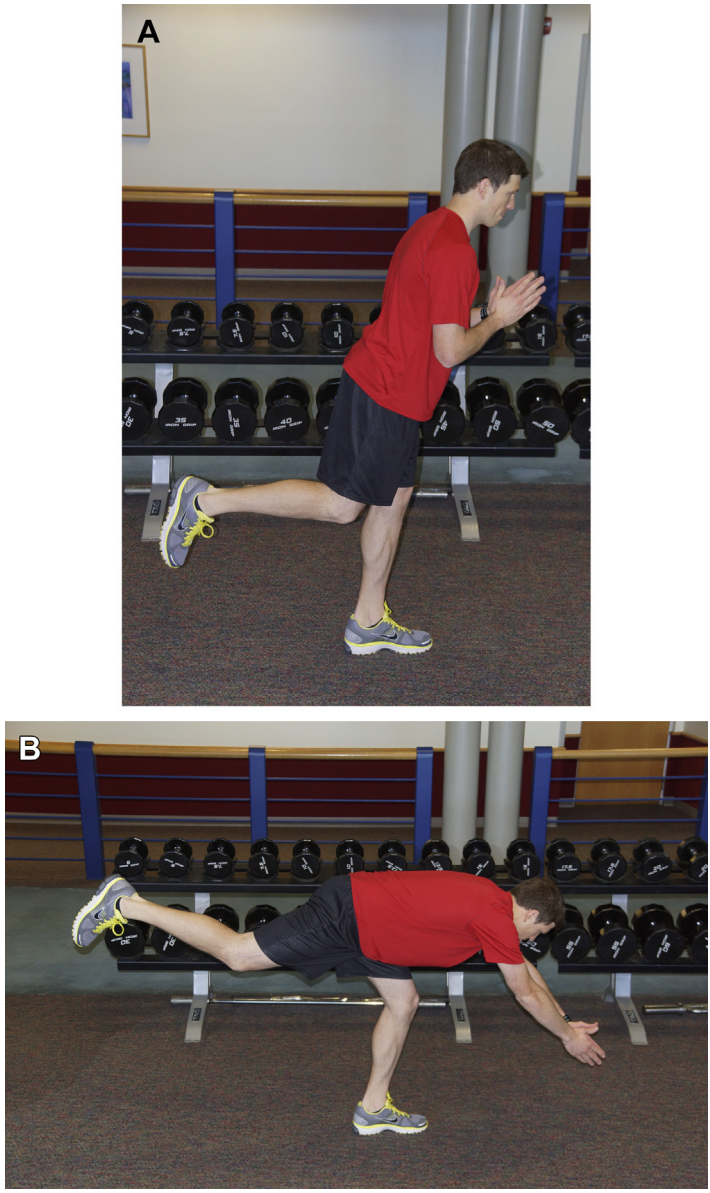

Fig. 6. The Diver. (*A*) Start by standing on the injured side, then (*B*) simultaneously flex the trunk and shoulders and extend the contralateral hip and knee, while maintaining a level pelvis.

- Carioca
- Boxer shuffles
- A skips
- B skips
- Forward and backward running
- Repetitive hop for distance

Fig. 7. The Glider. (*A*) Start with an upright trunk and majority of weight on injured leg on stable surface with one hand support, then (*B*) glide backward on opposite leg and stop before pain occurs. Return to start position using arms only.

- Eccentric hamstring training at end range of motion
  - Single-leg chair bridge (**Fig. 8**)
  - Single-limb windmill touches with dumbbells (**Fig. 9**)
  - Lunge walk with trunk rotation, opposite hand dumbbell toe touch (**Fig. 10**)
  - T-lift lunge walk (**Fig. 11**)
  - Single-leg dead lift
  - Single-leg dumbbell hang clean

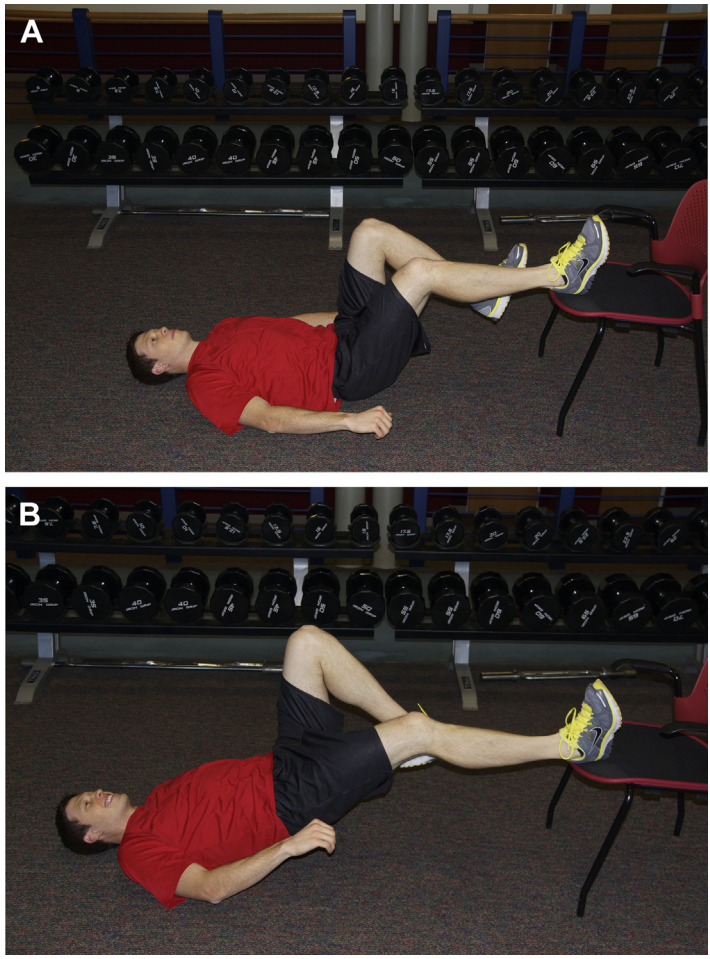

Fig. 8. Single-leg chair bridge. (*A*) Starting with 1 leg on stationary object, (*B*) raise hips and pelvis off ground.

- Modified Nordic curls using resistance cables to facilitate performance of exercise through a greater range of motion (**Fig. 12**)

Criteria for return to sport

- Pain-free palpation over the site of injury
- Full concentric and eccentric strength of the hamstrings (compared with the uninjured side) tested in a lengthened position; if using isokinetic strength testing, bilateral deficit should be less than 5%[67]
- Full concentric and eccentric muscular endurance of the hamstrings (when compared with the uninjured side), tested in a lengthened position; if using isokinetic strength testing, bilateral deficit should be less than 5%[67]
- Symmetric neuromotor properties (based on isokinetic testing)
  - Angle of peak torque within 5°[61]
  - Time to peak torque within 10% side to side[54]
- No fear or kinesiophobia, as measured by the hamstring active test, or Askling H-test[68]

Fig. 9. Single-limb windmill touches with dumbbells. Begin in (*A*) single-limb stance position with dumbbells overhead and (*B*) perform windmill motion under control with end position of (*C*) touching dumbbell near floor.

- High-speed running drills without experiencing pain or discomfort[66]

If patients are not making consistent improvements in strength or progression toward return to play by 12 to 14 weeks, they should be reevaluated by the physician. Adjuncts to rehabilitation may be considered at this time, such as platelet-rich plasma injection, dry needling, or cortisone injection.

SURGICAL TREATMENT OPTIONS

Surgical options for the treatment of an acute hamstring strain or tear are limited at this time. The nature of the injury and the technical difficulties of surgery prevent primary

Fig. 10. Lunge walk with trunk rotation, opposite hand dumbbell toe touch.

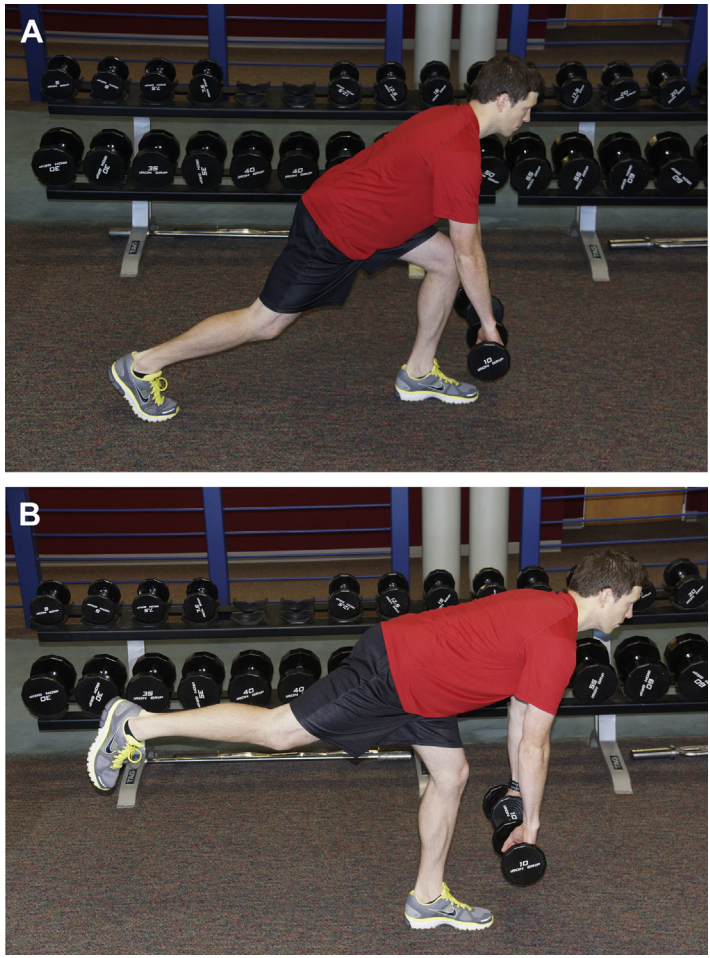

Fig. 11. T-lift lunge walk. Start in (*A*) forward lunge position, then (*B*) lift one leg off ground while maintaining a level pelvis.

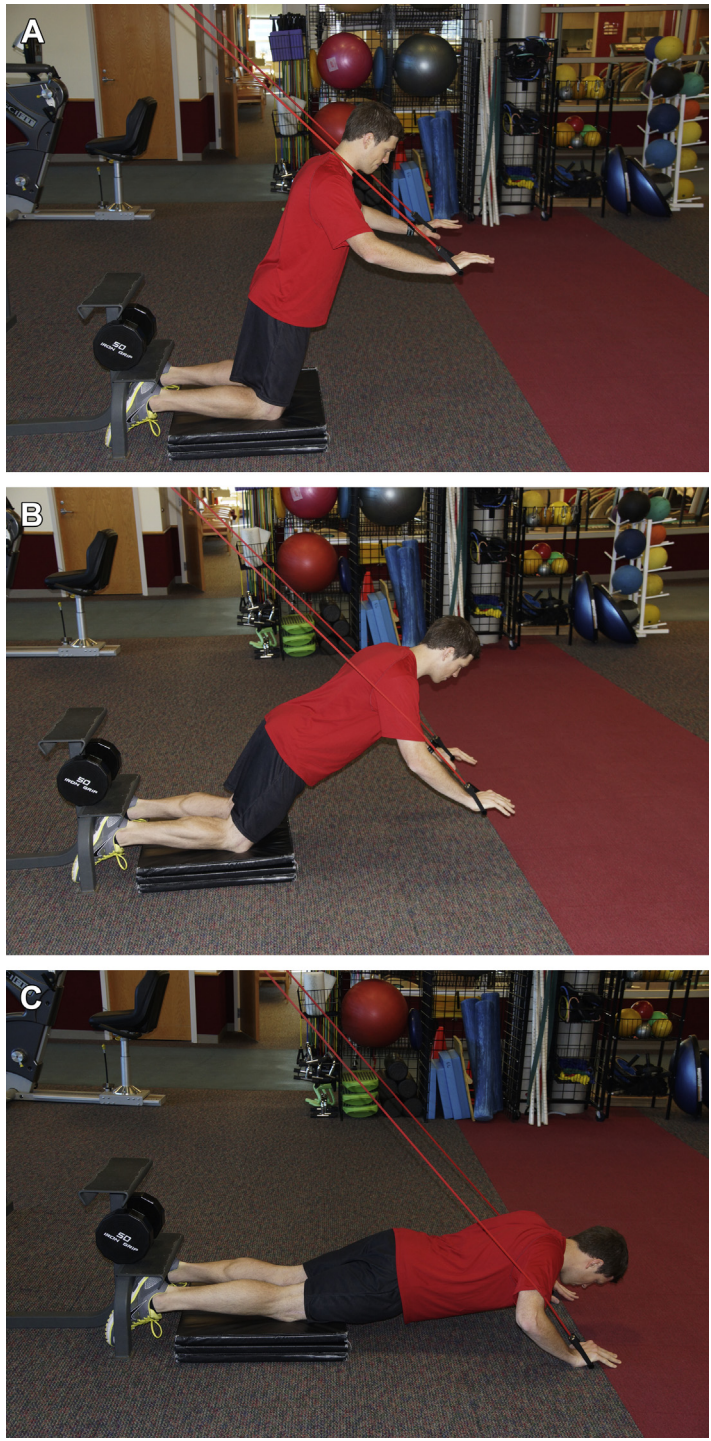

Fig. 12. Modified Nordic curls using resistance cables to facilitate performance of exercise through a greater range of motion. From (*A*) starting position, (*B*) lean trunk forward without flexing at the hips or low back until (*C*) maximum motion occurs. Return to starting position using push from floor and cables.

repair of the tissue from being a valid option. In some cases in which excessive scar tissue may be entrapping the sciatic nerve or creating intermuscular adhesions, surgical neurolysis or scar debridement may be an option.

TREATMENT RESISTANCE/COMPLICATIONS

One potential complication during the rehabilitation process is symptom exacerbation because of exercise intensity and range of motion. All exercises should be progressed based on the athlete's tolerance, and progression should be slowed if the athlete reports pain, increased stiffness, or anxiety with movement. A rehabilitation specialist's clinical decision making is paramount for safe progression of exercises without risking undue harm to the recovering athlete.

EVALUATION OF OUTCOME AND LONG-TERM RECOMMENDATIONS

Based on reinjury rates and the fact that abnormalities in MRI persist after being clinically asymptomatic, the authors recommend that athletes continue a program for performance enhancement and prevention of reinjury for the rest of the season and through the following off-season.[49] In addition, before starting their next season, the athletes should be screened for potential muscle imbalances, compensations, or weaknesses that would predispose them to other injuries.[2,61,69] Such off-season programs should include:

- Single-leg balance exercises and perturbation-type exercises
- Dynamic agility drills
- Eccentric hamstring strengthening, especially in lengthened positions
- Core and trunk stabilizing exercises

The Functional Assessment Scale for Acute Hamstring Injuries has been shown to be a reliable tool in documenting outcomes for acute hamstring injuries. The ability of this scale to determine readiness to return to play has not yet been validated.[70]

SUMMARY/DISCUSSION

Acute hamstring injuries continue to be one of the most common reasons for loss of playing time in athletes. By obtaining a complete subjective report with emphasis on injury mechanism and by performing a comprehensive physical evaluation, the rehabilitation specialist can determine the most accurate diagnosis and appropriate pathway for care. Adequate rehabilitation should address deficits in muscle strength, flexibility, neuromuscular control, and lumbopelvic stability, as these have been shown to allow the athlete to return to sport sooner and with less chance of reinjury.[2,49] Throughout the rehabilitation process, additional interventions should be used to address modifiable risk factors and should be continued through the off-season to decrease the risk for recurrent injury.

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