Diagnosis and Treatment of Hamstring Strains in Elite Athletes

The hamstring complex occupies the posterior compartment of the thigh and consists of three muscles: the semimembranosus, semitendinosus, and the biceps femoris (both short and long head). The semimembranosus, semitendinosus, and long head of the biceps femoris share a common origin site at the ischial tuberosity, while the short head of the biceps femoris originates at the linea aspera of the femur.[1] The semitendinosus and semimembranosus both insert on the medial tibial condyle, while both heads of the biceps femoris insert on the fibular head.[1] Given that the hamstring musculature acts to both flex the knee and extend the hip, crossing two joints, these muscles are highly susceptible to injury.[1] **(See Appendix A for a visual of hamstring musculature).**

Hamstring strains comprise a substantial portion of acute musculoskeletal injuries that occur in athletes, across numerous sports, and at every level of competition.[2] Sports that demand high-level sprinting or extremes of range of motion place athletes at increased risk of hamstring strain injury.[2] While hamstring strains are typically thought to be reserved for those participating in vigorous sprinting and decelerating activities (and are easily most common in these populations), another frequently overlooked population is dancers, due to the extreme ranges of motion these individuals are subject to.[2] In collegiate athletes, the sports most commonly implicated are: men's football, men's soccer, women's soccer, and track and field.[3] Although, it is important to be aware that hamstring strains can and do occur across nearly every sport imaginable, from cricket to bull riding.[3,4] The vast majority of hamstring strains seen in these collegiate athletes were the result of non-contact injuries, with both the rate and recurrence rate being higher in men.[3] Of particular clinical interest, the rate of hamstring strains that occurred during preseason competition was more than double the rate of hamstring strains suffered during the regular season.[3] This suggests poor athlete acclimatization to the necessary rigors of their sport, as well as activity ramp-up that is too steep.[3] Frequency of injury aside, one of the most debilitating aspects of hamstring strains is their high recurrence rate, with nearly one third of these injuries recurring within the first year of return to sport, with the subsequent injury often being more severe than the initial.[2] The risk for recurrence is highest during the first two weeks following a return to sport, suggesting a likely premature return to sport before full healing has occurred, and/or an inadequate rehabilitation program.[2] In addition to the injury itself being problematic, recurrent or untreated hamstring injuries may be causal of other pathologies, including, but not limited to: lumbar spine abnormalities, knee meniscal issues, abnormal quadriceps power, and enthesopathies.[4]

Biomechanically, the terminal swing phase of the gait cycle is thought to be to blame as the time during sprinting which hamstring strains typically occur.[2] During the second half of the swing phase, the hamstrings are active, stretched, and are absorbing energy from attempting to decelerate the limb in preparation for foot contact; these three factors work in conjunction to create the perfect environment to incur a strain injury.[2] The greatest stretch is placed on the biceps femoris, which likely contributes to its tendency to be the most frequently injured hamstring muscle of the three.[2] Hamstring strains such as these that occur during running are typically located along an intramuscular tendon or aponeurosis, and the adjacent muscle fibers.[2] This mechanism of injury (MOI) is proposed throughout the literature, often attributable to forceful eccentric contraction of the hamstrings while in a lengthened position.[5]

A very intriguing study utilized MRI to analyze muscle activity patterns within the hamstrings during activation, to attempt to explain this type of injury pattern caused by forceful eccentric contraction.[6] They found that those with a hamstring injury history demonstrated a much more synergistic pattern of muscle recruitment, as opposed to a more progressive pattern in the healthy controls.[6] The semitendinosus has the highest activation rate during the aforementioned problematic terminal swing phase of gait, meaning that the semitendinosus plays a prominent role in producing and controlling torque during the highest of loading conditions.[6] This led the authors to conclude that it is often through a compensatory mechanism that the biceps femoris becomes injured.[6] Specifically, any aberrant or inefficient recruitment of the semitendinosus muscle, places excessive stress on the biceps femoris as it attempts to shoulder the load (which it is less suited to do during this range of motion), resulting in higher instance of injury.[6] The authors note that this type of activation pattern can often occur as the result of fatigue, with the semitendinosus likely being more prone to earlier onset of fatigue.[6] Clinical implications surrounding these findings indicate that while the biceps femoris may be the injured muscle, it may not be solely to blame. Instead of the focus of rehabilitation centering around the biceps femoris, the semitendinosus deserves equal if not greater attention, due to its critical role in injury prevention and high-level performance.[6]

The other common method of hamstring injuries occurs during activities such as dancing or kicking, with movements that involve simultaneous hip flexion and knee extension, thus placing inordinate stretch on the hamstring musculature, across both the hip and knee joints.[2] These type of injures are more commonly found in the semimembranosus and its proximal tendon, as opposed to the intramuscular fibers.[2] These injuries tend to require a much longer recovery period before the athlete is able to return to preinjury competition levels, as opposed to the mid-substance injuries to the biceps femoris seen during sprinting.[2] This is most likely due to decreased blood-flow to the tendinous regions, as opposed to the much more vascular muscle tissue.

Aside from the increased likelihood of suffering a hamstring strain that goes along with participation in high-level sprinting or kicking sports, there are other anatomical, biomechanical, and demographic risk factors at play. These have been generally categorized into modifiable and non-modifiable risk factors. Modifiable risks include: shortened optimum muscle length, lack of muscle flexibility, muscle strength imbalance, insufficient warm-up, muscular fatigue, concomitant low back injury, and increased neural tension in the muscle.[4] Those factors determined to be non-modifiable are: muscle composition, age, race, and prior hamstring injury.[4] It is important to note that while many of these proposed risk factors are explicable by basic scientific principle, most are currently theory-based, with only a few demonstrating evidence-based clinical backing at this point in time.[4]

It has been shown that shortened optimum hamstring muscle length, the length at which the muscle is able to generate maximal force, is a risk factor for hamstring strains, and that those who generate peak hamstring torque in a larger angle of knee flexion may be more susceptible to strain.[4] It is through this same mechanism that poor flexibility is thought to be a risk factor for hamstring strains.[4] Studies have demonstrated that those with poor hamstring flexibility had a greater knee flexion angle for maximum knee flexion torque, indicating that an athlete with poor flexibility may have shorter optimum hamstring muscle length, and thus be more susceptible to injury.[4] However, this evidence has not been consistently borne out in clinical studies.[4] Regarding hamstring strength imbalance, two distinct strength ratios have been described: a bilateral hamstring strength asymmetry, and a hamstring-to-quadriceps imbalance within the same limb.[4] While some studies have generated support for a causal mechanism of either imbalance, other studies have refuted both, albeit with imperfect study designs.[4] At minimum, it is certainly in no one's best interest to have a hamstring muscle imbalance, as this will not be preventative in any way, and could possibly be a risk factor. The concept of tissue warm-up and the effect it has on the mechanical properties of said tissue (namely increasing the strength of tissue by increasing ultimate strain and stress at failure), is certainly a familiar one. For this reason, it makes sense conceptually that an inadequate physiological warm-up of the tissue prior to vigorous activity could have a detrimental effect and lead to higher rates of muscle strain injury. However, evidence is still lacking to prove this direct correlation.[4] The suggestion of fatigue as a modifiable risk factor was initially based on the clinical observation that many hamstring strains occurred during the latter portions of practice and competition.[4] The surmised underlying method is that fatigued muscles are capable of absorbing much less energy before failure.[4] Given the need to absorb the same amount of energy as non-fatigued muscle during the same intensity of competition, and a diminished physiological capacity to do so, the muscle would need to undergo more compensatory elongation than its non-fatigued counterpart, thus resulting in higher likelihood of failure.[4] While sometimes refuted, there are studies that reveal that negative responses in the hamstring musculature may occur in patients with already existing low back pain.[4] There may also be a link between lumbar posture, mainly increased lumbar lordosis, and instance of hamstring strain, as this anterior pelvic tilt places increased resting tension on the hamstrings.[4] It has been speculated that increased sciatic neural tension, such as revealed by a positive Slump test, may be associated with hamstring strains, however, it is still unclear if this increase in neural tension is in response to strain, or causative in nature.[4]

As far as non-modifiable risk factors go, scientific studies have found that Type II (fast twitch) muscle fibers were more susceptible to strain than Type I (slow twitch).[4] In addition to being more prone to injury, the resultant strains are often more severe in Type II fibers than in their Type I counterparts.[4] Although this has been scientifically explained, it has yet to be supported clinically.[4] It has been hypothesized that with increasing age, comes an increased risk of hamstring strain.[4] While this seems common sensical given the decreases in muscular ability that occur in conjunction with the aging process, it has yet to be demonstrated consistently in the literature.[4] The final two non-modifiable risk factors are the most universally agreed upon. Athletes of African or Caribbean descent tend to have a much higher instance of hamstring strains than those of English descent, suggesting that individuals of different races may have genetic differences in muscle fiber composition.[4] Lastly, and perhaps most significantly, are the contributions of previous hamstring injury to future injury.[4] Some studies have found prior injury to be the only significant predictor of future hamstring strain.[4] Given the high recurrence rate, it stands to reason that the scarring and fibrosis that occurs as a result of the healing response leaves the tissue in a weakened state, and makes it more susceptible to injury, especially in the short-term.[4]

While there is no standardized classification system for the severity of muscle strain injuries (hamstring or otherwise), broad categories of severity are widely recognized.[4] Grade I is defined as the most minor strain injury, and is described as minimal tearing of the musculotendinous unit with resultant minor loss in strength.[4] Characteristics of a grade II moderate strain injury involve a partial tearing of the musculotendinous unit with a significant loss in strength, and significant functional limitations.[4] Grade III is the most severe category of strain, as evidenced by a complete rupture of the musculotendinous unit with severe functional disability.[4] Thankfully, the vast majority of hamstring strains are classified as either grade I or grade II, with grade III strains occurring in only about 1% of all cases.[4] Grade III injuries may result in avulsion fractures of the ischium or ischial apophysis, or an avulsion of the hamstring tendons themselves.[4] Naturally, grade I strains result in the quickest return to full sport participation, while grade III strains require the most time away from competition, however, the average return times to full function after each grade of hamstring strain are variably reported by both sport and by study.[2,4] To give an example, in a study of European professional soccer players the average competition time lost by grade of injury was 17 +/- 10 days for grade I, 22 +/- 11 days for grade II, and 73 +/- 60 days for grade III.[4]

Most athletes who have suffered a hamstring strain will present with a sudden onset of posterior thigh pain that occurred during vigorous activity.[2] These individuals may or may not report hearing an audible pop (which itself does not define grade of severity), and are usually limited mainly by pain.[2] The presence of ecchymosis is possible, but not guaranteed, and local hematoma increases in likelihood with increasing severity of injury.[2] Patients with a grade I or grade II injury may initially experience negligible symptoms, or in fact be completely asymptomatic at rest or during the performance of ADL's, increasing the probability of a premature return to sport.[4] This can plunge the athlete into a recurrent cycle of reaggravation of the injury and unsuccessful attempts to return to sport.[4] This can cause a once minor acute strain to become chronic, leading to longer rehabilitation times, an increase in related comorbidities, and worse overall outcomes.[4] While the two main MOI's discussed previously will require differing recovery times, and may present in slightly different clinical fashions, general evaluative testing tends to be the same.[2] **(See Figure 1 and 2 in Appendix B for details on MOI and clinical presentation).**

Following a thorough subjective investigation, a battery of tests should be conducted. Range of motion about both the hip and knee joints should be analyzed, both passively and actively, with the extent of joint motion being determined by the onset of discomfort reported by the patient.[2] It is important to remember that especially for acutely injured athletes, pain and muscle guarding will often be the limiting factors, which may result in an inaccurate representation of actual muscle extensibilty.[2] Manual muscle testing (MMT) of the hamstrings and musculature around both the hip and knee joints (due to the nature of the hamstrings as two-joint muscles) should be assessed bilaterally for the sake of comparison, analyzing for both pain provocation and weakness.[2] Knee flexion MMT with the leg either internally or externally rotated can bias the medial or lateral hamstring respectively, and may assist in determining the site of the strain more specifically, with lateral rotation implicating the more oft-injured biceps femoris.[2] Palpation may also demonstrate clinical utility when it comes to identifying specifically painful areas, as well as searching for palpable defects in the musculotendinous unit itself.[2] Perhaps the most important use of palpation is the prognostic relationship that the location of maximal pain relative to the ischial tuberosity can have.[2] Specifically, the more proximal the site of maximal pain, the greater the time needed to return to pre-injury levels of competition.[2] It is believed that the closer this region is to the ischial tuberosity, the greater the extent of involvement the injury has with the proximal tendon (rather than the muscle belly), which will require a more lengthy recovery period.[2] Findings from the initial evaluation are less valuable in their ability to predict injury recurrence, with more severe initial injuries not necessarily having a greater risk of reinjury.[2] Prognostically, injuries that involve the muscle belly will often present as more severe upon evaluation (greater weakness, loss of range of motion, and tenderness to palpation), however, typically heal much faster than those involving the proximal tendon.[2]

Differential diagnosis is always of key importance for any pathology, and suspected hamstring strains are no different. Posterior thigh pain can be referred from a more proximal source, such as in cases of increased neural tension.[2] This potential explanation of pain is more likely in patients who present with what appears to be a milder grade I hamstring strain, especially when absent a specific and apparent MOI.[2] Another injury that can masquerade as a hamstring strain is a hip adductor strain.[2] Given the close proximity of the adductor muscles (particularly the gracilis and adductor magnus) to the hamstring muscles, pain sourcing from the adductors will often overlap with the medial and posterior portions of the thigh, and may be difficult for patients to distinguish from hamstring pain.[2] These types of injuries often have MOI's that involve quick acceleration or changes in direction, as well as resulting from extremes of hip abduction and external rotation, such as incurred when performing the splits.[2] Pain with this type of origin is often reproducible with resisted hip adduction, or palpation of the adductor tendons near their origin on the pubic ramus.[2] It should also be remembered that the adductor magnus has a second origin on the ischial tuberosity, shared with the hamstrings, which can further complicate its differentiation. While patients may in fact have an injury to their hamstring muscles, MOI matters. Contusions, like those that result from a direct impact sustained in a sport such as football, may have a similar clinical presentation (pain, bruising, activity limitation), but they are not classified as strains, and will require a different course of treatment.[4] **(See Figure 3 in Appendix C for signs/symptoms of hamstring strain vs referred pain).**

Imaging for clinical evaluation is often reserved for more severe cases, when a rupture is suspected, to determine the need for surgical intervention.[2] Typically, either ultrasound or MRI are the chosen methods, with MRI being considered superior at detecting deeper or residual injuries.[2] MRI has proven efficacious at confirming the severity of injury, thus serving as a tool to help predict the length of rehabilitation.[2] Both the length and total cross-sectional area (CSA) of injured tissue discovered via MRI are directly proportional to the required time away from sport before full recovery.[2] However, MRI has demonstrated limited clinical utility for predicting reinjury.[2]

The main goals of any rehabilitation protocol for a strained hamstring are to address any resultant deficits directly, as well as accounting for any predisposing risk factors that may have contributed to the injury, to not only return the athlete to prior level of competition, but also mitigate the risk of recurrence. In conjunction with increased risk factors, it has been suggested that the high rate of recurrence is likely due to a combination of persistent weakness, reduced extensibility of the injured tissue due to infiltration of scar tissue, and altered biomechanics and motor patterns of athletic movements.[2] Eccentric strength training has shown the ability to shift peak force development to longer musculotendon lengths, and thus may effectively restore injured tissue to optimum length, thereby reducing risk of reinjury.[2] This may in fact prove to be a better method for restoring lost range of motion than traditional flexibility exercises. While commonly included in many rehabilitation protocols, the effectiveness of typical static stretching for injured hamstring tissue remains unclear at best, and should be approached cautiously.[2] The hamstring musculature should not be addressed in a vacuum. Neuromuscular exercises that enhance control of the lumbopelvic region, as well as trunk stabilization and agility exercises, have shown the ability to reduce injury recurrence to a greater degree than simply a progressive stretching and strengthening program in those with acute hamstring strain.[2] It is hypothesized that improved lumbopelvic coordination allows for optimum biomechanics during high-demand athletic movements.[2] While there is support for a brief period of immobilization to allow for soft tissue approximation and healing, early mobilization increases blood flow to the injured area, and also promotes proper orientation of the collagenous fibers, leading to better tissue remodeling and a more functional muscle unit.[2]

A recent review of the literature assessed the usefulness of a multitude of physical therapy modalities in the hamstring strain population.[7] Cryotherapy is one of the most popular modalities for pain and swelling relief, and has been shown effective during the acute stage of muscular injuries.[7] Therapeutic ultrasound has yielded conflicting results, although this could be more attributable to lack of specific parameters and protocol, rather than the modality itself.[7] Low level laser therapy (LLLT) has shown excellent promise in the area of enhancing tissue healing and muscle repair post injury.[7] This has been attributed to the enhanced production of ATP, the migration of satellite cells, and promotion of angiogenesis, improving muscle regeneration and preventing fibrosis.[7] Manual therapy involving soft tissue mobilization and joint mobilizations of the pelvis has shown to have an analgesic effect and result in functional improvements following hamstring injury.[7] These treatment modalities can safely be used in order to improve the patient's ability to perform progressive therapeutic exercises to restore strength, range of motion, and return to functional activities.[7]

Time to return to sport and full recovery varies based on severity of injury and numerous individual factors, but a general protocol for grade I and grade II injuries can be confidently laid forth. Importantly, most protocols that exist in the literature are designed for injuries to the muscular tissue incurred during running, and not necessarily the proximal tendon. Little evidence currently exists regarding proper protocol for these injuries.[2] Broadly, protocols can be divided into three phases. Phase I focuses on minimizing pain and edema and protecting the injured tissue.[2] During this time, low-intensity exercises involving the lower extremity and lumbopelvic region should be performed within a pain-free range of motion.[2] This is the optimal time to incorporate the use of ice and NSAIDs, to reduce swelling, inflammation, and pain.[2] The use of crutches (and/or a supportive sling) may be recommended during this initial phase, depending on severity of injury.[2]

Phase II consists of the progression of range of motion and intensity of exercises per patient tolerance.[2] Eccentric hamstring activation is also initiated during this phase.[2] The hope is to achieve full range of motion by the completion of this phase, as well as promoting the ability to perform sub-maximal exercises within this full range, pain free.[2] Functional and sport-specific movements are also initiated, rather than the more isolated exercises found in phase I.[2]

Once progressed to phase III, the athlete may begin performing more aggressive and sport-specific exercises in preparation for a return to sport.[2] Increased intensity of eccentric hamstring strengthening, dynamic change of direction and agility drills, and challenging trunk stabilization should be the focus of this phase.[2] Sprinting and explosive acceleration are the final hurdles to clear, and should not be attempted until the very end of phase III, once the athlete has satisfied return-to sport criteria.[2] There is limited consensus on consistent return-to sport criteria, however, current recommendations are that the athlete: has achieved full range of motion, is able to perform four consecutive pain-free maximal effort hamstring contractions with a bilateral strength deficit of 5% or less, and is able to perform all sport-specific actions necessary (ex. jumping, running, cutting) with speed and intensity near maximum.[2] **(For a more detailed phase-by-phase summary, and return to sport criteria, please see Figure 4 in Appendix D).**

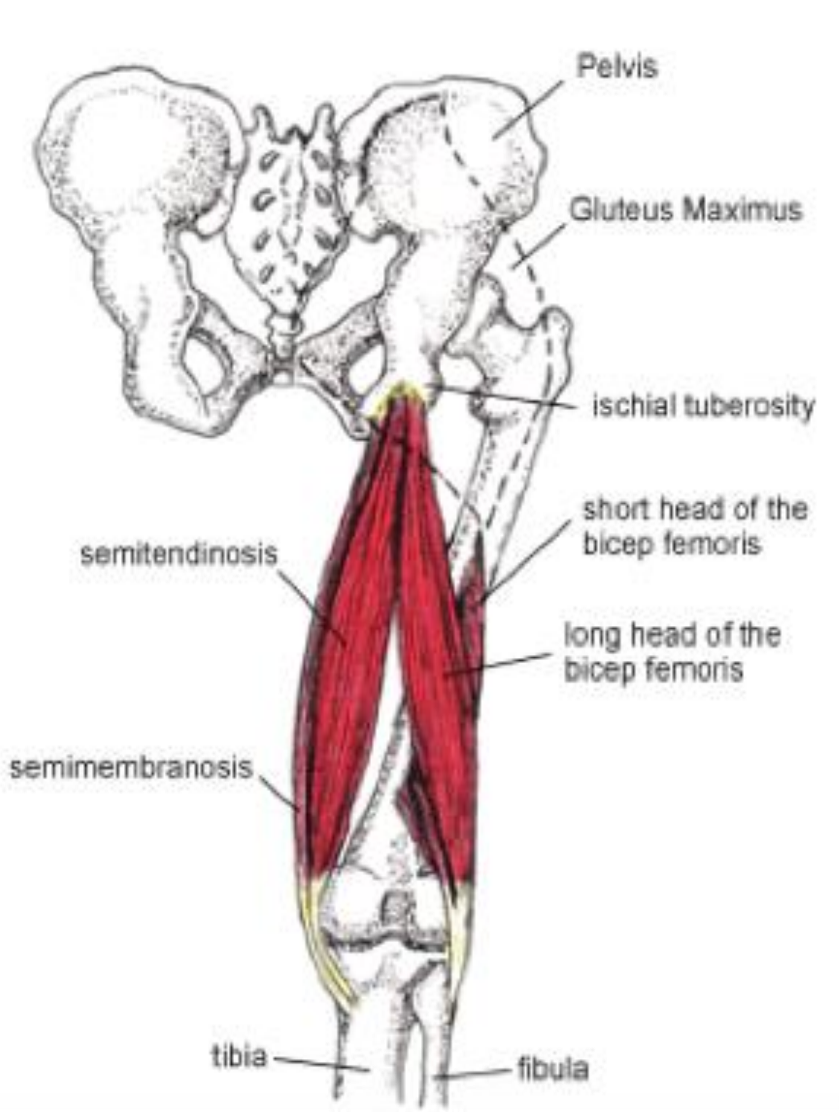
For those with a grade III injury who are looking to return to athletic performance, surgery will be necessary. Avulsions, tendinous ruptures, and muscle belly ruptures will require surgical intervention, with the best results occurring when intervention happens within four weeks of the initial injury.[8] While specifics regarding surgical technique are beyond the scope of this paper, they are thoroughly laid out in this cited article.[8] General postoperative rehabilitation will involve six weeks of toe-touch weight bearing and crutches while braced in full extension, with at least four months of physical therapy recommended.[8] Variations will be noted between surgeon-specific protocols. Return to sport times following these types of repair typically are between five and six months.[9]

Unfortunately, there is a scarcity of research surrounding preventative measures for hamstring strains. Unsurprisingly, most prevention techniques that are advocated have significant overlap with common treatment interventions. In general, addressing the aforementioned modifiable risk factors is as good a place to start as any. Despite inadequate hamstring and quadriceps flexibility being frequently implicated in the occurrence of strains, prophylactic stretching programs have shown little to no benefit in the prevention of these injuries, perhaps due to insufficient duration and frequencies, as well as low-quality studies.[2] However, the incorporation of eccentric hamstring strengthening exercises, both preseason and in-season, has demonstrated substantial reductions in the frequency of hamstring strain injuries.[2] Exercises such as Nordic hamstring curls, single leg eccentric RDL's, and lengthened state eccentric training using Thera-Band or cable column resistance may be an appropriate starting point for athletes.[10] Clinicians and coaches alike should be aware of the potential for higher magnitude delayed onset muscle soreness following eccentric training, and should utilize gradual ramp-up accordingly.[2] The same neuromuscular control exercises that are imperative in rehabilitation protocols, may also be of use for prevention.[2] Exercises targeting lumbopelvic and trunk control have demonstrated direct improvements in muscular control and discrimination of movement, which may transfer to injury prevention.[2] Lastly, adequate warmup should always be performed prior to competition, and may aid in muscle strain prevention.[11]

In summation, hamstring strains are extremely common across athletic populations, most frequently due to sprinting. Thankfully, the vast majority are initially relatively minor in nature. Rates of return to sport are near 100%, with time missed rather variable. The most important aspect of rehabilitation is to ensure the athlete is fully healed before attempting to return, to avoid a recurrent injury, as these are often more severe and result in greater time lost. Injuries to the muscle and surrounding fibers are more common, and will heal faster than injuries to the proximal hamstring tendons. General protocols should focus on decreasing pain, restoring range of motion and strength, addressing modifiable risk factors, and promoting a gradual return to sport. Perhaps the most important intervention, for both rehabilitation and prevention, is eccentric strengthening of the hamstrings in a lengthened position.

Appendix A – Hamstring Anatomy

Figure 1: Posterior view of the pelvis and leg, showing the origin, insertion, and course of the three hamstring muscles. Image reprinted from Physiopedia.[12]



Appendix B – Clinical Presentations by Injury MOI

Figure 1: Differentiation of hamstring strain injuries based on MOI. Image reprinted from Heiderscheit et al, 2010.[2]

TABLE 1 CATEGORIES OF HAMSTRING STRAIN INJURIES BASED ON INJURY MECHANISM, WITH ASSOCIATED FINDINGS FROM MAGNETIC RESONANCE IMAGING[7,8]

	Injury Mechanism	
	Running at Maximal or Near-Maximal Speed	Movement Involving Extreme Hip Flexion and Knee Extension
Activity	Sports involving high-speed running	Dancing or kicking
Involved muscle(s)	Primary: biceps femoris, long head Secondary: semitendinosus	Semimembranosus, proximal tendon
Location	Aponeurosis and adjacent muscle fibers, proximal greater than distal	Proximal tendon and/or musculotendon junction
Distance from ischial tuberosity (cm)*	6.7 ± 7.1 (range, −2.1 to 21.8)	−2.3 ± 0.8 (range, −3.4 to 1.1)
Length of injury (cm)†	18.7 ± 7.4 (range, 6.0 to 34.6)	9.8 ± 5.0 (range, 2.7 to 17.2)

**Distance between most caudal aspect of ischial tuberosity to most cranial aspect of injury. A negative value indicates the injury is cranial to the most distal aspect of the ischial tuberosity.*
† Measured in cranial-caudal direction.

Figure 2: Acute presentation of hamstring strain, clinical findings, and median time to return to preinjury level. Image reprinted from Heiderscheit et al, 2010.[2]

TABLE 2 TYPICAL ACUTE PRESENTATION AND OUTCOMES OF HAMSTRING STRAIN INJURIES BASED ON INJURY MECHANISM[7,8]

	Injury Mechanism	
	Running at Maximal or Near-Maximal Speed	Movement Involving Extreme Hip Flexion and Knee Extension
Ecchymosis	Minimal	None
Straight leg raise deficit*	40	20
Knee flexion strength deficit*	60	20
Level of pain	Moderate	Minor
Site of maximum pain (cm)†	12 ± 6 (range, 5-24)	2 ± 1 (range, 1-3)
Length of painful area (cm)‡	11 ± 5 (range, 5-24)	5 ± 2 (range, 2-9)
Median time to preinjury level (wk)§	16 (range, 6-50)	50 (range, 30-76)

** Percent deficit of injured limb compared to noninjured limb.*
† Distance from point of maximum palpatory pain to the ischial tuberosity.
‡ Measured in cranial-caudal direction.
§ Time needed for performance to return to preinjury level.

Appendix C – Signs, Symptoms, Differential Diagnosis

Figure 3: Signs and symptoms of a classic hamstring strain injury, compared to hamstring pain being referred from another source. Image reprinted from Heiderscheit et al, 2010.[2]

TABLE 3 COMMON SIGNS AND SYMPTOMS OF A HAMSTRING STRAIN INJURY COMPARED TO THOSE REFERRED TO THE POSTERIOR THIGH FROM ANOTHER SOURCE*

Symptom/Sign	Hamstring Strain Injury	Referred to Posterior Thigh
Onset	Sudden	Sudden or gradual
Pain	Minimal to severe	Minimal to moderate; may describe feeling of tightness or cramping
Function	Difficulty walking or running	Able to walk or run with minimal change in symptoms during the activity; may even reduce symptoms during the activity but increase after
Local hematoma, bruising	Likely with more severe injuries	None
Palpation	Substantial local tenderness possible; defect at site of injury	Minimal to none
Decrease in strength	Substantial	Minimal to none
Decrease in flexibility	Substantial	Minimal
Slump test	Negative	Frequently positive
Gluteal trigger points	Palpation does not influence hamstring symptoms	Palpation may reproduce hamstring symptoms
Lumbar/sacroiliac exam	Occasionally abnormal	Frequently abnormal
Local ultrasound or magnetic resonance image	Abnormal, except for very mild strains	Normal

* *Modified from Brukner and Khan.*[28]

Appendix D – Sample Rehabilitation Protocol

Figure 4: Phase-by-phase sample rehabilitation protocol and return to sport criteria. Image reprinted from Heiderscheit et al, 2010.[2]

Proposed guide for the rehabilitation of acute hamstring strain injuries. Suggested exercises, including sets and repetitions, should be individualized to the patient. Progression through the 3-phase program is estimated to require approximately 2 to 6 weeks but should be progressed on a patient-specific basis using criteria as indicated.

Phase 1

Goals
1. Protect scar development
2. Minimize atrophy

Protection

Avoid excessive active or passive lengthening of the hamstrings

Ice

2-3 times/d

Therapeutic exercise (performed daily)
1. Stationary bike × 10 min
2. Side-step × 10 m, 3 × 1 min, low to moderate intensity, pain-free speed and stride
3. Grapevine × 10 m, 3 × 1 min, low to moderate intensity, pain-free speed and stride (**ONLINE VIDEO**)
4. Fast feet stepping in place, 2 × 1 min
5. Prone body bridge, 5 × 10 s
6. Side body bridge, 5 × 10 s
7. Supine bent knee bridge, 10 × 5 s
8. Single-limb balance progressing from eyes open to closed, 4 × 20 s

Criteria for progression to next phase
1. Normal walking stride without pain
2. Very low-speed jog without pain
3. Pain-free isometric contraction against submaximal (50%-70%) resistance during prone knee flexion (90°) manual strength test

Phase 2

Goals
1. Regain pain-free hamstring strength, beginning in mid-range and progressing to a longer hamstring length
2. Develop neuromuscular control of trunk and pelvis with progressive increase in movement speed

Protection

Avoid end-range lengthening of hamstrings while hamstring weakness is present

Ice

Postexercise, 10-15 min

Therapeutic exercise (performed 5-7 d/wk)
1. Stationary bike × 10 min
2. Side-shuffle × 10 m, 3 × 1 min, moderate to high intensity, pain-free speed and stride
3. Grapevine jog × 10 m, 3 × 1 min, moderate to high intensity, pain-free speed and stride
4. Boxer shuffle × 10 m, 2 × 1 min, low to moderate intensity, pain-free speed and stride (**ONLINE VIDEO**)
5. Rotating body bridge, 5-s hold each side, 2 × 10 reps (**ONLINE VIDEO**)
6. Supine bent knee bridge with walk-outs, 3 × 10 reps (**FIGURE 3**)
7. Single-limb balance windmill touches without weight, 4 × 8 reps per arm each limb (**ONLINE VIDEO**)
8. Lunge walk with trunk rotation, opposite hand-toe touch and T-lift, 2 × 10 steps per limb (**ONLINE VIDEO**)
9. Single-limb balance with forward trunk lean and opposite hip extension, 5 × 10 s per limb (**ONLINE VIDEO**)

Criteria for progression to next phase
1. Full strength (5/5) without pain during prone knee flexion (90°) manual strength test
2. Pain-free forward and backward jog, moderate intensity

Phase 3

Goals
1. Symptom-free (eg, pain and tightness) during all activities
2. Normal concentric and eccentric hamstring strength through full range of motion and speeds
3. Improve neuromuscular control of trunk and pelvis
4. Integrate postural control into sport-specific movements

Protection

Avoid full intensity if pain/tightness/stiffness is present

Ice

Postexercise, 10-15 min, as needed

Therapeutic exercise (performed 4-5 d/wk)
1. Stationary bike × 10 min
2. Side-shuffle × 30 m, 3 × 1 min, moderate to high intensity, pain-free speed and stride
3. Grapevine jog × 30 m, 3 × 1 min, moderate to high intensity, pain-free speed and stride
4. Boxer shuffle × 10 m, 2 × 1 min, moderate to high intensity, pain-free speed and stride
5. A and B skips, starting at low knee height and progressively increasing, pain-free
   a. A skip is a hop-step forward movement that alternates from leg to leg and couples with arm opposition (similar to running). During the hop, the opposite knee is lifted in a flexed position and then the knee and hip extend together to make the next step (**ONLINE VIDEO**)
   b. B skip is a progression of the A skip; however, the opposite knee extends prior to the hip extending recreating the terminal swing phase of running. The leg is then pulled backward in a pawing type action. The other components remain the same as the A skip (**ONLINE VIDEO**)
6. Forward-backward accelerations, 3 × 1 min; start at 5 m, progress to 10 m, then 20 m (**ONLINE VIDEO**)
7. Rotating body bridge with dumbbells, 5-s hold each side, 2 × 10 reps
8. Supine single-limb chair-bridge, 3 × 15 reps, slow to fast speed (**FIGURE 4**)
9. Single-limb balance windmill touches with dumbbells, 4 × 8 reps per arm each leg (**FIGURE 5**)
10. Lunge walk with trunk rotation, opposite hand dumbbell toe touch and T-lift, 2 × 10 steps per limb
11. Sport-specific drills that incorporate postural control and progressive speed

Criteria for return to sport
1. Full strength without pain
   a. 4 consecutive repetitions of maximum effort manual strength test in each prone knee flexion position (90° and 15°)
   b. Less than 5% bilateral deficit in eccentric hamstrings (30°/s): concentric quadriceps (240°/s) ratio during isokinetic testing
   c. Bilateral symmetry in knee flexion angle of peak isokinetic concentric knee flexion torque at 60°/s
2. Full range of motion without pain
3. Replication of sport specific movements near maximal speed without pain (eg, incremental sprint test for running athletes)

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