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Factors Associated with Hamstring Injuries
An Approach to Treatment and Preventative Measures

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Summary

Following hamstring strain, rehabilitation is often prolonged and frustrating for the athlete and for the sports medicine clinician. Though the initial treatment of rest, ice, compression and elevation is accepted for muscle strains, no consensus exits for rehabilitation of hamstring muscle strains. This lack of agreement concerning rehabilitation of hamstring injury represents our lack of understanding of the mechanism of injury and the factors that contribute to hamstring strain. A hamstring rehabilitation model is proposed that is based on our current understanding of the aetiological factors that contribute to hamstring muscle strain. The influence and interaction of hamstring strength, flexibility, warm-up and fatigue are aetiological factors that should be addressed in the rehabilitation and prevention of hamstring strains. The rehabilitation model is, however, not without limitations and speculations. Further research is needed to clarify the etiological factors of hamstring strain and the efficacy of different rehabilitation protocols.

Hamstring strain in athletes participating in running and sprinting activities is a significant and complex injury (Brubaker & James 1974; Garrett et al. 1984; Worrell et al. 1991). Hamstring injuries often recur and can become chronic (Garrett et al. 1989; Worrell et al. 1991). During the rehabilitation process, both the athletes and sport medicine clinicians can become frustrated with the rate of recovery because of the slow progress and lingering symptoms that often persist (Burkett 1970; Garrett et al. 1989; Worrell et al. 1991).

The following aetiological factors of hamstring muscle strain have been identified: (i) hamstring strength imbalances (Burkett 1970; Christensen & Wiseman 1972; Heiser et al. 1984); (ii) lack of hamstring flexibility (Liemohn 1978; Worrell et al. 1991); (iii) muscle fatigue (Dorman 1971); and (iv) insufficient warm-up (Dorman 1971; Ekstrand et to resolve, which may be 7 to 14 days after injury in more serious injuries.

Ice application is critical to limit pain and inflammation after hamstring exercises, functional progression and practice activities. Limiting ice treatments to the first 24 to 36 hours is probably incorrect, in my opinion, because as long as the athlete is experiencing pain and limitation of function the inflammatory process is active. The use of an elastic bandage to compress the ice bag against the posterior thigh will help control oedema.

During the acute phase of rehabilitation, the athlete should retain a normal gait pattern. A heel-toe gait pattern with a cane or single crutch on the opposite side of the hamstring injury is advised. This is a difficult task as most athletes are noncompliant using ambulatory aids. Nevertheless, the clinician must educate athletes that if they are limping without using ambulatory aids they are prolonging their time out of sport because of tissue irritation and subsequent inflammation. Ambulatory aids will facilitate faster return to sport.

2.2 Acute Phase and Rehabilitation

After approximately 20 to 45 minutes of ice application, gentle active knee extension and flexion exercises should be performed in the seated position with the affected leg hanging off the treatment table. Early motion exercises, theoretically, prevent or decrease adhesions within the connective tissue (Kisner & Colby 1990). Athletes perform active knee extension and flexion exercises for the remainder of the icing period (20 minutes icing and 5 to 25 minutes active range-of-motion (AROM) exercises. If the athlete cannot actively perform this exercise, or experiences pain after several minutes of exercise, gentle passive pain-free range-of-motion (ROM) exercise with the uninvolved leg is recommended. If the clinician, however, monitors the athlete's responses and educates the athlete to progress symptom-free, rapid progress is achieved without increasing the inflammatory process.

2.3 Subacute Phase

The subacute phase begins when the signs of inflammation (swelling, heat, redness and pain) begin to resolve, which occurs 2 to 4 days after the initial injury (Kisner & Colby 1990). Once an injured athlete achieves full active extension without pain, resistance exercises can begin. This progression includes multiple angle submaximal hamstring isometric exercises (15 to 20° increments, 2 sets of 5 repetitions, 5 second contraction). Isometrics must be pain-free during and after the contraction. For example, if an athlete experiences stiffness and pain after beginning multiple angle hamstring isometrics, the intensity of the contraction is decreased (e.g. from 100% to 80-60% of maximal effort as perceived by the athlete). Stationary bike riding can also begin as tolerated by the athlete, for ROM and cardiovascular training.

Swimming pool activities can facilitate motion and facilitate strength gains when performed without pain. A progression of walking, emphasising normal gait and hamstring contractions, are helpful in the pool. Progressive jogging with a walk vest and use of a kick board can begin as tolerated. A jog and sprint progression begins with caution in the subacute phase to avoid increasing pain and inflammation. It is not uncommon for an athlete to have increased pain and stiffness after pool activities. During initial phases of pool activities, pool supervision is provided to control excessive stress to the weakened hamstring musculotendinous unit.

During the early phases of rehabilitation, electrical stimulation facilitates effective pain control (Denegar et al. 1989). Frequently, ice and electrical stimulation are used together. Many electrodes are 2 to 4 inches in diameter. When the electrodes are placed over the most tender areas, the electrodes may act as insulators and prevent cooling of the injury area. This speculation is extrapolated from previous research that demonstrates placing a towel between the ice and skin inhibits cooling (Knight 1985). Therefore, care should be taken to place the electrodes proximal and distal to the most sensitive area to allow adequate cooling of the inflamed tissue.

2.4 Remodelling Phase

Once multiple angle hamstring isometrics are performed at 100% effort, prone hamstring strengthening begins. The prone position for hamstring strengthening replicates the length tension relationship that occurs during running (Mann 1982; Stanton & Purdam 1989; Worrell et al. 1989). Moreover, proximal hip stabilisation and knee flexion may mimic the ground contact phase of running (Mann & Sprague 1980). Prone hamstring exercises begins unilaterally with ankle weights, on a knee table or on a variable resistance exercise table. Unilateral knee flexion exercises will indicate the extent of muscle performance dysfunction. However, muscle testing while pain is present is not a valid measure of muscle performance. As long as pain is present, neural inhibition prevents maximal motor recruitment (Lysholm 1987). Once pain is eliminated, concentric testing of the uninvolved hamstring for 1 repetition-maximum-effort serves as a long term goal for the involved hamstring. Initially, the hamstring strengthening programme consists of high repetitions and low resistance (table I), which facilitates motor recruitment without increasing pain or inflammation. If the athlete experiences pain, the weight is decreased, ensuring a pain-free progression. Isokinetic exercise can begin as tolerated after prone hamstring exercise is progressing without pain. Eccentric hamstring exercise in the prone position attempts to mimic the swing phase of running (Mann 1982; Stanton & Purdam 1989; Wood et al. 1984).

Generally, if exercises increase symptoms, the capacity of the connective tissue has been exceeded and further inflammation occurs. Therefore, either the intensity, duration and frequency or all 3 need to be decreased. Because individual athletes' ability to communicate and tolerate pain varies drastically, the rate of progression will vary. Again, all motions should be performed within pain tolerance.

As rehabilitation progresses, to a normal gait pattern, multiple angle isometrics, isotonic concentric strengthening, and more aggressive hamstring stretching can commence. Recent evidence demonstrates that hamstring injured athletes had significantly less hamstring flexibility than a matched control group (Worrell et al. 1991). Moreover, in the hamstring injured group, the injured hamstring muscle had significantly less flexibility than the noninjured hamstring (Worrell et al. 1991). Garrett et al. (1989) reported areas of inflammation and calcifications within the hamstring muscle group following injury, which may explain loss of hamstring flexibility that has been reported following hamstring strain (Worrell et al. 1991). Therefore, hamstring stretching cannot be overemphasised during hamstring rehabilitation. Again, stretching is pain-free and progressed as tolerated.

Stretching before exercise is critical because the ability of the musculotendinous unit to absorb energy is directly proportional to the resting length and muscle temperature (Safran et al. 1988; Taylor et al. 1990). To facilitate increases in connective tissue extensibility, moist heat or moist heat/electrical

Table I. Progressive resistance exercise protocol using the Line Work concept. Athletes perform 10 repetitions at each level at the weight indicated (kg) within the appropriate line. Once 10 repetitions are performed in the fourth set, athletes progress to the next line (from Joe Glieck, University of Virginia, Charlottesville, with permission)

Level	Set 1	Set 2	Set 3	Set 4
1	2	3	5	7
2	3	5	7	9
3	4	7	9	11
4	6	9	11	14
5	7	10	14	16
6	8	12	16	18
7	9	14	18	21
8	10	15	21	23
9	11	17	23	25
10	13	15	25	27
11	14	21	28	30
12	15	22	30	32
13	16	24	32	34
14	17	26	34	37
15	18	27	37	39
16	19	29	39	41
17	20	31	40	43

stimulation is applied to the tender area. Specifically, application of the heat modalities, especially ultrasound, to the proximal hamstring origin (8 to 10cm distal to the ischial tuberosity) is helpful because most hamstring injuries occur in this region (Garrett et al. 1989). In a recent research report (Sullivan et al. 1992), hamstring stretching in an anterior pelvic tilt (arching lumbar spine) was shown to be more effective than hamstring stretching in a posterior tilt (flatten lumbar spine). Also, proprioceptive neuromuscular facilitation (PNF) was not found to be significantly better than static stretch for increasing hamstring flexibility (Sullivan et al. 1992).

Static hamstring stretching is much easier to teach and to perform than PNF hamstring stretching. Static hamstring stretching is performed in a standing position with the pelvis in an anterior pelvic tilt with the stretching leg on a table. Athletes are instructed to retract their shoulders, increase their lumbar lordosis, and maintain their head horizontal while flexing forward as far as possible without pain for 15 seconds (fig. 2). In the anterior pelvic tilt position, athletes perform four 15- to 20-second passive hamstring stretches by leaning forward on the extended leg. The duration and frequency of this stretching programme is based upon the viscoelastic response of the musculotendinous unit (Taylor et al. 1990). Stretching is performed bilaterally without pain. Athletes perform 4 sets of stretching (4 cycles on each leg), 2 to 3 times each day.

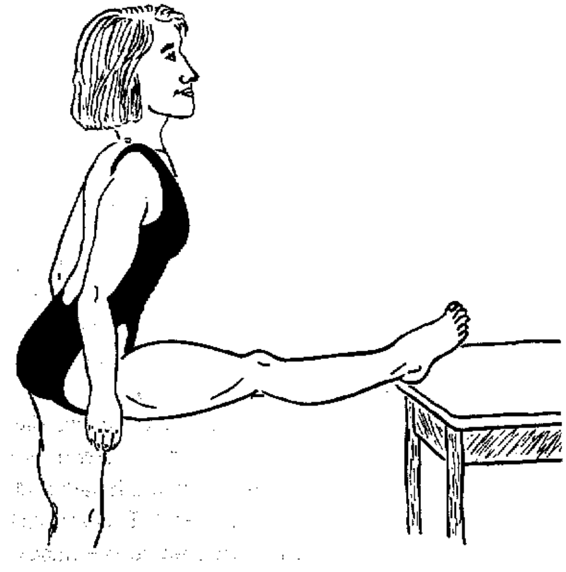

Fig. 2. Anterior pelvic tilt hamstring stretching.

The anterior pelvic tilt with shoulder retraction minimises compensation of the cervical, thoracic, and lumbar regions. Athletes need to be instructed on how to obtain an anterior pelvic position prior to the stretching procedure because of the difficulty learning this skill. In addition, if the athlete is extremely inflexible the stretching leg is rested on a chair or lower table that will allow rotation of the pelvis to obtain an anterior pelvic tilt. Athletes tend to flex forward (Hurdler's stretch) placing the pelvis in a posterior pelvic tile (flattened lumbar spine), which is not as effective in stretching the hamstring muscles because ischial tuberosities move forward closer to the hamstring insertions (Sullivan et al. 1992). In addition, compensation occurs at the cervical, thoracic, and lumbar spine in an attempt to bring the chin to the patella (fig. 3).

Once athletes are more comfortable with stretching and concentric strengthening exercises, an eccentric strengthening programme can commence. In the prone position, the 10-repetition unilateral concentric maximal weight (e.g. 1 × 10, 13.6kg) can be determined. Then approximately 10% should be added to this weight (15.0kg total), and a bilateral concentric contraction to 90° of knee flexion performed with the weight lowered eccentrically by the injured leg. Progress, as indicated by the progression scheme, is permitted depending on pain (see table I). Eccentric exercises are performed with caution because of the increased forces placed on the musculotendinous units. Again, if increased pain or stiffness is experienced, the load or repetitions should be decreased. After the athlete becomes comfortable with the above exercise and is within 10% of the uninvolved extremity, a more aggressive eccentric exercise programme can be initiated.

For an advanced eccentric exercise, the athlete stands parallel to a wall (using the upper extremity

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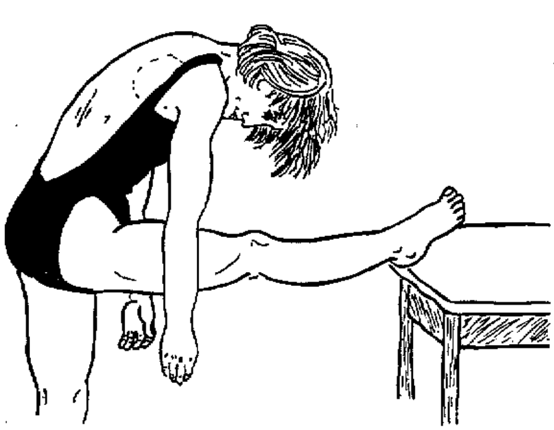

Fig. 3. Hurdler's stretch in a posterior pelvic tilt with compensation occurring in cervical, thoracic, and lumbar regions.

on the wall side as needed for stability) and simulates the swing phase of walking and running. During the swing phase, the athlete performs a quick quadriceps contraction and then attempts to catch or stop the lower leg before reaching full knee extension by a hamstring contraction (fig. 4). This exercise performed with 1.5 to 5.5 pounds (0.68 to 2.5kg) has been reported to approach 1000°/sec and peak torques of 225 to 300Nm (Stanton & Purdam 1989), which is similar to the functional angular speeds and muscular effort of sprinting (Wood et al. 1984). Once the athlete performs 40 catches (4 sets of 10 repetitions) without weight and without pain or increasing stiffness, ankle weights are added, generally in 1 pound (0.45kg) increments to 5 pounds (2.25kg). Because the angular velocity and hamstring forces are high, care must be taken to avoid reinjury. This exercise mimics the hip and knee position of sprinting (Mann 1982). If available, prone isokinetic exercise can be implemented at this time.

2.5 Functional Progression Phase

Once normal gait is achieved, a walking progression begins. During the early stages, stationary cycling, upper extremity exercises or pool activities are important for maintaining cardiovascular fitness. Caution is used in early pool activity to avoid increasing hamstring muscle pain.

Once the athlete walks rapidly for 20 to 30 minutes without pain, a walk and jog progression begins. Initially, a 3 minutes walk, 1 minute jog sequence is used, and this is progressed as tolerated to a 15- to 30-minute jog. Once the athlete is jogging for 15 to 30 minutes, a jog and sprint progression begins as permitted by symptoms. Most athletes complain of hamstring tightness after beginning this progression, or later as sprinting begins. Anecdotally, symptoms decrease and are sometimes eliminated if the athlete stops as soon as hamstring tightness is perceived, and performs anterior pelvic tilt hamstring stretching. Heat before exercise and ice after exercise or practice sessions continues to prevent inflammation as the progression is increased. Athletes who have sustained a hamstring injury are instructed and encouraged to maintain an in-season hamstring strengthening and stretching programme since they are at risk for reinjury (Garrett et al. 1989; Worrell et al. 1991).

Functional progression is more of an art than a science. Therefore, the above recommendations are only guidelines for the clinician and obviously athletes will vary in their response to this progressional sequence. Once the athlete is comfortable with the jog and sprint progression, an isokinetic muscle performance test is performed. This serves to assess rehabilitation efficacy and to encourage continued rehabilitation compliance if muscle deficits

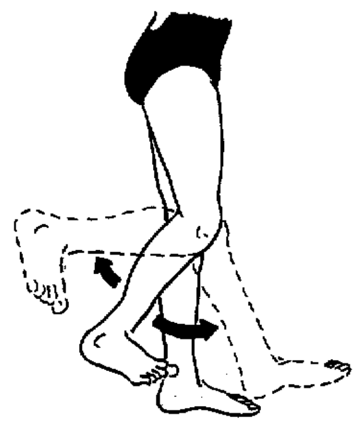

Fig. 4. Eccentric hamstring catches, which provides high forces to the hamstring muscle group.

exist. Because the validity of isokinetics to predict function has been questioned (Lephart et al. 1992), and the inability of isokinetics to assess increases in closed kinetic chain function has been determined (Worrell et al. 1993), the athlete's response to functional sport specific activities is the best indicator of readiness of return to activity. Table II summarises the proposed rehabilitation programme following hamstring muscle strain.

3. Warm-Up

An adequate warm-up period before exercise and stretching is recommended. Warm-up exercises should be specific to the hamstring muscle group (Ekstrand et al. 1983). In animals, increasing muscle temperature has been shown to increases the ability of the musculotendinous unit to absorb forces (Safran et al. 1988). Therefore, athletes with hamstring injuries must be educated in the importance of adequate warm-up, which includes anterior pelvic tilt hamstring stretches.

4. Fatigue

Recent animal research demonstrated that muscle fatigue and eccentric muscle contraction resulted in musculotendinous damage while no muscle damage occurred during muscle fatigue and isometric or concentric contraction (Safran et al. 1988). During the swing phase, when the hamstring muscles are eccentrically decelerating the lower leg, high forces are generated and if fatigue occurs an injury may result. Obviously, this is speculation and further research is needed to clarify the role of hamstring muscle fatigue and injury. However, the role of fatigue and hamstring muscle injury has been observed (Dorman 1971). In addition (Eddie Ferrell, personal communication), it has been reported that during a preseason conditioning test [1-mile (1.6km) timed run followed by an 880-yard (732m) test and sixteen 40-yard (37m) dashes the next day], 6 hamstring muscle injuries occurred. Clinical observations like this, will encourage prospective scientific inquiry into the role of muscle fatigue and hamstring strain. During preseason and early conditioning periods (high risk periods),

Table II. Summary of hamstring strain rehabilitation

Phases	Goals	Treatment intervention
Acute	Control pain and oedema	Ice and compression
		Ice and electric stimulation
	Prevent muscle fibre adhesions	Pain free PROM (gentle stretching), AAROM, AAROM
	Normal gait	Ambulatory aids
Subacute	Control pain and oedema	Ice and compression
		Ice and electric stimulation
	Full AROM	Pain free pool activities
	Alignment of collagen	Pain free stretching
	Increase collagen strength	Pain free submaximal isometrics
		Stationary bike
Remodelling	Control pain and oedema	Ice and compression
		Ice and electric stimulation
	Increase collagen strength	Prone concentric isotonic exercise
	Increase hamstring flexibility	Moist heat or exercise prior to anterior pelvic hamstring stretching
	Increase eccentric loading	Prone unilateral eccentrics, standing 'catch'
Functional	Return to sport without reinjury	Walk/jog, jog/sprint, sport specific skills
	Increase hamstring flexibility	Anterior pelvic hamstring stretching
	Increase hamstring strength	Prone concentric and eccentric exercise, standing 'catch'
	Control pain	Heat, ice and modalities as needed

Abbreviations: AAROM = active-assistive range of motion; AROM = active range of motion; PROM = passive range of motion.

proper carbohydrate nutrition facilitate glycogen replenishment with the goal of preventing or diminishing fatigue (Coyle & Montain 1992). Specifically, athletes at high risk for hamstring muscle injury (e.g. sprinter, jumper, hurdler) may benefit from liquid carbohydrates drinks to prevent hamstring injuries. This recommendation is speculative, but research supports the role of muscle fatigue and eccentric contraction in muscle injury (Lieber & Friden 1988) and carbohydrate fluid replacement can delay muscle fatigue in endurance athletes (Coyle & Montain 1992). Further research is needed to clarify the role of hamstring muscle fatigue and muscle injury.

5. Conclusions

Hamstring muscle strain is a complex multiple factor injury that represents the relationship between strength imbalances, lack of flexibility, muscle fatigue and insufficient warm-ups. Therefore, hamstring injury rehabilitation should specifically address each of the above aetiological factors. Progression of stretching, strengthening, and functional activity are pain-free to avoid increasing the inflammation process. Further prospective research is needed to clarify this complex injury and to identify the most effective rehabilitation procedures.

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