

Hamstring injuries in running/kicking sports

Hamstring injuries in running/kicking sports; an up date in the management and prevention of hamstring injuries for physiotherapists involved in the rehabilitation of sporting populations
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Hamstring injuries are the most common soft tissue injuries in running explosive sports. Characteristically, they form the 12-16% of all injuries in Australian and English football, while it is the most common injury in Australian Football League (AFL). There are estimated 5-6 hamstring injuries per club per season; 15-21 matches missed per club per season and 3-3.5 games missed per injury with similar figures in soccer (Heiser et al 1984, Orchard & Seward 2001, Orchard & Seward 2004, Sherry and Best 2004, Seward et al 1993, Woods et al 2004). This author refers only to the AFL injury statistics because the AFL injury survey is the world's longest running professional sport injury survey that has been publicly released on an annual basis (the NFL in USA has also conducted injury surveys for longer period but it doesn't provide an annual public release of data).

When the hamstring injury does occur? The first half of the float phase of the sprinting cycle, the hip rapidly flexes. Knee flexion is passive during this period and results from the rapid forward acceleration of the thigh during hip flexion. While hip flexion continues, the knee begins to rapidly extend. During the latter part of the float phase of running, the hamstrings eccentrically contract to decelerate the knee extension in order to stabilize the knee joint (Aagaard et al 2000, Kellis 1998, Fortier et al 2005). At that point the hamstrings group is predisposed to injury (Baratta et al 1988, More et al 1993, Stanton and Purdam 1989, Yasuda and Sasaki 1987).

Hamstrings tearing presents in two forms; sudden on set immediate pain or slow insidious on set with muscle tightness that will develop into sudden after or soon after fatiguing practice. Most hamstring injuries are of a single muscle near the muscle-tendon junction. Rarely, the hamstring muscle group may avulse from the ischial tuberosity (younger athletes or water skiers). The diagnosis can usually be made by history and physical examination, but MRI can be used to help pinpoint the extent and location of the injury.

Garrett et al (1989) reported that inflammation and tearing occur most often in the proximal and lateral musculotendinous junction, near the ischial tuberosity. By CT-scan in 10 acute hamstring injury situations he identified 5 in the biceps femoris (BF), 2 between BF and semitendinosus (ST), and 1 only in semimembranosus (SM). Others have also reported similar observations (Speer et al 1993, De Smet and Best 2000).

Hamstring tears in athletic populations are a significant and complex injury and often tend to become chronic. During the rehabilitation process, both athletes and medical staff can become frustrated with the slow rate of recovery and lingering symptoms that often persist (Brubaker and James 1974).

Two categories of possible contributing factors have been identified throughout the world literature. These are the intrinsic and extrinsic. In most cases two or more factors are associated with an injury. The degree of contribution of each factor varies and depends on multiple variables such as the site of injury, individual variations, level and type of sport, time of the season in which the injury occurs and the list goes on.

Since in very rare situations hamstring injuries are managed with surgery, the big challenge for the sports clinician is not only to treat the actual hamstring strain but also to identify and correct the associated impairments in order to decrease the return to sport interval and diminish the great possibility, in explosive-running sports, of injury recurrence; nevertheless the

biggest challenge of all is the return to sport decision.

Intrinsic contributing factors However, there is no evidence that shows a cause-and-effect relationship, retrospective studies have observed that soccer players and track and field athletes with tight hams show higher incidence of tears (Yamamoto 1993). Relative flexibility also causes postural variations such as increased lumbar lordosis. That could possibly also cause an increase in the resting tension of the hamstrings (Hodges 2000). This results in the hamstrings being functionally tighter, and more inclined to fatigue early (Thacker et al 2004, Worrell 1994). Another scenario is that tight quadriceps force hamstrings to work more during knee flexion thus predispose to injury due to overloading (Gabbe et al 2005, Kellis and Baltzopoulos 1997). From the other hand, excessive flexibility may lead to increased reaction time which predisposes hamstrings to injury also (Rosenbaum and Henning 1995).

Heel strike phase is common even in great speeds. Weak calf muscles lead to a typical running pattern of over-striding. Therefore, the hamstrings compensate excessively during propulsion and this can lead to hamstring fatiguing and tearing (Mero et al 1992, Purdam 2005).

Any other musculoskeletal imbalances like lumbar or sacroiliac joint stiffness, leg length discrepancy (LLD) or wrong foot biomechanics can breakdown the effective function of the lower extremities and pelvis during running and therefore can predispose to injury (Burkett 1970, Worrell 1994). Experts' support that hamstrings injuries co-exist with tight sacrotuberous ligament due to SIJ dysfunction (Hoskings and Polland 2005, Purdam 2005); however we can't say what cause what first.

Poor co-ordination of movement or early fatigue associated with muscle weakness, especially around the trunk, hip, knee and ankle joints are significant contributors to be assessed.

Wrong foot biomechanics can alter the function of the knee, hip and pelvis via the kinetic chain (Michaud 1997). Weak muscles around the hip (in particular Glut Max) can also increase the load of hamstrings during sprinting, via the posterior longitudinal myofascial slings (Hodges 2000, Lee 2004).

It is also suggested that muscle strength imbalances between the hamstrings and quadriceps may predispose towards injury (Burkett 1970, Grace et al 1984, Dorman 1971, Liemohn 1978). Hamstring injuries are more likely to occur if the isometric strength of the right and left knee flexors differs by more than 10%. Hcon/Qcon ratio less than 0.6 are believed as indicator for muscle injury (Baltzopoulos and Brodie 1989, Kannus 1994). However this ratio is dependent on angular velocity, test position, population group and use of gravity compensation (Kellis and Baltzopoulos 1997, Steindler 1955). Therefore, because its use does not relate to functional movements seen in sprinting, the Hecc/Qcon ratio been proposed of more practical significance to investigate injury predisposition (Coombs and Garbutt 2002, Garbutt et al 2001). More recent a Hecc/Qcon ratio of 1.0 recommended (Aagaard et al, 1995, 1998). However, in conjunction with EMG activity recording, during sprinting higher values have been measured (Donne and Luckwill 1996). This seems reasonable, considering the horizontal forces that generate around the knee joint during heel contact. Moreover Orchard (2001) was the first to report Hamstrings strain during isokinetic eccentric testing, highlighting its risk to injury. On the base of such conflicting results it appears that there is probably a complex, poorly understood neuromuscular coordination pattern that may predisposes the hamstring group to injury (Bennell 1998, Orchard 1997, Osternig et al 1986, Yamamoto 1993).

In eccentric exercise microscopic damage in muscle fibers is believed responsible for the stiffness and soreness the next day (DOMS). This normally resolves within one week. Because

hamstring injuries happen during eccentric loading, this microscopic damage with inadequate recovery and conditioning can progress to hamstring strain (Dorman 1971, Safran et al 1988).

This is explained by the concept of “optimum length” introduced by Brockett et al (2004). DOMS resulting from eccentric activity or scar tissue formation after strain decreases the optimum length of the hamstring group. This leads to an increased in the angle of peak torque of the knee flexors muscles. Thus, the hamstring group is producing its maximal force in its maximum length where the elastic in series components are susceptible to injury. Therefore, based on the above observations, peak torque angles greater than 20 degrees of knee flexion is considered a reliable predictor to hamstrings strain (Brockett et al 2004, Morgan and Proske 2003, Morgan et al 2004, Camilla et al 2000).

Fatigue may be reflected in a prolonged recovery time at neuromuscular junctions, which diminishes effective muscle activation, slows the clearing of metabolites from the muscle, and impairs the ability of the muscle to contract; thus increasing the risk of injury (Mair 1996). That’s why preseason and early conditioning periods are high risk periods, especially if training is commenced in hot and dry environment (Coyle and Montain 1992).

Moreover, fatiguing contractions have demonstrated decreased proprioception (Proske et al 2005). It is also proved that repeated ankle sprains can lead to poor proprioceptive control of the lower limb. This could also lead to overloading of the lateral hamstrings via the posterior longitudinal sling, due to poor firing of the Glut Max/Glut Mid (authors opinion based on Bullock-Saxton et al 1993, 1994 and Hodges 2000). Characteristically, Cameron et al (2003) observed a link between movement discrimination deficits and hamstring injury rates.

The most of all-obvious truth for hamstrings is the tendency for injuries to recur. Gabbe et al (2005) observed that older athletes (>23 years old) have greater possibilities of hamstrings injuries. Repeated minor injuries double the risk of tearing within 2 months (Best 1996, Best 2001, Orchard and Best 2002). Other lower limb injuries should also be taken into consideration. For instance mild knee joint effusion has been shown to cause quadriceps and hamstrings inhibition during running (Torry et al 2005). An alteration in the biomechanics of the knee joint due to menisci tears or degeneration may lead to excessive loading of the knee flexors and recurrent injury (Brockett et al 2004). A recent prospective study also reported that AFL footballers with previous history of groin injury or knee injury (ie. osteitis pubis and ACL injury) are more susceptible to hamstring tearing (Tummi et al 2006).

Recurrent hamstring injuries may also develop after a number of removed causes such as referred pain from the lumbar spine. This may occur due to disc bulges at the L4/5 or L5/S1 level which may result in nerve root irritation. The later may cause local muscle pain, spasm or a more prolonged generalized increase in tension of the hamstrings (Hodges 2000).

Extrinsic contributing factors

The most important extrinsic contributor to hamstring injury is inappropriate training. "Inappropriate" comprises all the factors that may affect the individual's ability to adapt to the varied stresses of recreational or elite level exercise, such as inadequate warm-up and cool-down, poor stretching, inappropriate training environment/sporting gear-equipment and the list goes on. For example, wrong shoes or orthotics have negative effects on the biomechanics of the lower limb. We should not however forget that running and kicking sports, such as soccer, football and sprinting require bursts of speed, rapid acceleration and prolonged running on cambered

surfaces which they are significant contributors to muscle injury anyway. Moreover, wrong technique of sprinting or a running style which is poorly coordinated may result in early muscle fatigue and injury (authors opinion based on the integrated model of function by Lee and Vleeming 1997, 2004).

However the role of fatigue on hamstring tear is still unclear, inadequate recovery is considered significant contributor to hamstrings strains (Calder 2002). Orchard anecdotally observed that afternoon running sessions predispose to hamstring injury in AFL (Orchard 1997). Moreover, Brockett et al (2001) observed that concentric exercise (especially in prone position which doesn't correlate with true running angles) decreases optimum length and predisposes to injury during eccentric loading.

The new formed scar tissue continues to regenerate several months after injury, where there are no symptoms (Best 2001, Orchard 1997). Moreover experts assume that footballers run with subtle gait alterations that may affect performance and predispose to re-injury (Orchard 1997). Prolonged treatment with non steroidal anti-inflammatory drugs (NSAID) decreases the peak torque production of the injured hamstrings (Mishra et al 1995). Experiments in rats proved that the use of corticosteroids after muscle injury, accelerates healing for the first two days, but seems to have detrimental effects in long terms compared with controls (Beiner 1999). Therefore, incomplete or inappropriate rehabilitation after previous injury in conjunction with early return to sport is another important contributor to hamstring strains (Brubaker and James 1974).

In summary, the current evidence suggests that muscle strength deficits/imbbalances, relative inflexibility, early fatigue and insufficient warm-up and recovery are seemed to be the most significant contributors to hamstring tears. All these factors interact with each other. The more factors are together in an athlete, the more predisposed to hamstring injury he/she

is (Worrell and Perrin 1992). This implies the need for early detection and correction of deficits in any of these principal areas. Therefore, the key to effective management of acute but more important for chronic hamstring injuries, is a thorough history taking and clinical examination based on validated clinical tests.

Strategies to reduce incidence of Hamstring injury in the future

The best way to prevent from future injury is to identify those individuals who are in high risk of injury and address the above mentioned contributing factors. If the clinician is involved with a sports club, this is easier by creating screening protocols for all athletes based on valid observations concerning the physical demands of the sport; biomechanical analysis and valid clinical assessment tools. An optimal screening protocol should include assessment of relative flexibility; core stability; training routine; warm-up and cool-down strategies; recent and past history of injuries; nutritional habits; personal lifestyle; possible yellow flags; equipment and sporting technique. The creation and completion of this protocol requires the contributions of trainers, coaches and the rest sports medical staff involved in a team.

The success of a prevention protocol and in extension a prevention program is often limited by various contributors. These mainly include: consensus of the medical team in a sports club; individual motivation; club's policy and the list goes on.

Warm-up and stretching

Perhaps the most controversial area in hams injury prevention is warm-up and stretching. The evidence supporting these ideas is sketchy at best and largely based on retrospective studies. Static stretching seems to be the most effective way as a pre-exercise warm-up among ballistic, PNF and dynamic stretching (Bandy 1998). The increased analgesia after PNF stretching may

aid in performance but theoretically increases the risk of injury when compared with static stretches (Sady 1982, Shrier and Gossal 2000). Ballistic stretch is believed to be more functional as sport activity involved dynamic movement (Sullivan et al 1992). Viscoelasticity of muscles at different temperatures (warm or cold weather) should also be taken into account (Thacker et al 2004). Four repetitions of 15-30 sec duration on each muscle group are believed enough to produce muscle lengthening. The duration of flexibility varies from some min to 1.5hrs, although in an experimental study, an extensive program of several weeks produced flexibility that persisted for several weeks (Draper et al 2004). However, the elasticity of slow-twist fibers is greater than fast-twist fibers (Draper et al 2004) and this should be taken into consideration when prescribing stretches to specific groups such as sprinters or black race populations. This is because these populations have predominance of type IIb/fast-twitch glycolytic fibers in their muscles (Woods et al 2004, Verrall et al 2001, Arnason et al 2004).

However little research indicates disadvantages on static stretching prior performance like decreased running economy and peak performance (Rosenbaum and Henning 1995), experts support dynamic sport specific stretches prior to sprinting exercise. In the contrary researchers suggest that stretching before exercise would not prevent injury for two reasons: 1) stretching has no effect on muscle compliance during eccentric activity, where most tears are likely to occur, and 2) stretching can produce damage at the cytoskeletal level (Gadjosik 1991, Schilling and Stone 2000). From the other hand, the ability of the musculotendinous unit to absorb energy is analog to resting length and tissue temperature (Taylor et al 1990). That's why stretching before exercise is believed essential. However, care should be taken with the stretching program with athletes processed hyper-laxity.

No research proves if flexibility relates to injury prevention

(Rosenbaum and Henning 1995, Shrier 1999). Therefore, relative flexibility is to be considered in clinical situations (Sullivan et al 1992, Purdam 2005). That's why the sports clinician's interventions should focus on the correction of asymmetries in flexibility between left and right lower limbs of involved individuals including both agonist and antagonist muscles. Duration of warm up should be set based on weather conditions and individual needs.

Strengthening

Biological studies have shown that eccentric exercise increases optimum length and peak torque of the muscle (Brockett et al 2001). Strengthening should focus on hamstring activity stimulated to sport specific tasks. Therefore, pulley machines should provide maximum resistance in end-range knee extension and the athlete should adopt prone position with the hips flexed at approximately 45 degrees to simulate the sprinting running pattern (Chlebourn et al 2001, Coombs and Garbutt 2002, Purdam 2005).

Kippers (1990) showed that the hamstrings load is greater proximally near the ischial tuberosity because the distance of attachment from the axis of hip motion is longer compared with that of the knee joint. Moreover, the lateral hamstring is the only muscle that controls medial rotation momentum of the knee joint. Based on the above observation, we could assume that the load on the biarticular long head of biceps femoris muscle is greater. This is consistent with the observed predisposition of the lateral hamstring group to injury in running sports. Therefore, ideal eccentric programs should focus more on biceps femoris isolation (Purdam 2005). Eccentric training should also encourage hip motion (0-90 degrees) with the knees fixed in extension, biased to maximal lateral hamstring activation (Chlebourn et al 2001).

Orchard (1997) suggested that daily double sessions in AFL, should balance running sessions in the mornings and weight

training in the evenings. This is because the evening training due to poor recovery (from morning session) predisposes to injury. Therefore, it is wiser to include weights in the evenings, which are less injury provocative (concentric contractions). Experts also suggest that eccentric training should not be included only pre-season, but also during season for obvious reasons.

Other weak sinagonists of the lower limb should also be addressed respectively to avoid uneven muscle loading via the kinetic chain through the functional slings. Training variables should focus on duration, repetitions, patterns and frequency of exercises, based on the above mentioned recommendations.

Core stability

A progressive training program should always take place starting from simple tasks with pressure biofeedback devices and continue with more complicated tasks. Advanced exercises with gym balls focused on local and global stabilizing muscles of the trunk, such as gluteals; erector spinae; abdominals and hip adductors is essential to create challenging programs for elite and asymptomatic recreational athletes (Fortier et al 2005).

Fatigue syndrome and Recovery

Recovery is an important component of maximum performance and injury prevention. There are four aspects of recovery that should be addressed individually as revealed from the screening findings. These are: 1) metabolic recovery, 2) neural recovery, 3) psychological recovery, and 4) environmental recovery. Fatigue syndrome should be screened by investigating for: recent loss of weight; loss of appetite; adequate hydration during day; adequate meals reach in carbs; warm-up/cool down techniques; recovery strategies (self recovery, spa, saunas, pools, float cubicles, meditation, self massage); sleeping patterns; recent environment change; psychosocial issues (partner, family, financial); loss of motivation; low sugar diet; loss of power-strength-endurance;

resting HR-blood lactate before and five minutes after sub-maximal effort; muscle tenderness similar to DOMS; head colds-allergic reactions or other infections that indicate weakened immune system and also hormonal dysfunction particularly in female athletes as it can create similar to fatigue symptoms (Calder 2002, Dolman 2005).

It is evident that stretching doesn't improve DOMS and force loss following heavy eccentric exercise. Massage like transverse friction and transverse gliding over hams, however, seems to help muscles to recover from metabolic fatigue and should be done firmly twice a week through the year, especially in high risk periods (Brukner and Khan 2003).

It has been proposed that micro-damage after DOMS results in non-uniform lengthening of sarcomeres (Morgan et al 1990). This sarcomere lengthening instability leads the muscle to work eccentrically beyond its optimum length (length-tension relation). Therefore, if localized tightness is not addressed the muscle will be prone to further microscopic damage and tearing (Brockett et al 2004). That's why trigger point release, with dry needling and specific soft tissue techniques for localized muscle tightness are essential (Purdam 2005).

Education

Once the sports clinician has summarized the screening findings, education is one of the most important ways to help a team or an individual especially when very young athletes are involved. The focus should always be on the importance of continuous and correct stretching (with anterior pelvic tilt), recovery strategies, core stability and sport specific strengthening exercises, not only through the season but also off-season.

Other strategies

Low back maintenance treatment, correction of foot biomechanics and replacement of additional equipment such

as old orthotics, inappropriate running shoes, and high risk exercising devices should also be considered.

Prevention from re-injury

In general lines, the same prevention principles count for those athletes that are already recovering from a hamstring tear and those with no muscle injury in a team. Based on the severity of the previous injury, the way of management, and the identified contributors, the prevention program will be individualized. However, the new post-injury formed tissue doesn't have the same strength with a healthy muscle (Brockett 2004). This should be taken always into account with respect to total loading during training.

Furthermore, although 4 x 30 sec stretches per muscle group is sufficient to increase range of motion in most healthy people, it is likely that longer periods or more repetitions are required in post-injury shortened muscle groups (Thacker et al 2004).

It is also well supported that post-injury early eccentric loading increases the numbers of sarcomeres in series and therefore significantly shifts the optimum angle for torque generation to longer muscle lengths (Brockett et al 2004). Therefore, early pain free eccentric loading should be considered for every individual recovering from strain injury.

Another very important strategy which needs special education of the injured individual is the identification of tight spots along the posterior thigh muscle group and self-release techniques. A good technique is to educate the athlete how to sit on his hamstrings (sitting on a bench) with a firm object under the tight spots (usually his hand or a golf ball) while at the same time he/she lengthens the muscles actively by extending his knee, while maintaining his/her lumbar lordosis.

It appears that Isokinetic exercise helps to reduce recurrent hamstring injuries and to assess whether the injured athletes are safe to return to full competition in soccer (Heiser et al

1984). However, because the validity of isokinetics to predict function has been questioned (Aagaard et al 2000, Coombs Garbutt 2002) and the inability of isokinetics to assess increases in closed kinetic chain function has been evident (Worrell et al 1993) the athletes' pain free performance to sport specific drills should be considered as the gold standard to determine readiness to return to sport in optimal situations. Needless to mention again that isokinetic dynamometry predisposes to re-injury (Orchard 2001). However, based on the last observation by Orchard (2001) we could also advocate that isokinetic dynamometry simulates the demands of the sport and is preferable for an athlete in risk of injury to be injured during testing than in the game where he/she could put her self into danger for more serious injury. Table 1 summarizes some sport specific screening tests before return to full competition from this authors experience with NFL clubs.

Return to sport decision

It is very challenging for the clinician to decide when it is safer for the athlete to return to full competition and usually depends on the clubs policy, the teams expectations for the athlete, the time of the year etc. The most recent published AFL injury report (Orchard 2006) observed that from 1997 to 2005, hamstring injury incidence (1997=6.8, 2005=5.2) and recurrence rate (1997=37%, 2005=27%) have gradually decreased. This reflects the effectiveness of new rehabilitation programs based on the observations mentioned in this paper and a more conservative return to sport policy, allowing better recovery. The injury severity though, (average number of games missed per new injury) has stayed fairly constant (1997=3.1, 2005=4.4). Orchard (2006) concludes that because the recurrence rate is also gradually dropping, that indicates that the new hamstring tear keeps players out for longer, but the new injury recovery time is being counterbalanced by the reduced time missed from recurrent injuries.

There is too much conflicting information in the literature around this fascinating and interesting topic which challenges daily athletes and sports medical staff. That's why this author wouldn't attempt to propose a specific examination or rehabilitation guideline, or even exercise schemes for different populations; which to this author's opinion they have catalytic effects in the long term recovery and re-injury prevention of hamstring injuries in explosive running sports. However in table 2 there are summarized some general strengthening exercises focused on recovering hamstring groups and some later sport specific exercises to allow safest return to full competition based on personal experience with NFL athletes. They shouldn't consider in any case a complete exercise protocol, but they should only form a reference point.

Conclusion

Hamstring tears in explosive running sports are prevalent and unfortunately, often recurrent, with prolonged rehabilitation and persistent disability. Most hamstring injuries are of a single muscle near the muscle-tendon junction. Rarely, the hamstring muscle group may avulse from the ischial tuberosity (most common in younger athletic populations). The diagnosis is always a challenge and can usually be made by history and physical examination, but MRI can be used to help pinpoint the extent and location of the injury and estimate the return to sport interval in football injuries. Initial treatment typically consists of rest, ice, compression, elevation, and pain relief. There is no consensus on optimal rehabilitation. The biggest controversy exists on the areas of later rehabilitation and re-injury prevention. However a holistic approach consisted of functional exercises with stretching and strengthening and correction of wrong biomechanics and education has been shown to be effective in daily clinical practice with sport clubs and individuals.