

## Hamstring Injuries: Risk Assessment and Injury Prevention

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### Abstract

**Introduction:** Hamstring injuries are one of the most common injuries associated with sports participation. The aim of this review is to outline identified risk factors and examine preventative strategies for reducing the occurrence of this form of injury. **Methods:** An electronic search of Medline and SCOPUS was carried out for key words related to the area. **Results:** A number of risk factors, including both intrinsic and modifiable, were identified. Important aspects of an exercise programme were then outlined based on these risk factors. **Conclusion:** A programme specifically designed to reduce the risk of hamstring injury by taking a strategised approach to exercise prescription may reduce the risk of hamstring injury. However, further research is required to determine the optimal programme for reducing the risk of injury.

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**Key words:** Muscle, Rehabilitation, Strain

### Introduction

The aim of this article is to outline the factors involved with, and a potential strategy for preventing, one of the most common injuries in nearly all forms of team and individual sports; the hamstring strain.<sup>1-4</sup> Analysis of epidemiological studies assessing these sports consistently ranks hamstring strain injuries as one of the most prevalent factors resulting in missed playing time by athletes.<sup>4,5</sup> Hamstring strains, particularly of the biceps femoris, have been shown to be the most common injury in football and Australian Football League (AFL), accounting for 12% and 15% of all injuries in these codes respectively. An average of 5 athletes per football club and 6 athletes per AFL club suffer from hamstring injuries each season, with approximately 18 days of team training missed per injury.<sup>6,7</sup>

Another supporting factor for focusing on the prevention of hamstring injuries is the recurrence rate. Hamstring injuries have been shown to have almost double the rate of recurrence in comparison with other sporting injuries, with 12% of hamstring injuries recurring in comparison with a 7% recurrence rate for all other injuries in football.<sup>7</sup>

The high injury rate and potential for recurrence enforces the need to produce a holistic training programme that has a specific aim of reducing this injury. However, to create an injury prevention strategy we must first uncover:

1. How the injury occurs, and
2. Potential risk factors

### How the Injury Occurs

The vast majority of hamstring injuries occur in non-contact situations while the athlete is running.<sup>7</sup> The athlete often feels a sharp twinge in the lateral portion of the posterior thigh, which signifies a muscle strain. While a hamstring muscle strain is quite common in sports, thankfully a complete tear of the hamstring muscle is very rare, occurring in roughly 1% of all hamstring injuries.<sup>7</sup>

Epidemiological evidence suggests that the actual occurrence of hamstring muscle strains often takes place during an eccentric contraction of the hamstring muscles.<sup>8-10</sup> More specifically, it has been previously suggested that it is the portion of eccentric hamstring contraction occurring during the descending limb of the muscle's length-tension relationship that results in hamstring injuries.<sup>11</sup> This is postulated to be due to non-uniform lengthening of sarcomeres attributed to sarcomere length instability, resulting in microscopic damage to the muscles of the hamstring.<sup>12,13</sup> If a sport requires multiple eccentric contractions, these microscopic areas of damage may result in a "weak link" of the musculature, from which a major soft tissue tear may arise.<sup>11</sup>

While this description attempts to outline how the injury

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occurs, the reason why the hamstring is susceptible to injury must also be explained. The role of the hamstring muscle in movement is multi-factorial. For example, during the swing phase of the running movement the muscles of the hamstrings are required to perform many roles in a brief period of time. The hamstring muscles are required to:

- Contract eccentrically, decelerating the extension of the knee,
- Contract quasi-isometrically while controlling stability of the knee joint,
- Perform a rapid countermovement from knee extension to knee flexion, and
- Play a part in extension of the hip joint.

All of these functions performed either simultaneously or in rapid succession result in intense loading of the hamstrings in an elongated position.<sup>14</sup> Frequent performance of this movement, as performed during any sport requiring repeated bursts of running, may result in multiple areas of microscopic damage in the muscles of the hamstring. As the athlete becomes more fatigued and their technique suffers, the hamstrings must play an even greater role as a stabiliser, and therefore the extent of the loading is likely to increase dramatically. The accumulation of numerous micro-tears, compounded by the sequentially greater magnitude of muscle damage as the athlete becomes fatigued, may be responsible for the increase in hamstring injury risk as a half of football progresses.<sup>7</sup>

While the previously mentioned mechanisms may be a component of hamstring injury, there is little evidence of the reason why hamstring injuries occur with such prevalence and what predisposes certain athletes to become injured.<sup>8</sup> The following section will discuss potential risk factors for hamstring injury.

### Potential Risk Factors

Previous studies have cited numerous potential risk factors associated with hamstring strains in non-injured athletes. These are:

- The attachment sites and anatomy of the muscles,<sup>7</sup>
- Lack of flexibility,<sup>15</sup>
- Poor lumbar posture and core stability,<sup>16</sup>
- Fatigue,<sup>17</sup>
- Inadequate warm-up,<sup>17</sup>
- Insufficient hamstring strength in comparison with the quadriceps,<sup>18,19</sup> and
- Position of peak hamstring torque.<sup>11</sup>

Each of these factors will be discussed individually in the following section:

#### *The Attachment Sites and Anatomy of the Muscles*

This is the only one out of the previously mentioned risk factors that cannot be rectified without resorting to major

surgery. Of the 3 muscles making up the hamstring group, the biceps femoris is the most commonly injured with 53% of hamstring strains occurring to this muscle.<sup>7</sup> This may be because of the anatomy of the muscle, with 2 separately innervated heads. This dual innervation may result in mistimed contractions, leading to reduced force production and greater instability of the muscle when faced with a rapid eccentric contraction.<sup>14</sup> While every athletes muscles originate and insert in similar positions, slight variations in these sites may predispose an athlete to injury. For example, an extensive femoral attachment of the short head of the biceps femoris results in a less mechanically efficient structure for force production, potentially increasing the risk of hamstring strain.<sup>15</sup>

While these anatomical differences between athletes may result in an increased risk of injury, there is little that can be done to rectify the attachment points. However, the remaining risk factors can all be relatively easily modified.

#### *Lack of Flexibility*

Poor hamstring flexibility is a commonly proposed risk factor for soft tissue injury.<sup>15</sup> It is believed that a tighter musculotendinous structure may reduce the ability of the muscle to elongate rapidly without injury. A stiffer system may apply greater muscular opposition to the eccentric contraction, whereas a more compliant muscular system would transfer the eccentric loading to the tendon. This transfer of the load to the tendon would reduce myofibrillar strain, potentially reducing the risk of soft tissue injury.<sup>20</sup>

While this risk factor appears somewhat theoretically sound, previous research reveals inconclusive results. Some studies have found poor flexibility as a contributing factor (for example: Jonhagen et al 1994<sup>21</sup>) while others have shown that it makes no difference (for example: Hennessy and Watson, 1993<sup>16</sup>). Furthermore, although this risk factor is relatively easy to test using the common sit and reach test, the validity of this test for assessing hamstring flexibility is somewhat poor. The correlation between hamstring flexibility and sit and reach scores has been reported as moderate at best.<sup>22</sup>

The previously mentioned limitations of hamstring flexibility testing and the use of the results as a risk factor for injury restrict the usage of hamstring flexibility as a criterion measure for potential injury risk. Despite the difficulty in precisely assessing this characteristic, the inclusion of a hamstring flexibility programme into the athletes training schedule may potentially prevent soft tissue injury.

#### *Poor Lumbar Posture and Core Stability*

Core stability and strength training has received a great deal of interest in recent years, and appears to provide

benefits for reducing the risk of hamstring injury. Excessive lordosis of the lower back has been suggested as a risk factor for hamstring injury because it places the gluteal and hamstring muscles in a mechanically disadvantaged position.<sup>16</sup> Therefore, a basic posture pre-screening of athletes may provide valuable information as to who is at risk of hamstring injuries. These athletes can then be given a specific core strengthening/stability programme to help improve posture. These programmes may consist of pilates, yoga or various other forms of core strengthening and balancing exercises.<sup>23</sup>

### *Fatigue*

As previously mentioned, an athlete will begin to display a reduction in motor control as they become fatigued.<sup>17</sup> This results in a greater role of the stabiliser muscles, of which the hamstrings play a primary role for the lower body.<sup>24</sup> This greater loading, along with the damage that has occurred from numerous eccentric contractions, may result in soft tissue injury.<sup>25</sup> To overcome the effect of fatigue on injury, we have to reduce the level of fatigue that the athlete encounters. While this could theoretically be done by reducing playing time or implementing more breaks in play, the optimal method would be to ensure the players fitness levels are high. Not only would this reduce their risk of injury, it would also enhance their sporting performance.

### *Inadequate Warm-up*

The potential for an inadequate warm-up to increase the risk of injury is evident through the mechanism of thixotropy. As the athletes' muscles increase in temperature they become less viscous.<sup>26</sup> This allows for greater elasticity of the muscles, which may potentially increase ability to absorb strain without tearing.<sup>20</sup> A cold or inadequately warmed up muscle is stiffer and therefore more resistant to lengthening. If the athlete attempts a rapid eccentric contraction of the hamstrings under this condition, the muscle may be more likely to tear. Therefore, it is essential that an athlete has reached a point in the warm-up where the muscle group is at an optimal operating temperature for both enhanced performance and reduced injury risk. However, determining a muscle temperature for optimal elasticity of the muscles is difficult, and therefore the athlete should be instructed to warm-up to a point where they feel that the muscle is in a state of readiness for the following competition.

### *Insufficient Hamstring Strength in Comparison With the Quadriceps*

Commonly referred to as the quadriceps to hamstring strength ratio, a good balance in strength between the knee flexors and extensors is believed to result in a more stable

joint that has a lower risk of hamstring injury.<sup>18,19</sup> This strength ratio is often tested isokinetically, with the concentric force levels for flexion and extension compared.<sup>18,19</sup> While the minimal acceptable ratio for reducing hamstring injuries is open for conjecture, a common standard suggests that the hamstring should be able to produce >60% of the force levels recorded by the quadriceps.<sup>18,27</sup> This ratio can be balanced out by emphasising hamstring exercises in the athletes resistance training programme.

While the use of this strength ratio does provide some information in regards to the functional ability of the lower limbs, it does have 3 major drawbacks. Firstly is the fact that the testing is performed isokinetically. This is not readily accessible for a number of athletes, and furthermore does not replicate the rapid changes in movement velocity encountered during the swing phase in running, where the majority of injuries occur.<sup>25</sup> Secondly is the fact that the testing is concentric, whereas the vast majority of injuries occur during rapid eccentric contractions of the hamstrings.<sup>25</sup> Therefore, the application of a concentric strength measure to a rapid eccentric movement is somewhat limited.<sup>28</sup> Finally, a strength ratio such as the one commonly used does not take into account the position of the movement where the peak force occurs. As previously mentioned, the majority of muscle damage occurs during the descending limb of the hamstrings length-tension curve. Therefore, the ability to produce high force levels in this range of movement (ROM) to prevent instability may reduce the risk of hamstring injury.

### *Position of Peak Torque*

The position where peak torque occurs is important because producing maximal torque at a more extended knee ROM results in a smaller descending limb of the hamstring contraction.<sup>11</sup> This may potentially reduce the risk of injury by decreasing sarcomere instability during the eccentric contraction. In regards to the length-tension relationship, it is suggested that the greater the knee extension angle at which peak torque is produced the lower the risk of hamstring injury.<sup>11</sup> Therefore, training to increase the knee extension angle at which peak hamstring torque is produced would result in reduced eccentric hamstring loading occurring during this descending limb of the length-tension relationship.

### **Training for Hamstring Injury Prevention**

A successful hamstring injury prevention strategy would attempt to nullify these previously mentioned modifiable risk factors. For example, fatigue can be overcome by training in a way that ensures that the athletes fitness level exceeds the demands of the competition. The next section will outline a method of overcoming the remaining risk

factors (lack of flexibility, insufficient hamstring strength in comparison with the quadriceps, position of peak torque and poor core stability) during a resistance training session.

#### *Warm-up*

Cycling provides a predominately concentric warm-up, allowing for a sufficient increase in muscle temperature while reducing the potential for pre-training micro-trauma of the muscle fascicles due to eccentric contractions. The warm-up should aim to be between 5 and 10 minutes in duration, and should be of a light to moderate intensity and produce a light sweat. A multiple hill climb setting allows for bursts of moderate intensity activity between low intensity effort, more effectively preparing the athlete for training than a steady state, low intensity warm-up. It is essential that the athlete is warmed up enough to complete intense eccentric contractions, as these exercises should form the basis of a hamstring injury prevention programme.<sup>29</sup>

#### *Pre-Activity Stretching*

While it remains uncertain if stretching actually reduces the risk of injury,<sup>30</sup> the addition of controlled, dynamic stretching into the warm-up would appear to provide advantages. Effective pre-exercise stretching must be movement specific, and therefore would be tailored towards the movements occurring in both the exercise session and during the sporting activity.<sup>31</sup> An example of a sport-specific dynamic stretch is performing an exaggerated stride pattern. For this stretch, the athlete balances on one leg while performing cyclical stride patterns with the other limb that exceed ROM used during normal running gait. This further increases the muscle temperature while preparing the athlete to activate the muscle group throughout the entire functional ROM.

#### *Hamstring Exercises*

Resistance training exercises are often prescribed to increase the strength, size, muscular endurance or power of a muscle group.<sup>32</sup> However, the aim of the exercises used for hamstring injury prevention should be to increase flexibility, enhance core stability, change the position of

peak torque to a more extended knee angle and increase both concentric and eccentric hamstring strength without negatively effecting performance.

One method of hamstring training that provides beneficial adaptations in regards to a number of these risk factors is the Nordic hamstring exercise. This exercise is known to increase eccentric strength more effectively than traditional resistance training exercises.<sup>33</sup> Furthermore, this form of training also results in beneficial adaptations in regards to position of peak torque, concentric hamstring to quadriceps strength ratio and vertical jump performance.<sup>29,34</sup> There is also evidence that eccentric specific training increases hamstring flexibility.<sup>35</sup> Epidemiological evidence also supports the theory that this method of training reduces the risk of hamstring injury.<sup>36</sup>

This exercise consists of the athlete starting in a kneeling position, with their torso from the knees upwards held rigid and straight. A training partner applies pressure to the athletes' heels to ensure their feet stay in contact with the ground throughout the movement, isolating the muscles of the hamstrings and gluteals. The athlete begins the exercise by slowly lowering their body forwards against the force of gravity, using the hamstrings to control descent into the prone position. This eccentric contraction of the hamstrings is held for as long as possible by the subjects during lowering of the body, ensuring that the hamstrings are contracting to as long a muscle length as possible. Once the athlete is no longer capable of controlling descent using an eccentric contraction of the hamstrings, they perform a push-up jump followed by concentric contraction of the hamstrings to raise themselves back up to the starting position. The exercise protocol is shown in Figure 1, which displays the starting position, the midrange of the movement and the upper body ground contact respectively.

Upon first performance of this exercise it is not uncommon for the athlete to feel a pulling sensation in the muscles of the hamstrings. This may be due to the extremely intense nature of the exercise, with the hamstring and gluteal muscles being responsible for controlling the descent of the upper body. In this case, a number of the weaker muscle



Fig. 1. Start



Midrange



Ground Contact

fibers may in fact be destroyed, with the stronger fibres surviving and providing a protective effect.<sup>37</sup> However once the athlete is a few weeks into the exercise, they are likely to be able to lower their upper body to a point much closer to the ground. An advantage of this exercise is that the leverage position requires that the intensity increases as the upper body becomes closer to the ground. This results in beneficial position of peak torque adaptations towards a more extended knee angle.

While this method of training does possess many potential benefits, it does not appear to increase concentric hamstring strength.<sup>29,33</sup> Combining this method of training with resistance training exercises, such as hamstring curls or Romanian dead lifts, may help to achieve optimal quadriceps to hamstring strength ratios for both eccentric and concentric contractions. A combination of eccentric and concentric specific training protocols would appear to provide the best potential for reducing the risk of hamstring injury in athletes.

In regards to the other risk factors, including core stability exercises that focus on the muscles of the lower back, such as the superman and swiss ball back extensions, would help improve posture and limit the effect of lumbar lordosis on hamstring injury risk. Repeating the dynamic hamstring stretches performed in the warm-up should also be performed prior to the cool-down after the training session. This could also include more aggressive stretching such as proprioceptive neuromuscular facilitation and facilitated stretching.<sup>31</sup>

### **Athletes with Prior Hamstring Injury**

While these previously mentioned risk factors all may contribute to the risk of hamstring injury, one of the primary indicators is a previous hamstring strain.<sup>20</sup> Research shows the re-injury rate for soft tissue hamstring tears is higher than recorded for other injuries,<sup>7</sup> possibly due to calcification in the re-formed musculotendinous system.<sup>20</sup> A common, yet somewhat limited method of rehabilitating these injured athletes is to focus on traditional resistance training exercises to decrease the magnitude of difference in strength levels between the quadriceps and hamstring muscles. This is based on the theory that a more balanced strength ratio reduces the overload on the hamstrings when it is acting as the antagonist.<sup>18,19</sup> However, even when a satisfactory balance between quadriceps and hamstring strength post-injury is obtained the risk of re-injury remains high. Although the muscle balance may be satisfactory after rehabilitation, one of the noticeable differences between the injured and non-injured limb is the position of peak torque.<sup>11</sup> Therefore, the Nordic hamstring stretch exercise would appear to be beneficial for these previously injured athletes.

However, while this form of eccentric specific training is an effective method of shifting the position of peak torque to an optimum length for injury prevention, in previously injured athletes the intensity of the exercise may cause re-rupture of the soft tissue. Therefore, it is important for the athlete to progressively include eccentric training into their training programme. For example, an athlete may begin with decline treadmill running at a slight angle. In subsequent sessions, the angle could be increased to place more eccentric loading on the muscles. Once the athlete can perform steep decline treadmill running, they may be able to perform a pulley assisted Nordic Hamstring Stretch. Each session the mass on the pulley system is reduced, allowing for more of the athletes body weight to be incorporated into the training programme.

### **Inclusion of Eccentric Training into a Periodised Training Programme**

Due to the intense nature of the Nordic hamstring stretch and other eccentric specific exercises, it is not recommended that they be performed year round. However, leaving too much time between training sessions may result in severe delayed onset muscle soreness occurring at the beginning of each microcycle that the exercise is included in. This may be detrimental to performance and could also increase the risk of injury. Including these exercises in every second training microcycle would appear to be sufficient, as the protective mechanism gained from eccentric training has been shown to remain long after the last eccentric training bout.<sup>38</sup>

### **Conclusion**

Soft tissue hamstring injury is the most prevalent injury in a number of sports. Although there are a large number of potential risk factors, the majority can be readily minimised as part of an athletes normal preparation and competition programme. By creating and implementing a strategised approach to injury prevention, more of the athletes time can be spent competing and training instead of rehabilitating.

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