DETAILED REVIEW OF THE MOST EFFECTIVE WAY TO REDUCE HAMSTRING INJURIES[1]

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Abstract

Aim: *This review aims to outline the predisposing factors of HSIs and to determine any relationships between factors that may shed light on the best way to reduce HSI risk. This study will aim to bring together the causes, risk factors and interventions associated with HSIs to better understand why HSIs are as common in the sporting population. We are working under the hypothesis that HSIs are a combination of factors and not just a sole factor that can unlock the problem.*

Method*: Five high-level pieces of research on each individual factor were researched and then funnelled down to the most relevant research to be included. Individual factors were then discussed and cross reverenced where applicable to other factors of HSIs. Where possible the referenced risk factors were highlighted by factors that may be linked to causing HSIs.*

Main Body: *In total, there was 15 different risk factors researched and linked to each other to form a discussion that helped she light on how to combat risk factors and also help identify if there may be more than one factor for an athlete.*

Conclusion: *This study gives an in-depth understanding of a wide range of risk factors for HSIs. It also shows that injuries will happen in sport. Furthermore, it highlights the fact HSIs are multifactorial and the only real way to combat them is to address each individuals risk factors to reduce the chance of injury via a baseline score of specfic tests around the HSIs factors.*

Introduction

Hamstring injuries (HSI) are one of the most common sports injuries known in sporting populations (Brubaker and James, 1974; Garrett, 1999). Woods *et al* (2002) stated that 12% of all professional football injuries are HSIs with a financial burden of around £74.7 million per year which usually means a player missing a significant amount of playing time (Woods, 2004a) and are accompanied by a high reoccurrence rate which can be as high as 51% in the following 12 months (Sherry, 2004). These injuries are most common in sports that have reoccurring intense acceleration such as running, hurdling, jumping, and kicking. Hamstring strains account for 50% of muscle injuries in sprinters and are the most common injury in hurdling (Brubaker and James, 1974). There have been extensive studies undertaken like Ekstrand (2011) who noted that muscular injuries represented

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31% of the total injuries that occurred in 51 European football teams between 2001 and 2009 of which the cause of 27% of the time absence of activity. Mallo et al. (2012) found that 25% of injuries of Spanish sub-elite football players were muscle strains and that these injuries caused 32% of lost games due to injury. Most hamstring strains in the United States National Football League are sustained during noncontact activities, with sprinting as the primary activity.48 ''Speed positions'' (receivers, defensive backs, and running backs) have significantly higher rates of hamstring muscle strains compared with ''strength positions'' (offensive and defensive linemen) (Ali and Leland, 2012). Sports with ballistic movements such as skiing, dancing, skating, and weight lifting are associated with hamstring injuries, particularly the proximal avulsion type (Le Gros Clark, 1945). It is hugely important to remain aware of the multifactorial nature of HSIs if we are to find an effective way to prevent HSIs.

Thesis Aim

This review aims to outline the predisposing factors of HSIs and to determine any relationships between factors that may shed light on the best way to reduce HSI risk. I will aim to bring together the causes, risk factors and interventions associated with HSIs to better understand why HSIs are as prevelent in the sporting population. We are working under the hypothesis that HSIs are a combination of factors and not just a sole factor that can unlock the problem.

Methodology

Aims and Objectives

The primary aim of this study was to explore what the most recent research tells us about HSIs. There have been numerous studies published about different factors that may lead to HSIs but there was still no conclusive evidence as to why they seem to happen no matter what type of protocol is implemented. The study was undertaken with the task of looking at the most researched risk factors in recent years. This was done by researching the most relevant and highest quality of studies. It was then our job to try link risk factors to each other and put in place any information as to why there is no conclusive evidence to prevent HSIs more effectively. Therefore, the objective of this paper is to be able to write an informative piece that will shed some light on the topic.

Research

I asked my peers for any research on HSIs that they thought was relevant in the last 30 years. I then asked some trusted work colleagues who have done some research on HSIs to point me in the direction of some proper published research. I then received some information from my supervisor about the areas of HSIs that would be most relevant to me. I then wrote out a research plan of dates and tasks to complete and set about reading for a total of 2 hours per evening for four weeks. This was done to give myself a baseline understanding of the types of studies out there and it allowed me to design my study to be a little different from the usual. I studied research on individual factors linked to HSIs. Having looked at numerous papers I was able to choose the best studies and the highest quality research to speak on.

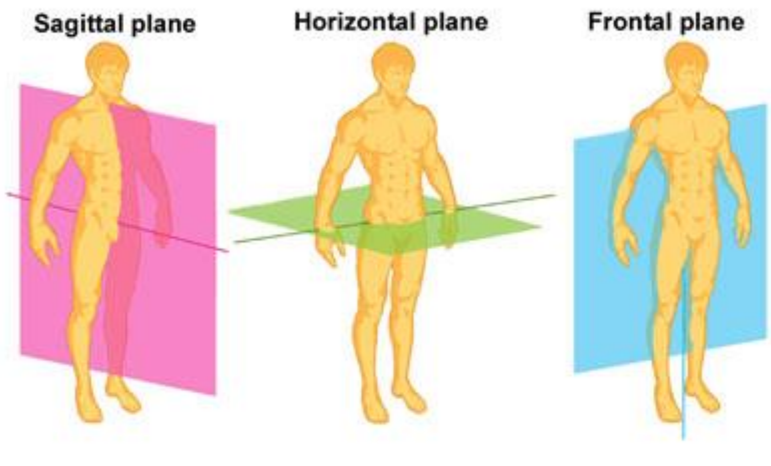
Data/Research Collection

I decided to gather 5 high-level pieces of research on specfic factors and then funnel it down to the most relevant research to be included in my thesis. I then discussed each factor and tried to cross reverence where applicable to other factors of HSIs. I described each study and tried to outline the good aspects of the study but also if there was any bias, flaws or further issues with the way it was undertaken. Where possible I also cross referenced some risk factors with each other with the aim to highlight factors that may be linked and the cause of an athlete's higher risk to HSIs.

Literature Review

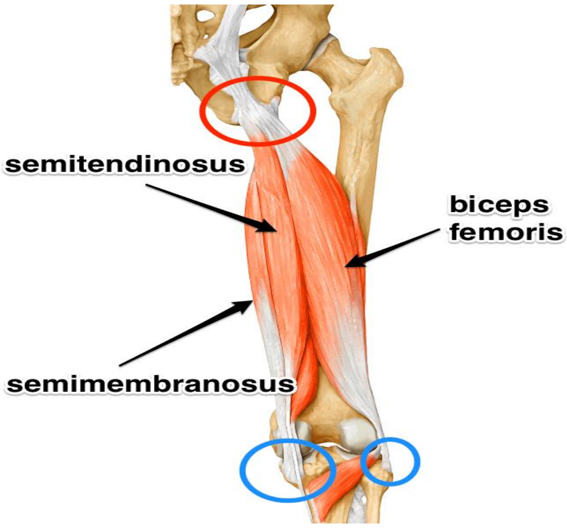
Anatomy & Planes of Motion

The hamstrings are a group of muscles that include the biceps femoris, semitendinosus and semimembranosus. However, the posterior part of the adductor magnus may also be included because of its movement pattern in extension, for this reason it is sometimes referred to as the 4th hamstring. All three hamstrings arise from the ischial tuberosity, they travel down the posterior part of the thigh (Colosimo et al., 2005). The Semitendinosus (ST) is characterised by being described as a long tendon leading into the pes anserinus at the medial proximal tibial metaphysis, along with both the sartorius and gracilis muscles (Warren and Marshall, 1979). The semimembranosus (SM) insertion is medial/anterior to the semitendinosus (SM) and runs into the groove on the postero-medial surface of the medial condyle of the tibia, it then forms a fibrous expansion called the oblique popliteal ligament (LaPrade, 2007).



Planes of Motion
Source: (Mmafit.org, 2018)

The biceps femoris (BF) is formed of two parts, the long head and the short head. The long head arises with the semitendinosus tendon at the ischial tuberosity and migrates down and attaches at the postero-lateral aspect of the distal femur. The short head arises at the linea aspera at the posterior aspect of the femoral shaft, the lateral supracondylar ridge and the lateral intermuscular septum (Rolls and George, 2004). The two heads unite just proximal to the knee joint, and insert into the head of the fibula. The tendon at its insertion becomes readily palpable at the postero-lateral aspect of the knee joint. Considering that information on the hamstrings functions we can already see that there is a complex relationship between the hamstring muscles and the plane of motions they work in.



Hamstings
Source: (Keil et al., 2018)

The ST, SM and BF long head all take neurological innervation from the tibial portion of the sciatic nerve (Kujala, Orava and Järvinen, 1997). The short head of the bicep takes its innervation from the common peroneal part of the sciatic nerve (Draganich, Jaeger and Kralj, 1990).

Hamstring Actions

As a group, the four muscles act by extending the hip and flexing the knee. Individually, however, certain components provide rotational forces on the lower leg about the knee thus adding to the stability of the joint (Clanton and Coupe, 1998; LaPrade, 2007).

The hamstrings are one of the main hip extensors of the body, as well as extension of the hip joint and flexion of the knee joint, the biceps also assist in external rotation of the lower leg at the knee (Linklater et al., 2010). The biarticular role of the hamstrings allows for both extension at the hip and flexion of the knee during a concentric movement. This also allows significant lengthening during concurrent hip flexion and knee extension, as seen in kicking movements and running phases (Novacheck, 1998; Brockett, Morgan and Proske, 2004). These intricate lengthening needs of the hamstrings as they act on the hip and knee are thought to heighten the hamstrings risk to injury, excessive lengthening may surpass the mechanical limits of the muscle (Chumanov, Heiderscheit and Thelen, 2007). If the hamstring is subjected to repeated surpassing of its limits it can also lead to unmanageable microscopic muscle damage that exceeds the loading capacity of the muscle, leading to a tear of hamstring fibres (Morgan, 1990).

Hamstring Injury Risks

Reported risk factors for HSIs include age, previous injury, ethnicity, strength imbalances, flexibility, muscle fatigue and nerve issues (Gabbe et al., 2006). Of these, little is known, definitively, about why previous injury increases the risk of potential HSIs. However, there are interventions put in place to reduce the rate of HSIs by addressing modifiable risk factors have mainly put the focus on increasing eccentric strength, correcting strength imbalances and improving flexibility (Hagglund, 2006). The response to these intervention protocols have seen a mixed bag of failure of success rates and failure. There have been some studies presented suggesting that neuro-muscular inhibition following HSIs may hinder the rehabilitation plans and may even lead to poor hamstring muscle restructure and function (Aagaard et al., 1998; Poulsen, 1998). We know that accumulated muscle damage and/or a single event of maximal exertion may also contribute to HSIs (Koulouris et al., 2007). Potentially, these factors interact to varying degrees depending on the injurious activity type (i.e. running, kicking) (Yu et al., 2008). Furthermore, anatomical factors, such as the biarticular organization, the dual innervations of biceps femoris (BF), fibre type distribution, muscle architecture and the degree of anterior pelvic tilt, have all been implicated (Brooks et al., 2006). Each of these variables impact upon HSI risk via many different mechanisms that include increasing hamstring muscle strain and altering the susceptibility of the hamstrings to muscle damage (Lee et al., 2009). There are a certain amount of HSIs factor that are most commonly referred to. This chart below shows the multifactorial nature of HSIs.

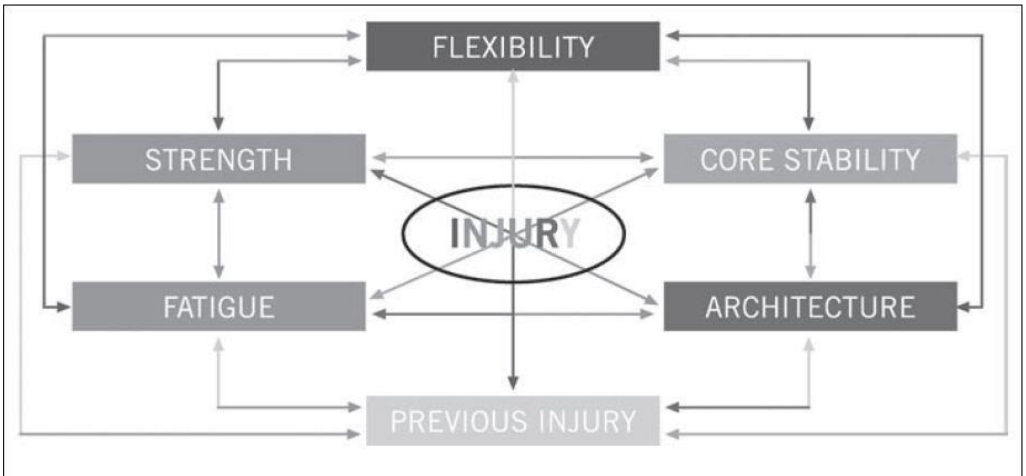


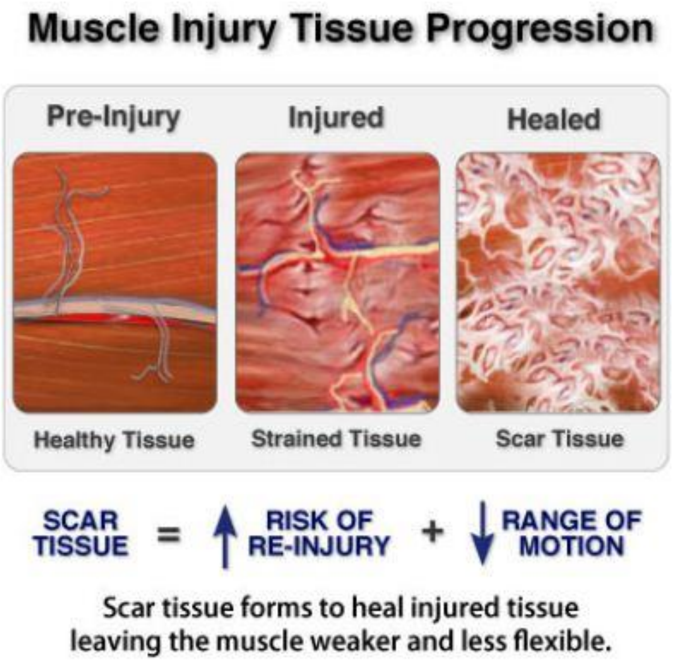
Figure 2 New conceptual model for hamstring strain injury.

Injury Factors Chart

Source: DTPhysio's Blog, 2018

Previous Injury

In the weeks following a HSI, the area of effect muscle tissue is often unable to fully regenerate to its pre-injury condition. For example, imaging studies have found evidence of scar tissue as soon as 6-weeks post-injury (Connell et al., 2004), and animal models have shown that such scarring persists indefinitely (Best et al., 2001; Kaariainen et al., 2000).



Source: Kit, 2018

The replacement of contractile tissue with connective scar tissue after injury could change force transmission paths (Huijing, 2003). This may be a factor and alter the stiffness in the surrounding and adjacent muscle fibres. This in turn can influence the force–length properties of the musculotendon unit and alter joint movement patterns (Silder et al., 2008). Numerous studies note that muscles stiffness due to the injured muscle not only suffering atrophy but becoming shorten and/or stiff through inactivity as a risk factor sure to previous injury). Furthermore, long term inactivity has been linked to a reduction of eccentric strength (Croisier et al., 2015) and reduced angle of peak torque (Brockett, Morgan and Proske, 2004) which in turn can lead to alteration in lower limb running biomechanics (Ruan, 2017; Slavotinek, 2006; Opar et al., 2014).

A study by (Hagglund, 2006) recorded injuries during the first season of the study and then cross referenced them with the injuries sustained during the following season, and to compare injury risk and injury pattern between consecutive seasons. They did this by medical records of 12 elite Swedish male football teams and prospectively recorded individual exposure and time loss injuries over two full consecutive seasons (2001 and 2002).

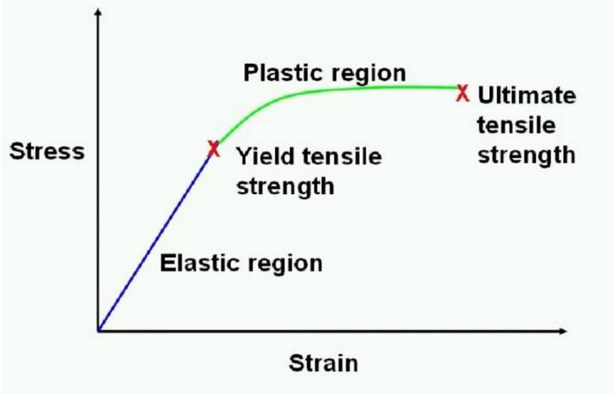
Table 4 Injury patterns in the 2001 (n = 262) and 2002 (n = 263) seasons

	Training		Match play		Total	
	2001	2002	2001	2002	2001	2002
Injury type						
Overuse	165 (47)	159 (45)	59 (23)	73 (31)	222 (37)	232 (39)
Strain	65 (19)	79 (22)	76 (30)	33 (14)***	141 (23)	112 (19)
Sprain/joint injury	49 (14)	58 (16)	41 (16)	42 (18)	90 (15)	100 (17)
Contusion	41 (12)	33 (10)	52 (21)	57 (24)	93 (15)	90 (15)
Fracture	6 (2)	4 (1)	11 (4)	12 (5)	17 (3)	16 (3)
Dislocation	4 (1)	2 (<1)	2 (<1)	3 (1)	6 (<1)	5 (<1)

Source: Hagglund, 2006

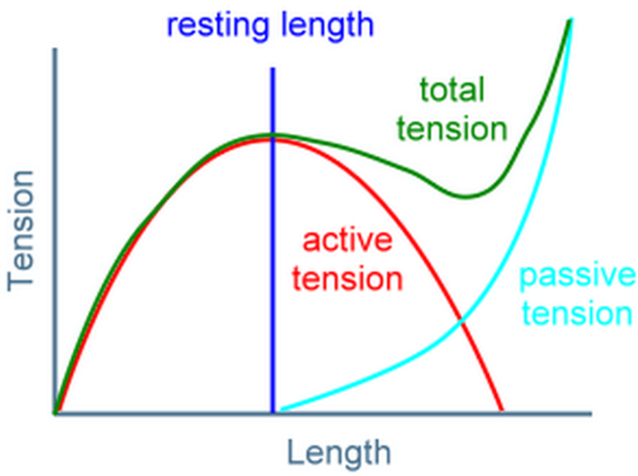
A multivariate model was used to determine the relation between previous injury, and the risk of injury. The study results noted that players who were injured in the 2001 season were at a higher risk of becoming injured. The risk of any injury in the following season compared with non-injured players (hazard ratio 2.7; 95% confidence interval 1.7 to 4.3, $p<0.0001$). Interestingly, the study found that players with a previous injury such as groin, hip/knee/ankle joint or hamstring were found to be twice as likely to suffer a similar injury the following season. A study over a longer period would be a real indicator of this type of factor.

It should not be overlooked that the rehab process should also be earmarked as a factor of re-injury. If an athletes rehab is over zealous or ramped up at the wrong time then it may lead to re-injury (Croisier, 2004). The study by **(**Croisier, 2004) explored the idea that athletes who were exposed to rehab protocol that were not continuously monitored or even off the cuff increase of intensity of rehab were more likely to re-injury the same structure/area. They highlighted the necessity to put in place a though diagnosis of injury causation and then the injury should be conducted with constantly guidance of the therapist to insure re-injury risk is reduced. A brilliant study by (Silder, Reeder and Thelen, 2010) looked at the after effect of tissue remodelling after injury. The noted that post injury the structure may not function as it did before injury. They tried to prove this assessing the effect of prior hamstring strain injury on muscle tissue displacements and strains during active lengthening contractions.



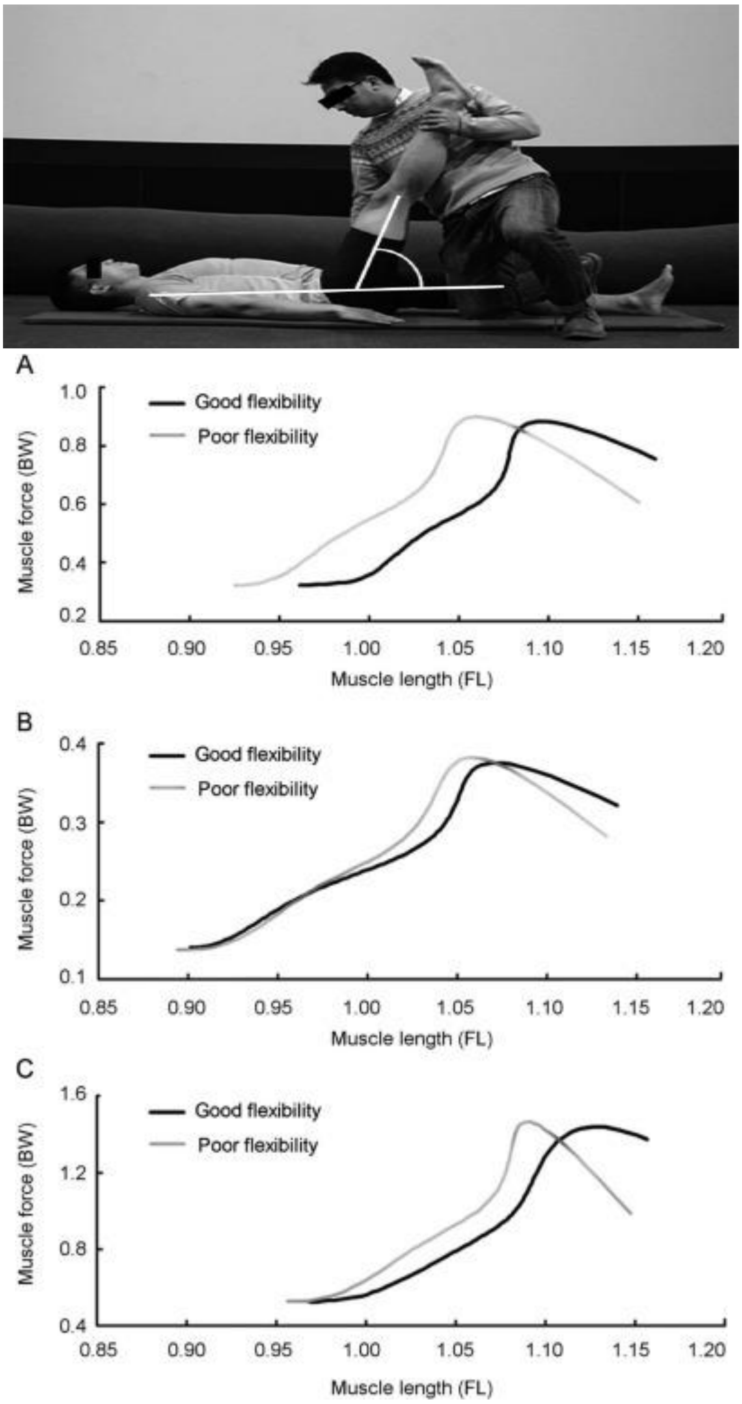
This graph shows the stress strain graph and at what points it can be overloaded and enter the plastic region Source: (Pollen, 2018).

There were 11 healthy participants and 8 participants with previous HSI injury. All the previously injured participants had returned to sport before the study began. The participants performed cyclic knee flexion-extension on an MRI-compatible device using elastic and inertial loads, which induced active shortening and lengthening contractions. They used the MRI imaging to measure tissue velocities within the biceps femoris during these muscles activation. Numerical integration of the velocity information was used to estimate two-dimensional tissue displacement and strain fields during muscle lengthening. The largest tissue motion was observed along the distal musclo-tendon junction (TMJ), with the active lengthening muscle exhibiting significantly greater. They noted that while both sets of participants were under strain during loading of the MTJ, The previously injured subjects showed restricted tissue motion and significantly greater strains near the proximal MTJ.



Tension and muscle length Chart.
Source: (Pollen, 2018).

They concluded that post-injury remodelling of tissue may alter the range of motion in the tissue seen by muscle tissue and play a big part in re-injury to the relatively larger localized tissue near the proximal MTJ. This would seem to indicate that tissue that that may be strong but lacking in ROM is more likely to become re-injured. This may be backed by a study from (Worrell et al., 1991) that looked to compare isokinetic strength and flexibility scores between hamstring injured and non-injured athletes.

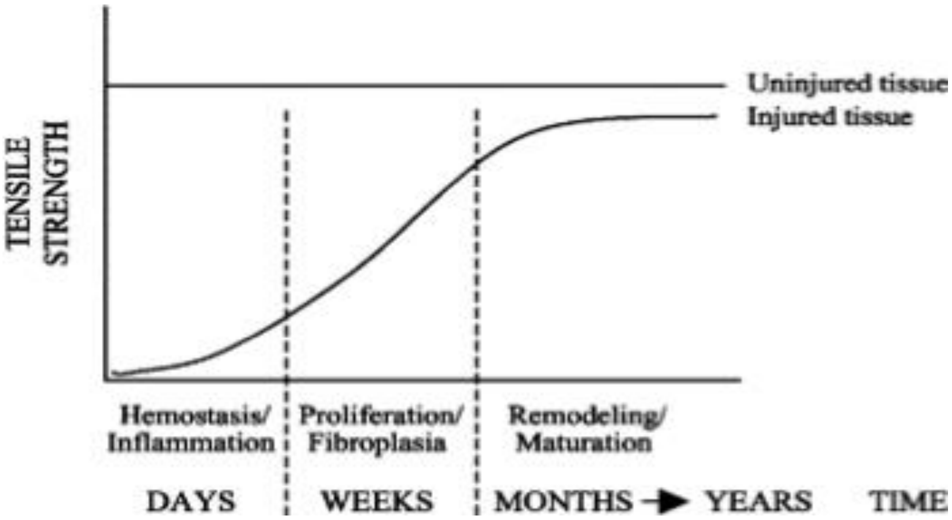


Hamstring Length Force Graphs.
Source: (Wan et al., 2017)

Hamstring muscle length–force relationships of 2 participants with different flexibility: (A) biceps long head; (B) semimembranosus; (C) semitendinosus.

Muscle length was normalized as a fraction of femur length (FL). Muscle force was normalized as a fraction of body weight (BW).

Sixteen university athletes with history of hamstring injury were tested using motor dominance, sport, and position against sixteen university athletes without history of hamstring injury recorded. Each participant underwent tests to assess concentric and eccentric quadriceps and hamstring peak torque and reciprocal muscle group ratios. A Kinetic Communicator dynamometer was used at 60 degrees /sec and 180 degrees /sec. Every participant hamstring flexibility was determined by passively extending the knee while the hip was maintained at 90 degrees of flexion and measurements were taken. After the data was analysed using Analysis of Variance they noted that there was no difference in strength between the injured and non-injured groups. However, they did note that the injured group were significantly less flexible than the non-injured group. This would lend proof to the hypothesis that the injured athletes undergoing remodelling of tissue after injury tend to be less flexible at the MTJ, this may lead to a heightened risk of HSI.



Tissue Loading Chart

Source: Electrotherapy.org, 2018

It would be remiss to mention that after a sustained period of inactivity post injury that there is going to be a certain amount of atrophy of muscle (Appell, 1990).

A study by (Silder et al., 2008) used magnetic resonance imaging to investigate long-term changes in muscle and tendon morphology post hamstring strain injury. Images were taken from 14 participants who had had a hamstring injury grade one/two between five and 23 months, the study also included 5 healthy participants. The hamstring tendon and muscle scars volumes measures in the biceps femoris long head (BFLH), biceps femoris short head (BFSH), the proximal semimembranosus tendon, and the proximal conjoint biceps femoris and semitendinosus tendon. The difference in tendon and muscle volume were compared statically from the previously injured athletes against the healthy athletes.

High resolution static images.
Source: (Silder, Reeder and Thelen, 2010).

Images were obtained for all subjects and used to assess bilateral asymmetries in hamstring morphology. This example shows the visible differences in tendon/aponeurosis morphology at the site of prior injury that was evident for all of the previously injured subjects

The results showed that there was an increased low-intensity signal present along the musculotendon junction at the site of presumed prior injury for 11 of the 14 subjects. This would suggest of persistent scar tissue. The 13 subjects with biceps femoris injuries displayed a significant decrease in BFLH volume ($p < 0.01$), often accompanied by an increase in BFSH volume. Two of these subjects also presented with fatty infiltration within the previously injured BFLH. This study has showed that there is a period of remodelling due at the site of the HSI. This would surely highlight the fact that many athletes would return to sport before the remodelling process is over and the tissue would be a higher risk of injury due to the inflexibility and atrophy at the site of previous injury (Silder, Reeder and Thelen, 2010).

Age

Age has long been linked HSIs or recurrent HSIs, there have been studies done across sports such as football, rugby and Australian football that have concluded that players over the age of 24 have an elevated risk of HSIs (Orchard, 2001; Gabbe, Bennell and Finch, 2006; Woods, 2004; Hagglund, 2006; Petersen et al., 2010). Furthermore, there have been follow up studies stating that each year of age the risk of HSIs increased by 1.3 times fold in Australian Footballers (Verrall, 2001) and up to 1.8 times fold more in soccer players (Henderson, Barnes and Portas, 2010). It is important to note that all the studies that noted this used regression or multivariate analysis to conclude that increasing age is an injury risk (Woods, 2004). A very interesting study by (Gabbe, Bennell and Finch, 2006) that looked to shed some definitive light on why HSIs risk increased with age looked at decreased hip flexibility and increased weight in athletes over the age of 25.

This study did show significance but the increase was moderate and in line with expected risk ratios (Gabbe, Bennell and Finch, 2006). Other noted studies that identified increasing age as a risk factor for HSIs looked at decreased muscles mass and strength as a probable risk (Gabbe et al., 2006). There was a standout flaw of that study as the data may have been influenced by the fact it included non-elite, non-athletic cohorts of significantly greater age ranges than are observed in elite sport, furthermore the study included athletes with lumbar spine pathologies (Orchard, 2004).

A study by (Gabbe et al., 2006) noted that there were significant differences between old and young athletic groups in respect to body weight, body mass index, hip flexor flexibility, hip internal rotation and ankle dorsiflexion range of movement. Body weight and hip flexor flexibility were significant independent predictors of hamstring injury in players aged > or =25 years. They concluded that as the athlete progressed they should areas that are modifiable be looked after as the method to reduce HSIs. An interesting study undertaken by (Kirkendall and Garrett, 1996) looked at athletes unmodifiable age linked with loss of muscle mass as a greater risk to HSIs. They noted that muscles loose both cross-sectional area and fiber numbers, with type II muscle fibers being the most affected by aging. This may also be accompanied by some denervation of fibers. The combination of these factors leads to an increased percentage of type 1 fibers in older adults. At a metabolic level, the glycolytic enzymes seem to be little affected by aging, but the aerobic enzymes appear to decline with age. Aged skeletal muscle produces less force and there is a general reduction of intensity of fiber contraction and of the mechanical characteristics of the muscle (Lundby and Jacobs, 2015). However, neither reduced muscle demand nor the subsequent loss of function is inevitable with aging. When highlighted in time and proper measure lept in place to use as a base line these losses can be minimized or even reversed via specific training. Endurance training can improve the aerobic capacity of muscle, and resistance training can improve central nervous system recruitment of muscle and increase muscle mass (Burgomaster, Heigenhauser and Gibala, 2004). The common conclusion of all the mentioned studies were aimed at keeping physical active throughout life to prevent much of the age-related impacts on the skeletal system.

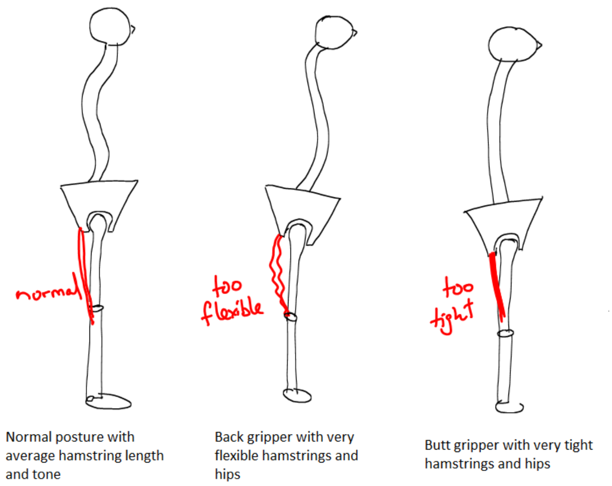
Ethnicity

It has been touted that ethnicity may be a risk factor for HSIs. However there are limited studies done on this topic. Studies by (Verrall, 2001; Woods, 2004; Brooks et al., 2006) have identified Aboriginal and Black African or Caribbean ethnicity as risk factors for HSIs. This study by (Verrall, 2001) tried to highlight risk factors for hamstring muscle strain injury using magnetic resonance imaging (MRI) to define the diagnosis of posterior thigh injury. The prospective cohort study used two elite Australian Rules football clubs, the anthropometric characteristics and past clinical history of 114 athletes were recorded. Players were followed throughout the subsequent season, with posterior thigh injuries being documented. While this study did note ethnicity as a factor it didn't identify it as a sole factor of increased risk of HSIs. A more in-depth study by (Woods, 2004) over two years recruited the medical staff at 91 professional clubs and documented the injuries of players. They used a specific injury assessment form to highlight HSIs. The study noted an average of 90 days and 15 matches missed per club in each season due to SHO. In 57% of cases, the injury occurred during running. Hamstring strains were most often observed during matches (62%) with an increase at the end of each half ($p<0.01$). Groups of players sustaining higher than expected rates of hamstring injury were Premiership ($p<0.01$) and outfield players ($p<0.01$), players of black ethnic origin ($p<0.05$), and players in the older age groups ($p<0.01$). Only 5% of hamstring strains underwent some form of diagnostic investigation. The re-injury rate for hamstring injury was 12%. However, this study also didn't highlight ethnicity as a sole factor for increased HSIs, they concluded like the other studies that a differential diagnosis and patient-specific assessment should be undertaken with an open mind.

The reason ethnicity has been noted as a risk factor is due to the higher amount of fast twitch fibres in these population (Friden and Lieber, 1992; Lieber and Friden, 1988). Furthermore, there is a reported exaggerated anterior pelvic tilt in these populations which may lead to the hamstrings being in a lengthened position when activated thus increasing the risk of a HSI (Hennessey and Watson, 1993).

Flexibility

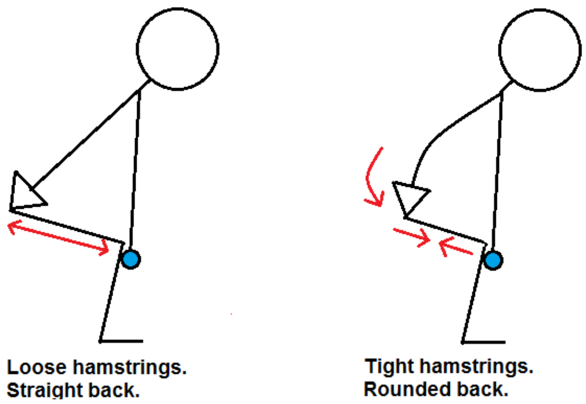
Lack of flexibility has long been associated with the heightened risk of HSIs without having a any conclusive significance (Worrell and Perrin, 1992; Witvrouw et al., 2004). It was suggested that the more flexible the hamstrings were that the more force to could absorb while being in a less the preferable lengthened position (Lewis, 2014; Bennell, Tully and Harvey, 1999). But is there a situation where your chances of injury are increased if you too flexibly as opposed to inflexibly as in the pic below.



Hamstring Length Linked to Pelvis Position.
Source: Why Things Hurt, 2018

Numerous studies that looked at the link between the sit and reach test scores link to HSIs in Australian and American footballers all failed to find significant results to link both (Arnason et al., 2007; Bennell, Tully and Harvey, 1999; Gabbe et al., 2006). Furthermore, the study by the latter also noted that poor hamstring flexibility, judged by active and passive knee flexion test of straight leg raise test, was not a risk factor for HSIs. A study by (Yeung, Suen and Yeung, 2009) also concluded that sprinter with reduced hamstring flexibility did not increase the risk of contracting a HSI. Bennell et al. (1999) investigated the lumbo-femoral relationship in the toe-touch test, i.e. rather than limiting movement at the spine, pelvis and hip, discrete measurement of movement at these points was recorded and analysed in relation to subsequent injury (Foreman et al., 2006). There was no significant association was found, the research suggests that the greatest alteration in the lumbo-femoral relationship occurs in the first third of the toe-touch test rather than at the end position where the measurement was taken (Van et al., 1995). Further analysis of the lumbo-femoral ratio throughout range would help identify any association.

This depicts the effect of the lumbar region in a seated position where tight hamstrings are indicated.



Source: (Pieciak, 2018)

However, there are numerous studies that claim links between flexibility and HSIs risk (Henderson, Barnes and Portas, 2010), (Bradley and Portas, 2007), (Witvrouw et al., 2003). One of these studies, (Witvrouw et al., 2003) hypothesized that increased tightness in the hamstrings would leave players more sceptical to HSIs. The study examined 146 male professional soccer players at the start of the 1999-2000 Belgian soccer league. The players monitored did not have a history of muscle injury in the lower limb in the previous 2 years. The flexibility of the hamstring, quadriceps, adductor, and calf muscles of these players we remeasured before the start of the season. All the players monitored throughout the season had to register all injuries that occurred. After the results were analysed they concluded that the players that showed signs of increased tightness of the hamstring or quadriceps muscles had a statistically higher risk for a HSIs. Henderson, Barnes and Portas (2010) also reported that lack of range of motion was linked to an increased risk in HSIs. This study however also looked at the players performance levels, angle of peak torque and other factors so they could only conclude that hamstring tightness was only a part of a multifactorial reasoning for increased risk to HSIs.

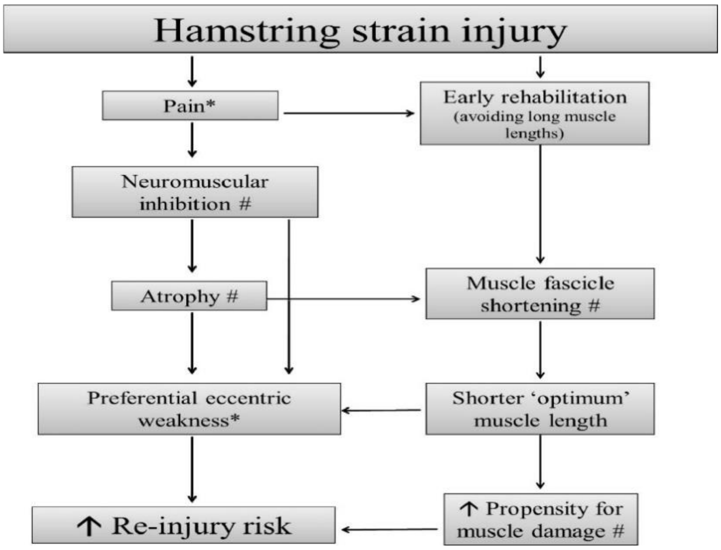
With no definitive confirmation of the influence of hamstring inflexibility when it comes to increased risk factors for HSIs, it might be wise to keep in mind there may be flaws in the tests or even the way the tests were administered for each participant. Most of the studies mentioned concluded that hamstring flexibility is most likely part of a multifactorial issue that causes the increased risk to HSIs.

Poor Trunk Stability

A less investigated risk of HSIs is the role of poor trunk stability. However, a study by Sherry (2004) compared the success rate of 2 different rehabilitation programs for acute HSIs. They took 24 athletes with acute HSIs and randomly assigned them to 1 of 2 rehabilitation groups. In total 13 of the athletes undertook a program that consisted of agility and trunk stabilization exercises in a progressive manner and icing (PATS group). The other 11 athletes underwent a protocol consisting of static stretching, isolated progressive hamstring resistance exercise, and icing (STST group). The data collected looked at the number of days for full return to sports, injury recurrence within the first 2 weeks and lower-extremity function after HSIs. The results of this study are a little bit difficult to read but seem to learn on favour of the PATS group, even if the difference was not significant. They did state that the average time required to return to sports for athletes in the STST group was 37.4 +/- 27.6 days, while the average time for athletes in the PATS group was 22.2 +/- 8.3 days. The STST group showed a significantly higher risk of re-injury in the first two weeks of returning to sport, where 6 of 11 athletes undergoing the stretching and strengthening program suffered a recurrent HSI, in comparison to zero of the 13 athletes in the PATS group. After 1 year of return to sports, re-injury rate was significantly greater in the STST group. Seven of 10 athletes who completed the hamstring stretching and strengthening program, as compared to only 1 of the 13 athletes who completed the progressive agility and trunk stabilization program, suffered a recurrent HSI over the following 12 months. The results of this study would learn towards concluding that a progressive core strengthening and agility program is a more effective way of preventing recurrent HSIs in the sporting population. It should be noted however that the severity of HSI was not noted. This could have swayed the data if a group of athletes were to of had more severe HSIs that would automatically entail a longer return to play timescale.

Neurological Impairment

Due to the anatomical site f the Sciatic nerve it has often been reported that nerve pain sometimes accompanies HSIs (Miller et al., 1987; Carmody and Prietto, 1995).



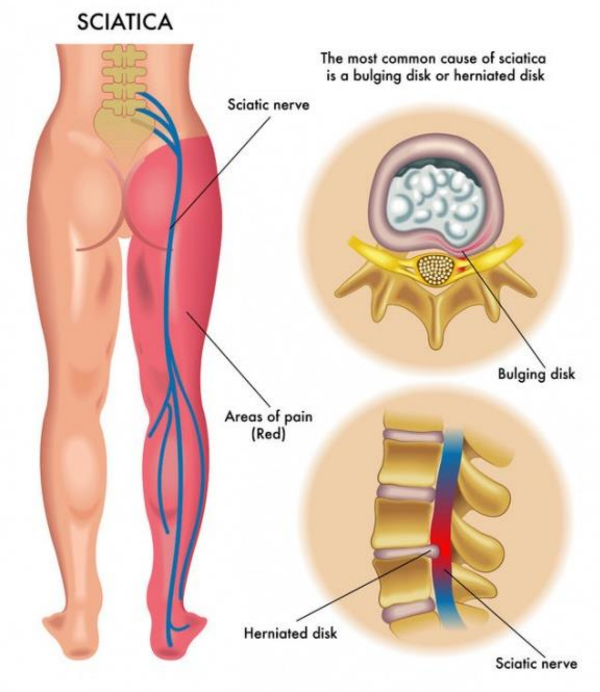
Hamsting Injury Chart

Source: (Van Heumen et al., 2018)

The above pic shows the phases of a hamstring strain and how neural inhibition is involved in the process of injury

A study by Kouzaki et al. (2017) looked to assess sciatic nerve conductivity in athletes with a history of HSIs. They used 27 athletes that had a history of HSIs and classed it as the injured group. They also had a control group that consisted of 16 athletes with no history of HSIs. The study measured the proximal and distal latencies and calculated the sciatic nerve conduction velocity to evaluate neuronal conductivity. The results of the study stated that both proximal latency and distal latency of the injured limb in the injured group were significantly longer than those of the uninjured limb ($p<0.05$). The nerve conduction velocity of the injured limb in the injured group was significantly lower than that of the uninjured limb ($p<0.05$). Due to these results, the study concluded that the sciatic nerve conductivity impairments do exist in athletes with a history of HSIs. A study by (Wilson et al., 2017) further back this by looking at the sciatic based symptoms after a proximal avulsion fracture and repair with referring symptoms to the distal hamstring. The study paid attention to neurologic symptoms in operative patients and compared against pre- and postoperative patients. There were 162 patients reviewed in total. Of the162 patients: 67 (41.4%) operative and 95 (58.6%) nonoperative. Sciatic nerve symptoms were noted in 22 operatives and 23 nonoperative patients, for a total of 45 (27.8%) patients (8 [4.9%] motor deficits, 11 [6.8%] sensory deficits, and 36 [22.2%] with neuropathic pain). Among the operative cohort, 3 of 3 (100.0%) patients showed improvement in their motor deficit postoperatively, 3 of 4 (75.0%) patients' sensory symptoms improved, and 17 of 19 (89.5%) patients had improvement in pain. A new or worsening deficit occurred in 5 (7.5%) patients postoperatively (2 [3.1%] motor deficits, 1 [1.5%] sensory deficit, and 3 [4.5%] with new pain). Predictors of operative intervention included lower age (odds ratio [OR], 0.952; 95% CI, 0.921-0.982; $P = .001$) and complete avulsion (OR, 10.292; 95% CI, 2.526-72.232; $P < .001$). The study went on to conclude that when there is and under recognised effect on the sciatic nerve the made masquerade as HSIs in avulsion injuries of the hamstrings.

A study by Orchard (2004) that asked the question if there was a connection between lumbar spine region pathology and hamstring and calf injuries in athletes. The paper looked at the common occurrence of calf and HSIs in the older athletes and questioned if it could be linked to theory that subtle lumbosacral canal impingement of the L5 nerve root could be the causative factor. The paper looked at MRI images of disc position and their impact on the L-5 nerve. They looked at the link between disc height and disc degeneration in the athlete's Lumbar spine. The went on to conclude there is every possibility that the impingement of the L5 nerve root could be the cause to HSIs.



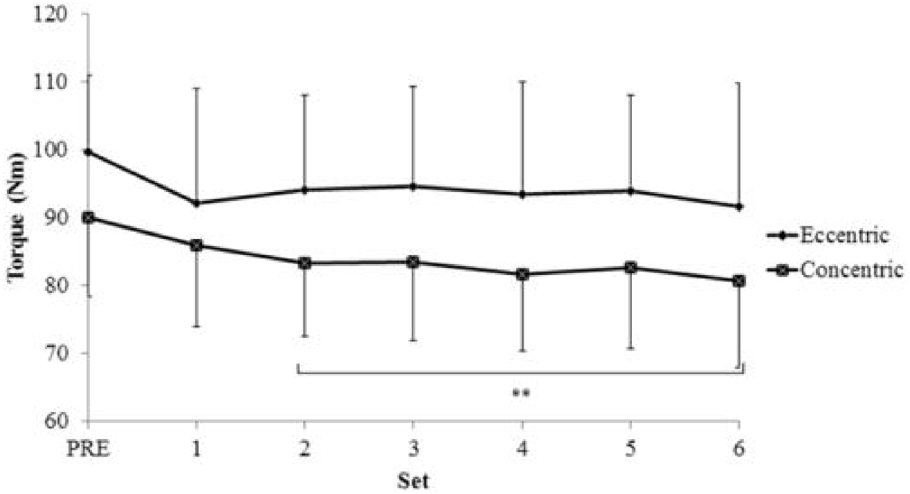
Disc Issues Related to Hamstring Pain.
Source: *https://www.ansellchiropractic.com.au/complete-sciatica-guide/*

However, it should be noted that when we have the impingements of the never in certain areas such as lower back or piriformis they are usually named as sciatic or piriformis syndrome respectively. They went on to advise that an in-depth assessment will highlight the issue and the treatment should be directed by the outcomes of the assessment.

Fatigue

Fatigue is another factor that has been long linked to causation of HSIs (Heiser et al., 1984; Worrell and Perrin, 1992; Mair et al., 1996). It is noted in a wide number of studies that the greater number of HSIs occur in the latter parts of the games, for this reason these is a lot of studies that concluded that fatigue is a big factor in HSIs (Brooks et al., 2006; Woods, 2004; Mayor, 2004; Hawkins and Fuller, 1999).

The effect of fatigue on muscle lengthening properties, on rabbits, was initially examined in a laboratory setting. The muscles that were pre-fatigued via electrical stimulation absorbed less energy before failure when compared with unfatigued muscles. The data showed that muscles are injured at the same length, regardless of the effects of fatigue. However, fatigued muscles are able to absorb less energy before reaching the degree of stretch that causes injuries (Mair et al., 1996). This would suggest that even those though muscles injured at the same length the number of time the muscles is lengthen increases the hamstring to Injury. As that study was perform on rabbits we should really apply human movement patterns to any conclusions. The below graph shows how torque values decrease after successive reps or tasks.



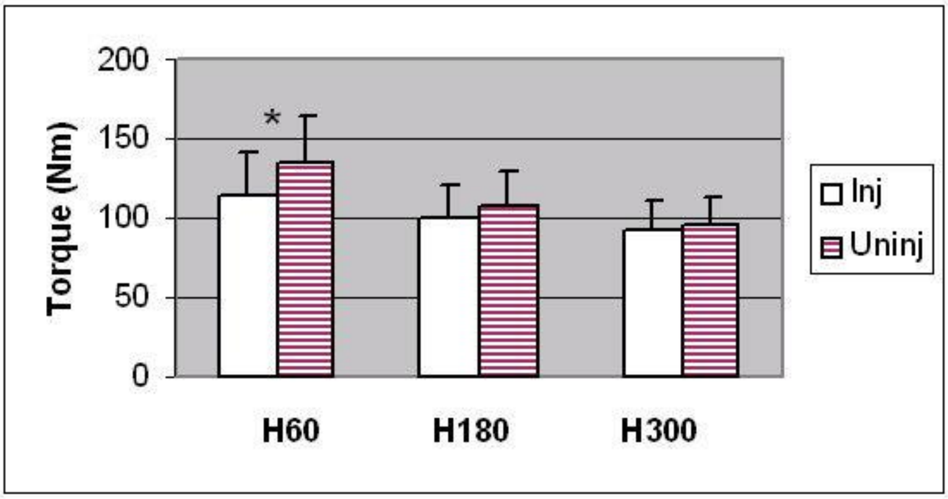
Eccentric vs Concentric Hamstring Chart

Source: Marshall et al., 2015

A study by (Pinniger, Steele and Groeller, 2000) showed the fatigue of the hamstrings induced by repeated dynamic efforts leads to an increase in the amount of knee extension observed during the terminal swing phase of running. The increased knee flexion could be expected to lead to a greater strain on the hamstring at the end of range during the terminal swing phase (Thelen et al., 2004). If we consider this we must also look at a study by (Allen, Leung and Proske, 2010) that looked at elbow and knee flexors positioning after a bout of fatigue. They found that knee flexor position was altered to where the individuals thought it was after fatigue. This would suggest that an individual's perception of how lengthened the hamstring may be is not quite true and this may inadvertently increase the risk of HSIs through repeated lengthening due to the reduced proprioception capability by the individual. (Morgan, 1990) suggested that such deficits in proprioception when fatigued may elevate the risk of HSIs given that continual over-lengthening would lead to microscopic muscle damage that may accumulate to become macroscopic damage, ie HSIs.

Hamstring Strength

Many studies have pitted one hamstring against the other, hamstring strength in an injured limb vs a non-injured limb. Furthermore, numerous studies found that used comparisons of knee flexor strength between previously injured and uninjured athletes that noted a significant difference in strength deficit in the previously injured hamstrings (Croisier, 2004; Dauty, 2016; Opar et al., 2012; LEE et al., 2009). These studies did not however highlight the fact there may have been some weakness in on leg before the injury. Interestingly, if we highlight hamstring weakness as a risk to injury then it may be a long-lasting issue that even a lengthy rehab and return to play protocols can't overcome as studies done months after injury still show a weakness in the injured hamstring (Brown et al., 2008; Jonhagen, Nemeth and Eriksson, 1994; Sugiura et al., 2008).
I have found two prospective studies that suggested that a low eccentric hamstring to concentric quadriceps torque ratio (the functional H:Q ratio) would leave athletes at an elevated risk of HSIs (Croisier et al., 2008; Sugiura et al., 2008), it must be noted that Bennell et al, (1998) concluded that there was no such association.



Torque in Healthy vs Unhealthy Hamstrings
Source: (O'Sullivan et al., 2008)

Comparison of hamstrings (H) average peak torque values between previously injured (Inj) (n = 13) and uninjured (Uninj) (n = 29) dominant limbs at 60°/sec, 180°/sec and 300°/sec. * indicates a statistically significant difference ($p < 0.05$)

Another interesting protocol to address HSIs through strength has been the Nordic Hamstring Curl (NHC) protocol. There have been some lengthy studies that lend evidence to the beneficial role of NHC in hamstring eccentric strength which in turn reduces the risk of HSIs (Arnason et al., 2007; Petersen et al., 2011). Roughly half the participants followed a strict plan of completing the NHC protocol 24 times in the 10-week pre-season before being continued once each week in the competitive season. Petersen et al. (2011) concluded that these participants were six times less likely to suffer a recurrence than previously injured players from control teams. This finding strongly supports the benefits of eccentric hamstring training in rehabilitation from hamstring strain.

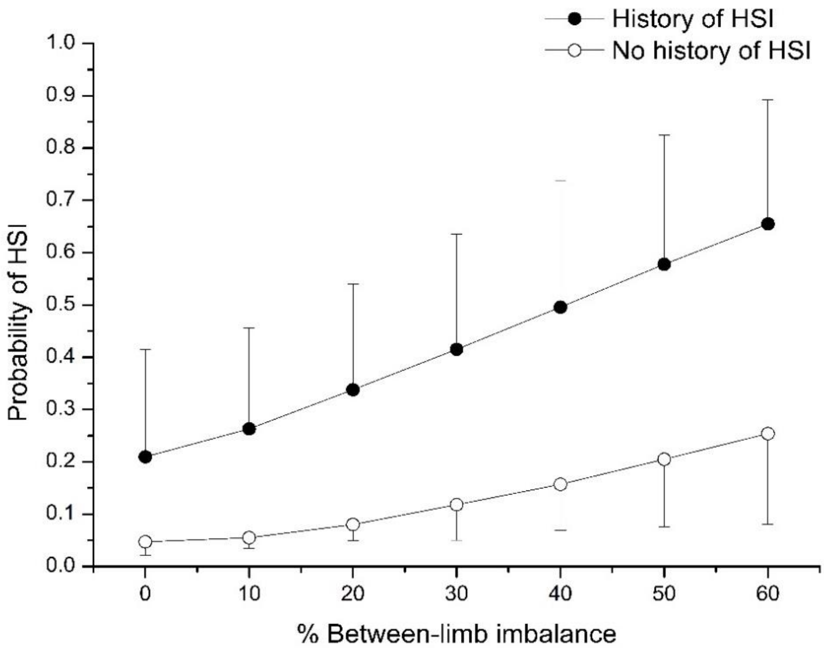
Strength Imbalance

Much like strength of the hamstring has linked to a risk of HSIs, a strength imbalance has been a topic of discussion for quite some time (Burkett, 1970; Khan, 2009). The study by (Croisier et al., 2008) looked to prove if reduced strength could be an indicator of possible HSIs. It also then tried to establish if correcting the strength imbalance to reduce the risk or incidence of HSIs. To try achieving this they tested 687 soccer players in preseason using an standardized isokinetic testing protocol. They took both the concentric and eccentric strength score of the players to highlight the differences. They then put the players into four group classifications according to their scores and previous HSIs called the relative risk group. Unfortunately, little over half of the players were retested. Of the groups retested there was a total of 35 HSIs recorded. They noted that the rate of muscle injury was significantly increased in cases with untreated strength imbalances in comparison with players showing no imbalance in preseason (RR 4.66 with 95% CI 2.01 – 10.8). The risk of HSIs stayed significantly high in players with strength imbalances and subsequent compensating training but no final isokinetic control test than in players without imbalances (RR 2.89 with 95 % CI 1.00 – 8.32). Conversely, normalizing the isokinetic parameters reduced the risk factor for injury to that observed in players without imbalances (RR 1.43 with 95% CI 0.44 – 4.71) (Croisier et al., 2008). The study goes on to conclude that strength imbalance detection should be used as a preseason tool to give an early indication of HSIs. Furthermore, they also conclude that untreated strength imbalances increase the rate of subsequent hamstring injury, while restoring normal strength ratios of agonist/antagonist in players with preseason imbalances will significantly reduce the risk of HSIs.

Another study by looked at the role of muscle imbalance to predict HSIs was undertaking using track athletes at American footballers. They used the same set of tests on both groups that included cable tension test on knee flexion, knee extension and finally the sit and reach test. While this study claimed that muscle imbalance was an indicator of HSIs I find it hard to understand how the sit and reach test was applicable. Furthermore, the two sports are drastically different in movement. It’s not to assume that American footballers may be less flexible and more powerful. The track athletes event also is not mentioned, this could be a significant factor due to the wide range of types of events and different hamstring requirements of each.

Hamstring Bilateral Asymmetry

It has been suggested that a significantly weaker hamstring on one leg in comparison to the other leg, may predispose the weaker hamstring to a higher risk of HSIs. A study by (Orchard et al., 1997) recorded the preseason measurements of 37 Austrialian Rules football league teams for quadriceps and hamstring muscle concentric peak torque at 60, 180, and 300 deg/sec on a Cybex 340 dynamometer. The players were then monitored throughout the season. A total of 6 players sustained hamstring injuries that meant missing playing time. Upon investigation of the data of which started that the hamstring-to-quadriceps peak torque ratio at 60 deg/sec on the injured side was less than the hamstring peak torque ratio at 60 deg/sec in the other hamstring. The study noted that the players that had incurred these injuries all had a bilateral weakness on the same side that was injured. A study using elite sprinters by (Sugiura et al., 2008) looked at muscle strength of the hip extensors, as well as of the knee extensors and flexors. The data collected was investigated to determine if a possible relationship between strength deficits and subsequent hamstring injury within 12 months of testing was identified. The study simulated the specific muscle action during late swing and early contact phases when sprinting to determine the outcome. This was a very interesting study as there had been no prospective studies in elite sprinters that examine the concentric and eccentric isokinetic strength of the hip extensors and the quadriceps and hamstring muscles, at least not in a fashion that reflects the muscle actions in late swing or early contact phases of sprinting.



Limb imbalance in injured and uninjured hamstring
Source: (Bourne et al., 2015)

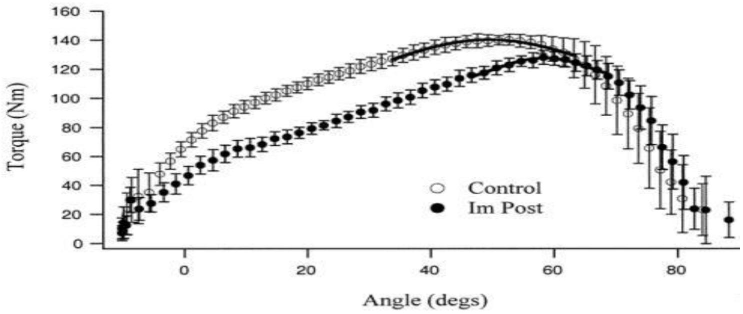
The study performed Isokinetic testing on 30 male sprinters to assess hip extensors, quadriceps, and hamstring muscle strength. The sprinters were monitored and the occurrence of hamstring injury injuries were noted during the year following the measurements. The strength of the hip extensors, quadriceps, and hamstring muscles, as well as the hamstrings-quadriceps and hip extensors- quadriceps ratios were compared.

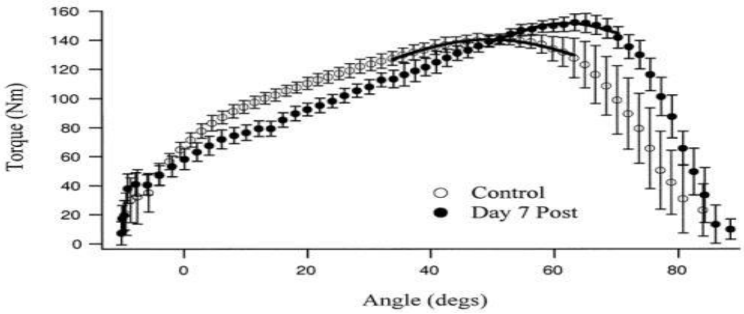
Over the one year period there was 6 noted hamstring injuries. After the Isokinetic testing at a speed of 60 degrees /s, it revealed weakness of the injured limb with eccentric action of the hamstring muscles and during concentric action of the hip extensors. When the data was looked at there was notable difference in strength on the weaker limbs side to the one that was not injured. The study went on to conclude that HSIs in elite sprinters were associated with weakness during eccentric action of the hamstrings and weakness during concentric action of the hip extensors, but only when tested at the slower speed of 60 degrees /s. Contrary to this conclusion, a study by (Yeung, Suen and Yeung, 2009) who looked for the best way to predict HSIs in prone to injury athletes. The 44 athletes were monitored during training and matches over a 12 month period. This was done via preseason assessment of hamstring flexibility, concentric and eccentric isokinetic peak torque and peak torque angle. Of the 44 athletes monitored there were 8 HSIs recorded. When the date was investigated it stated that using ox regression analysis it revealed that athletes with a decrease in the hamstring: quadriceps peak torque ratio of less than 0.60 at an angular velocity of 180 degrees/s have a 17-fold increased risk of hamstring injury. The study went on to conclude that it is the difference peak torque at certain angles and not overall strength was the true predictor of HSIs in preseason.

Angle of Peak Torque

There has been a lot of studies focused around isokinetically-derived angle of peak knee flexor torque measurements to identify risks for HSIs (Brockett, Morgan and Proske, 2004; Brockett, Morgan and Proske, 2001; Heiderscheit et al., 2005). Furthermore, these scores have been used as a marker of re-injury risk, return to play protocol and rehabilitation process while having very limited evidence to support it (Orchard, Best and Verrall, 2005; Warren et al., 2008; Brughelli, Nosaka and Cronin, 2009).

Eccentric exercise, where the contracting muscle is lengthened, produces microscopic damage in muscle fibers, and sensations of stiffness and soreness, the next day (Jones, Newham and Clarkson, 1987). These usually resolve within a week but a more lingering effect can be a muscle strain. Because strain injuries are known to occur during eccentric contractions, it is hypothesized that the microscopic damage from eccentric exercise can, at times, progress to a muscle strain (Prasartwuth, Taylor and Gandevia, 2005). As the amount of microscopic damage depends on the muscle's optimum length for active tension, it is also proposed that optimum length is a measure of susceptibility for muscle strains (Jordan et al., 2009). A study by Brockett, Morgan and Proske (2004) took the mean optimal angle of peak torque of 27 athletes with the optimum angle determined by using isokinetic dynamometry. Nine of the athletes had a history of unilateral HSIs and they were compared against the other 18 athletes with no history of HSIs. The results of the study found that in previously injured muscles, torque peaked at significantly shorter lengths than for uninjured muscles. These results lead to the study concluding that shorter optimum of previously injured muscles makes them more prone to damage from eccentric exercise than uninjured muscles. The shorter optimum in the previously injured muscle may reflect the muscle's preinjury state or be a consequence of the healing process and this may account for the high reoccurrence of HSIs. With this in mind is it acceptable to state that if we exercise a protocol to shift the optimum rage to a preferred length will it then lead to a reduced risk of HSIs.





Source: Brockett, Morgan and Proske, 2001

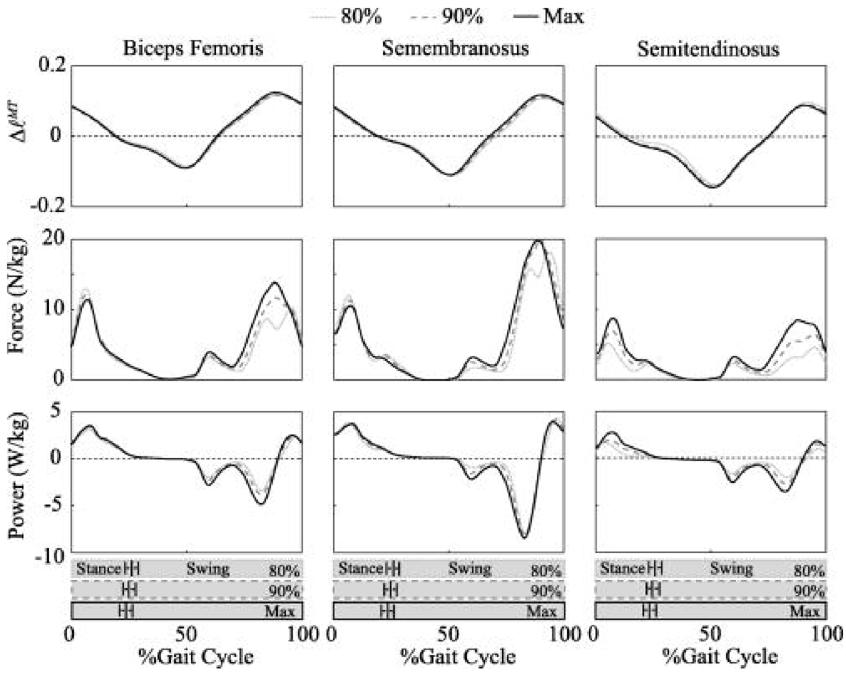
Brockett, Morgan and Proske (2001) stated that by doing a session of unaccustomed eccentric exercise would cause damage to muscle fibers due to the DOMS effect, while followed up that initial session within a week with another session would lead to a less severe damage to the fibers. With this in mind they set about training10 athletes, 8 male and 2 female, using Hamstring Lowers as an exercise. There used the parameters of 2 sets of 6 repetitions which was performed on specially designed apparatus. Hamstring angle-torque curves were constructed for the athletes while they performed maximum voluntary knee extension and flexion movements on an isokinetic dynamometer. Testing sessions were performed over the week before eccentric exercise, immediately post exercise, and daily, up to 8 days post exercise. Six subjects performed a second bout of eccentric exercise, 8 days after the first, and measurements were continued up to 10 days beyond that.

The results of the study showed a significant shift of the optimum angle for torque generation. It also showed longer muscle lengths immediately post exercise (7.7 degrees +/- 2.1 degrees, $P < 0.01$) this would indicate an increase in series compliance within some muscle fibers. Furthermore, the athletes also displayed fewer signs of muscle damage after the second exercise bout. This is somewhat of a ground-breaking study as it is the first to show a sustained shift in optimum angle of human muscle as a protective strategy against injury from eccentric exercise.

These finding were back up by a study by (Brughelli et al., 2010) that randomly assigned 28 profession footballers from Spain division 2 league to a eccentric program. There was a exercise intervention group (EG) or a control group (CG). Over the course of the 4-week period, two athletes from the control group suffered HSIs and 2 athletes dropped out. After these drop outs, both groups (EG, n = 13; and CG, n = 11) performed consistent football training during the four-week preseason. The results showed a definite shift in the optimum lengths of the knee flexors were significantly increased by 2.3° in the CG and by 4.0° in the EG. The optimum lengths of the knee extensors were significantly increased only in the EG by 6.5°. These results showed undeniable results that eccentric exercise can increase the optimum lengths of both the knee extensors and knee extensors flexors after a bout of eccentric specific training.

Running Mechanics

It is commonly stated that sprinting, jumping, cutting and stretching are causes of HSIs (Askling et al., 2002; Ekstrand & Gillquist, 1983; Brooks et al., 2006). The act of running accounts for the majority of HSIs in sports such as rugby (Brooks et al., 2006) and soccer (Woods, 2004), this would give weight to the point that the cycle of running effect of hamstrings is demanding. This is further backed by the studies by (Yu et al., 2008; Chumanov, Heiderscheit and Thelen, 2011) that noted that the hamstrings are active for the entirety of the gait cycle, with peaks inactivation during the terminal swing and early stance phases.



Source: Chumanov, Heiderscheit and Thelen, 2011

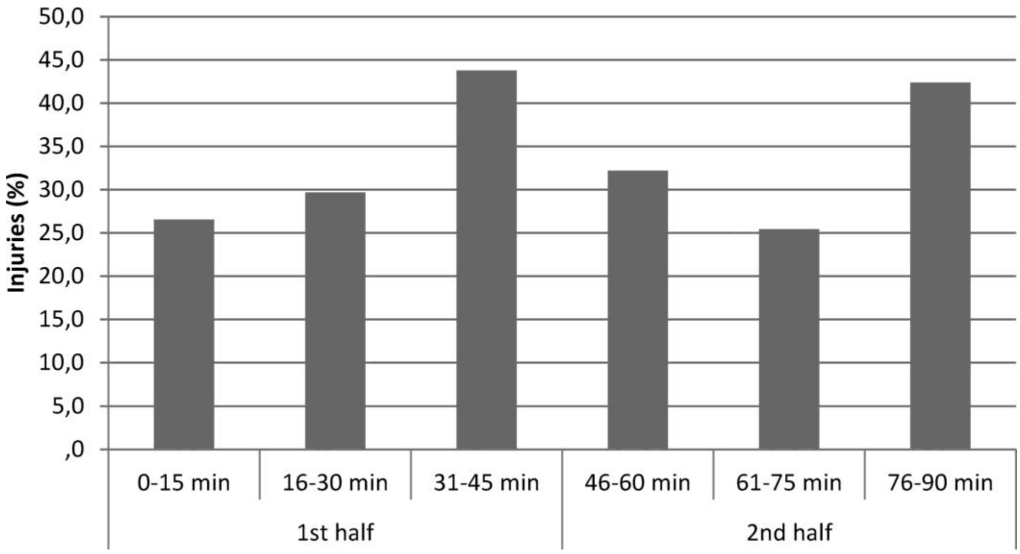
Hamstring musculotendon quantities over 3 simulated sprinting gait cycles (80, 90 and 100% of max speed) for a representative subject. Average (±1 SD) toe-off times are denoted, occurring earlier in the gait cycle as speed increased. The length excursions ([DELTA] [script l]^{MT}) of the hamstring musculotendons are relatively consistent across running speeds, with the lengthening phase constrained to swing phase. Peak swing phase musculotendon forces increased with speed for each of the hamstring muscles. The hamstrings stretch and do negative work (i.e., integral of negative power) on the system from 50% to 90% of the gait cycle and then shorten and do positive work from the end of swing through stance phase.

During the terminal swing phase, the hamstrings are required to contract forcefully whilst lengthening to decelerate the extending knee and flexing hip (Novacheck, 1998). The hamstrings also reach their maximum length during the terminal swing (Thelen et al., 2004). This leaves the hamstring contracting at a high force while it is in its most outer range and with the least amount of fibers overlapping and therefore leading to a high risk of HSIs (Thelen et al., 2004), couple this with the accumulation of this occurring a repeated amount of times over a game period which will take its toll (Thele et al., 2005). Interestingly, the hip reaches its maximal torque while in extending during the contact with the ground during sprinting over ground (Yu et al., 2008). During this phase, the hamstrings are acting mainly concentrically to extend the hip however, previous studies have also noted that an eccentric contraction of the hamstrings occurs during the late stance phase of over ground sprinting (Novacheck, 1998). While the stance phase is possible period of high risk of HSIs due to high hip extension and knee flexion torque (Mann, 1981), it does have the slight advantage of having much shorter hamstring lengths compared with terminal swing (Mann and Sprague, 1980).

Discussion

Following the initial hamstring injury, the predisposing factors must be addressed to help reduce injury moving forward. One of the most pressing factors of re-evaluation risk of re injury is the fact that due to player demands there may not be an adequate amount of time to complete a comprehensive return to play protocol. The most obvious downfall of this is the fact that they may not only be more likely to have a diminished sporting performance but carry a high re-injury rate (Koulouris et al., 2007; Verrall et al., 2006). It should be stated that an adequate warm up should be implemented both before injury and certainly post injury with the emphasis on the causative factor of initial injury. The purpose of a warm up is to prepare one’s body for competition or performance via increasing connective tissue extensibility **(**Hawkins and Fuller, 1999).

That same study went on to highlight that the majority of HSIs recorded in English professional football were credited to less than preferable muscle conditioning and lack of evidenced based warm ups. Here this graph shows the most common time during a football match of 90 minutes that HSIs are most likely to happen, as seen here it is noted that at the end of both half's are the most common time which may point to a factor of conditioning.

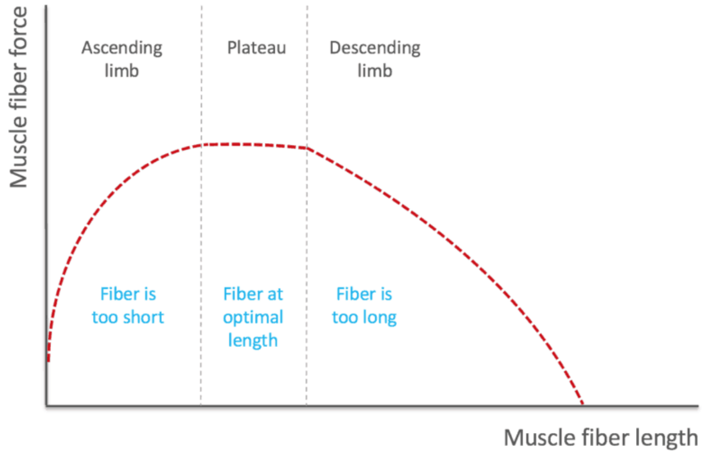


Common Time Frames for Hamstring Injuries
Source: Lundblad et al., 2013

Physically it should be noted that regeneration and remodeling of an injured muscle may continue for up to 9 months after injury, this may be some months after a player has returned to play (Timmons, 2010). Even with these noted risks it is commonly seen in the professional sporting environment, even though a re injury may include an extended period time away from sport for their prize asset (Hallén and Ekstrand, 2014).

Up to now the general consensus for returning to sport has usually been when an athlete can achieve a full range of motion, preferable running form, cutting and change of pace (Tol, 2013). The problem with this is that it is quite vague and a very broad measure which does not incorporate each athlete predisposing factors (Slavotinek, 2006). Injury prevention strategies are numerous. A very common prevention for HSIs is a flexibility program. A major flaw in this as an effective protocol is the lack of clear and decisive guidelines on length of each stretching session and how often (Arnason et al., 2007; Dadebo, 2004). Interestingly, it has been identified that quadriceps lack of flexibility brings an increased risk factor to HSIs, the post effect of a hip flexor flexibility program has not been shown to reduce the risk of HSIs (Gabbe, 2005). It would be best to conduct randomized controlled trials to compare between specific flexibility programs against a control group to determine if stretching should continue as part of the HSIs prevention protocol.

A commonly noted causative factor of HSIs is a reduced angle of peak torque in the hamstrings. Timmins et al. (2015) recently showed that in legs that have had a previous biceps femoris long head HSI displayed shorter biceps femoris long head fascicles compared with the other uninjured legs hamstrings, this less than optimal factor can lead to HSIs. Furthermore, some unpublished work that I have got my hands on have noted that semi pro or professional soccer players that show who display shorter biceps femoris long head fascicles at the beginning of pre-season are 4 times more likely to get a HSI in the season compared to players who have longer fascicles. These results seem to give some small explanation to the force–length relationship of biceps femoris and the benefit of having muscle fibre with longer force length capabilities will mean a reduction in chances of HSIs. Numerous studies have noted that once an athlete overcomes initial HSIs they are less vulnerable to injury after a bout of extended eccentric loading of the hamstrings of which the effects can last a extended period of time (Nosaka et al., 1991). It has been suggested that a rightward shift in the angle of peak torque can help prevent HSIs. This graph shows the relationship or muscle fibers and force. It can be taken from this that the more force the muscle can create in the longer lengths the safer the hamstrings will be.



Muscle Fibre Force vs Fibre Length Graph
Source: Strength & Conditioning Research, 2018

A very popular mode of hamstring prevention protocol is the Nordic Hamstring Curl. This exercise is conducted by having the athletes controlling and eccentric force of lowering their body while lengthening the hamstring muscles using various sets and reps. The picture below shows the most commonly used sets and reps for HSIs prevention

Training Protocol for the Nordic Hamstring Exercise

Week	Sessions Per Week	Sets and Repetitions
1	1	2 × 5
2	2	2 × 6
3	3	3 × 6-8
4	3	3 × 8-10
5-10	3	3 sets, 12-10-8 reps
10+	1	3 sets, 12-10-8 reps

Source: northcurlcurlphysio.com, 2018

Conclusion

This study has reviewed 15 different risk factors of HSIs and managed to link some factors that may lead to a heightened risk of HSIs. It is obvious that injuries are going to happen in sport and especially injuries that have some many risk factors like HSIs. At the very least this study has highlight the fact that players may have a predisposition to a risk factor of HSIs and this can be combatted through a baseline score of test. It is the view of the writer that not only should a thorough assessment be made of the initial injury but the treatment thereafter should be led by the findings of the assessment. Furthermore, if we have an athlete who is more likely to have a HSI due to a certain factor then his continued exercise plan should incorporate the current research on best way to avoid that factor. Even further, where possible the players warm up before his or her sport should incorporate a protocol that will emphasise the suggested area for a period until the values of the risk factor have returned to normal.

Declaration

No portion of the work in this dissertation has been submitted in support of an application for another degree or qualification of this, or any other, university, or other institute of learning.

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