Clinical risk factors for hamstring muscle strain injury: a prospective study with correlation of injury by magnetic resonance imaging

G M Verrall, J P Slavotinek, P G Barnes, G T Fon, A J Spriggins

Abstract

***Objective*—To prospectively establish risk factors for hamstring muscle strain injury using magnetic resonance imaging (MRI) to define the diagnosis of posterior thigh injury.**

***Method*—In a prospective cohort study using 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. Hamstring intramuscular hyperintensity on T2 weighted MRI was required to meet our criteria for a definite hamstring injury. Statistical associations were sought between anthropometric and previous clinical characteristics and hamstring muscle injury.**

***Results*—MRI in 32 players showed either hamstring injury (n = 26) or normal scans (n = 6). An association existed between a hamstring injury and each of the following: increasing age, being aboriginal, past history of an injury to the posterior thigh or knee or osteitis pubis (all $p<0.05$). These factors were still significant when players with a past history of posterior thigh injury (n = 26) were excluded. Previous back injury was associated with a posterior thigh injury that looked normal on MRI scan, but not with an MRI detected hamstring injury.**

***Conclusions*—Hamstring injuries are common in Australian football, and previous posterior thigh injury is a significant risk factor. Other factors, such as increasing age, being of aboriginal descent, or having a past history of knee injury or osteitis pubis, increase the risk of hamstring strain independently of previous posterior thigh injury. However, as the numbers in this study are small, further research is needed before definitive statements can be made.**

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Keywords: hamstring muscle strain; thigh injury; magnetic resonance imaging; risk factors

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A hamstring muscle strain is the most common injury causing a player to miss a game in Australian Rules football.[1] This type of injury is the cause of about 20% of all missed games because of injury in this code of football.[2 3] Although hamstring strain injuries occur commonly, our understanding of the pathophysiology and the factors that predispose athletes to muscle strain injury is limited. Review papers agree that well devised prospective studies of the risk factors for hamstring muscle (posterior thigh) injuries are lacking.[4 5]

In general, risk factors can be broadly categorised into muscle risk factors and clinical risk factors. Muscle risk factors that have been studied include muscle weakness,[2 6–8] lack of flexibility,[9 10] increased muscle stiffness,[11] poor lumbar posture,[12] poor warm up,[9 13] and muscle fatigue.[9 14] Most of these muscle risk factors are difficult to assess and quantify for the purpose of a prospective human clinical study.

Previous studies have shown that the principal clinical risk factor is that many injuries are recurrences of a previous injury. Hence a past hamstring injury has been shown to be a risk factor for future injury.[1 6 15 16] It has also been postulated that a clinical risk factor may be playing at a higher competition level.[17 18] However, these studies also conclude that previous injury and increasing age of the athletes may be confounding variables in the assessment of this risk factor. Few data exist on other clinical risk factors or anthropometric characteristics of athletes that may predispose to an increased likelihood for hamstring muscle injury. It is unclear how age, height, weight, and race of the athlete or having a past history of common football injuries to the back, knee, and/or groin, for example, may effect the risk of sustaining a hamstring muscle strain injury.

The diagnosis of hamstring strain is usually made on clinical grounds. In Australian football there is considerable controversy in many cases of posterior thigh injury (PTI) as to whether a muscle strain is the cause. This is especially so for minor or grade I hamstring strains, where other possible causes for the pain may include referred pain from neuromeningeal structures such as the lumbar spine and sciatic nerve or from nearby muscles such as the gluteal and piriformis.[19] "Back related" hamstring strain is an undefined term generally signifying that the injured athlete has both local hamstring signs and positive lumbar spine signs, and this term has been used to describe these grade 1 and referred pain injuries.[6 20] Risk factors may not be the same for these different diagnoses. Magnetic resonance imaging (MRI) has been shown to be sensitive for diagnosing hamstring muscle strain injuries[21] and better than computed tomography for delineating the extent of injury.[22]

The aim of the study is to establish anthropometric and clinical risk factors for posterior thigh (hamstring strain) injury using MRI to confirm hamstring muscle injury. Elite

Australian Rules footballers were used as subjects to correlate the presence of past clinical history, such as past PTI, back, groin, and knee injuries, with those football players who sustain a PTI during the subsequent playing season. The correlation between anthropometric variables such as age, height, weight, and race with PTI was also studied. After injury, all athletes underwent MRI examination of the posterior thigh to establish the presence or absence of muscle strain injury.

Method

Ethical approval was obtained before the start of the study. The entire senior playing lists of two professional Australian Rules football clubs were registered: 43 from one AFL (Australian Football League; national competition) club and 71 from one SANFL (South Australian National Football League; state competition) club, making a total of 114 subjects. The AFL is the premier competition for Australian Rules football, with the SANFL being a second tier competition.

One author (GMV) interviewed all players before the start of the season. The following were recorded for each player: age, height, weight, and race (aboriginal or non-aboriginal).

Any past history of severe injury was recorded during the interview, and this was correlated with information from the respective team doctors (GMV, PGB). When required, clinical notes were reviewed. The injuries recorded were:

(1) Severe knee injury defined as (*a*) anterior cruciate ligament (ACL) reconstruction, (*b*) previous lateral patellar dislocation, or (*c*) arthroscopic diagnosis of degeneration secondary to a previous knee injury—for example, lateral meniscectomy, posterior cruciate ligament (PCL) deficiency.

(2) Groin injury diagnosed as osteitis pubis, with the athlete missing match playing time because of this injury. In all cases the diagnosis was confirmed using MRI at the time of injury, with all affected players having appreciable parasymphyseal bone marrow oedema.

(3) Severe back injury defined as a specific clinical diagnosis recorded by the team doctor in the past, with the injury having been investigated with radiological imaging (*x* ray, computed tomography, and/or MRI).

A past history of a PTI was recorded when the injury occurred within the previous two playing seasons and resulted in at least one missed match. A PTI that occurred more than two playing seasons previously could not be verified by the clinical notes of the respective team doctors. Interview alone about a PTI that occurred more than two years previously was not considered a reliable record of past injury and was not included in the results.

In this study an injury was recorded at the onset (acute or chronic) of posterior thigh pain that resulted in missed training and/or playing time. Contact injuries were excluded. All athletes with an injury underwent MRI examination (1.5T Siemens) of the posterior thigh 48–120 hours after the injury to determine the cause. The MRI protocol included axial T1 and T2 inversion recovery in addition to sagittal T1 and T2 inversion recovery sequences. To help locate the suspected muscle strain, a skin marker was placed over the area of maximal posterior thigh tenderness. The MRI scans were reviewed independently by two musculoskeletal radiologists (JPS, GTF), and, when disagreement about the findings occurred, the scans were further reviewed until consensus was reached.

A positive MRI scan was the detection of T2 intramuscular hyperintensity at the site of the PTI. This was called a hamstring muscle strain. A negative MRI scan was a normal appearance at the site of the suspected muscle strain. This was called a referred pain PTI.

The anthropometric characteristics (age, height, and weight) were assessed by comparing injured with uninjured players, with Mann-Whitney U tests for the non-parametric data sets of age and height and *t* test for the parametric data set of weight. Because of the small numbers in this study, other variables (aboriginal descent, past history of PTI, previous injury to the groin, knee, or back) were analysed using Fisher's exact test. A p value of less than 0.05 was considered significant in all analyses. Multiple variable regression analysis was then performed to establish the presence of the major risk factors for hamstring muscle strain, with odds ratio and confidence limits calculated.

The statistical tests were performed for the following:

(1) National competition players compared with state competition players to establish any differences in the cohorts.

(2) Athletes with hamstring muscle strain compared with those without for (*a*) all of the cohort to establish risk factors for hamstring muscle strain, (*b*) with those players with a past history of PTI excluded from the cohort to establish risk factors for hamstring muscle strain independently of a previous PTI, and (*c*) with all players with a past history of PTI, injury to the knee, groin, or back excluded from the cohort to establish anthropometric risk factors for a hamstring muscle strain independently of these previous serious injuries.

(3) Athletes with referred pain PTI compared with those without to establish risk factors for a PTI for which the MRI scan was normal.

Results

Table 1 gives the anthropometric variables and results of the player interview for past clinical history. There were no significant differences between players from the national club and the state competition club.

Thirty four of the 114 football players (30%) had a PTI during the playing season, 19 AFL players and 15 SANFL players; this difference was significant (χ^2 = 6.8, p<0.01, Fishers p<0.01).

Thirty two of the athletes with PTI had MRI scans to establish the diagnosis, hamstring muscle strain or referred pain PTI. The remaining two chose not to be involved in the study. In all, 35 MRI scans were performed

Table 1 Comparison of anthropometric variables and past clinical history of players from the AFL and SANFL

	AFL (n=43)	SANFL (n=71)	Total (n=114)	U, t, or χ^2	p Value
Age (years)	22, 21.9 (3.0)	20, 21.4 (3.5)	20.5, 21.6 (3.4)	U=1342	0.276
Height (cm)	183, 185.0 (7.9)	182, 183.3 (7.0)	183, 183.9 (7.4)	U=1359	0.325
Weight (kg)	86, 85.8 (9.8)	81, 82.5 (9.4)	83, 83.8 (9.6)	t=1.78	0.078
Aboriginal descent	5	3	8	χ^2=2.24	0.112
PH-PTI	11	15	26	χ^2=0.32	0.371
PH-knee injury	2	8	10	χ^2=1.47	0.195
PH-osteitis pubis	7	10	17	χ^2=5.10	0.475
PH-back injury	9	8	17	χ^2=1.97	0.129

Where appropriate, values are median, mean (SD).
AFL, Australian Football League (national competition); SANFL, South Australian National Football League (state competition); PH, past history; PTI, posterior thigh injury.

because three athletes had bilateral injuries during the playing season. In each case of bilateral injury, the MRI diagnosis was the same on both sides, hamstring muscle strain (two athletes) or referred pain PTI (one athlete).

For 26 of the 32 injured players who had MRI scans, the scan was abnormal, consistent with hamstring muscle strain. In the remaining six, the scans were normal and the injury was diagnosed as referred pain PTI.

The anthropometric variables and past clinical characteristics of the 26 players who sustained a hamstring muscle strain were compared with those of players without (table 2). There was a significantly increased risk of injury with older age, being of aboriginal descent, a past history of PTI, a past history of knee injury, and a past history of osteitis pubis. The increased risk of injury with a past history of back injury approached significance (p = 0.06). Regression analysis of the hamstring muscle strain (R = 0.405) shows that older age, a past history of PTI, being aboriginal, and a past history of knee injury are the most significant risk factors (table 3).

When a past history of PTI is excluded as a possible confounding factor, the same risk factors for a hamstring muscle strain are still significant (table 4). In this analysis, a past history of back injury is not significant (p = 0.275) (table 4).

When all athletes with these previous serious injuries (PTI, osteitis pubis, back or knee injury) (n = 43) were excluded from the cohort, there were seven players with hamstring muscle strain and 64 uninjured. Of the anthropometric variables, age (being older) (U = 96, p = 0.01) was a significant risk factor for hamstring muscle strain, but height (U = 213, p = 0.83) and weight (t = 1.5, p = 0.16) were not.

Only two significant risk factors were found with respect to referred pain PTI: past history of PTI (four of six athletes; Fisher's exact, p = 0.02) and a past history of a back injury (five of six athletes; Fisher's exact, p<0.01). Athletes sustaining a referred pain PTI were on average taller (median height 189.5 cm) than those without this injury (median height 182 cm); this difference approached but did not reach significance (Mann-Whitney, p = 0.07).

Table 2 Comparison of anthropometric variables and past clinical history of players with hamstring muscle strain and uninjured players

	Injured (n=26)	Uninjured (n=88)	U, t, or χ^2	p Value
Age (years)	24.5, 23.9 (3.1)	20, 20.9 (3.1)	U=545	0.000
Height (cm)	182, 183.6 (7.2)	183, 184.0 (7.4)	U=1104	0.789
Weight (kg)	85, 85.5 (8.8)	82.5, 83.3 (9.9)	t=1.622	0.317
Aboriginal descent	5	3	χ^2=7.70	0.015
PH-PTI	13	13	χ^2=14.1	0.000
PH-knee injury	6	4	χ^2=8.6	0.009
PH-osteitis pubis	8	9	χ^2=6.68	0.023
PH-back injury	7	10	χ^2=3.83	0.063

Where appropriate, values are median, mean (SD).
PH, Past history; PTI, posterior thigh injury.

Table 3 Regression analysis for hamstring muscle strain

	B	Significance	OR	95% CI
Age	0.245	0.005	1.3	1.1 to 1.5
PH-PTI	1.58	0.006	4.9	1.6 to 15.1
PH-knee injury	1.73	0.035	5.6	1.1 to 28.1
Aboriginal	2.42	0.005	11.2	2.1 to 62.5

OR, Odds ratio; CI, confidence interval; PH, past history; PTI, posterior thigh injury.

Table 4 Comparison of anthropometric variables and past clinical history of players with hamstring muscle strain and uninjured players excluding those with a past history of posterior thigh injury (n=26)

	Injured (n=13)	Uninjured (n=75)	U, t, or χ^2	p Value
Age (years)	24, 23.8 (2.6)	20, 20.6 (3.0)	U=199	0.001
Height (cm)	184, 184.1 (6.9)	182, 183.4 (7.3)	U=451	0.672
Weight (kg)	84, 85.6 (8.3)	81, 82.2 (9.2)	t=1.151	0.252
Aboriginal descent	3	3	χ^2=6.35	0.039
PH-knee injury	3	3	χ^2=6.35	0.039
PH-osteitis pubis	4	4	χ^2=8.67	0.015
PH-back injury	2	5	χ^2=1.15	0.275

Where appropriate, values are median, mean (SD).
PH, past history.

Discussion

RISK FACTORS FOR HAMSTRING MUSCLE STRAIN

Past history of PTI

A past history of PTI is a significant risk factor for a hamstring muscle strain. Athletes with a such a history had a 4.9 times increased risk of hamstring strain than those without. This confirms results from previous studies.[1 6 15 16] A muscle strain injury usually occurs at the musculotendinous junction,[23] and the area undergoes remodelling with resultant scar formation. Scar tissue is thought to be not as functional as the original tissue, therefore the risk for further injury is increased.[24]

Past history of knee and groin injury (osteitis pubis)

After exclusion of athletes with a past history of a PTI, both a previous knee injury and a previous groin injury (diagnosed as osteitis pubis) still achieve significance as risk factors for hamstring strains. It can be postulated that, after injury to the knee or groin, the biomechanical properties of the lower limbs change, thereby increasing susceptibility to hamstring injury. This could be caused by

either the injury itself or the rehabilitation regimen undertaken in the recovery phase, or a combination of the two. Another interesting observation in this study is that, of the six athletes with a previous ACL reconstruction (three bone-patellar-bone, three hamstring), four (two bone-patellar-bone, two hamstring) had a hamstring injury during the playing season. With the high incidence of ACL injury and groin injury in Australian Rules football,[1 3] this could be an area of future study.

Age

It would appear that the older the athlete the increased likelihood of hamstring muscle strain. This result is also similar to those from other studies.[17 18] In contrast with the previous studies, our work has also shown that, even when the confounding factor of a previous PTI is excluded, increasing age is still a significant risk factor for hamstring injury. An increase in age of 1 year increases the likelihood of a hamstring injury by 1.3 times independently of a past history of PTI. The reason why increasing age is a risk factor is not readily apparent.

Race

A significantly increased risk for injury was found when the athlete was of aboriginal descent even when previous PTI was excluded. Aboriginal players are considered to be the fastest and most skilful (and most exciting) players in Australian football. It has been proposed that athletes with a type II (fast twitch) fibre predominance are more prone to muscle strain injury.[25 26] Aboriginals playing in elite Australian football may therefore have proportionately more hamstring type II muscle fibres and therefore have an increased risk of hamstring muscle strain.

RISK FACTORS FOR REFERRED PAIN PTI

Past history of back injury

A past history of back injury did not correlate with an increased risk of hamstring injury but did correlate with an increased risk of referred pain PTI. About 19% of all PTIs that occurred during an entire Australian Rules football playing season were not associated with any MRI detected hamstring muscle damage. The pain experienced by the athletes with this injury may be a result of referred pain to the posterior thigh from the neuromeningeal structures for example. This correlation between a past back injury and a normal scan after a PTI provides some evidence for the term "back related hamstring strain". However, a more accurate description of this would be "back related posterior thigh pain". More research needs to be undertaken to assess the validity of this assertion.

Past history of PTI

A past history of a PTI was also associated with an increased risk of a referred pain injury and hence was the only risk factor that was associated with having both a hamstring muscle strain and a referred pain PTI. The explanation for this is that it was not possible to differentiate on interview alone whether a previous PTI was an actual hamstring muscle strain or a referred pain PTI, as no imaging had previously been performed. Therefore some of the players with a past history of PTI would have had a previous hamstring injury with subsequent reinjury, whereas some would have had a previous referred pain injury also with a subsequent reinjury.

COMPARISON WITH AFL INJURY SURVEILLANCE DATABASE

A recent study of hamstring strains in all AFL matches between 1992 and 1999[20] also showed that age, independently of a past history of hamstring injury, was a risk factor, with similar relative risk (1.3) and confidence intervals (1.1 to 1.6). A past history of injury was also a significant risk factor but had a lower relative risk (2.4) compared with our study (4.9). A history of previous injury was recorded in our study by direct interview, and therefore previous injuries that may have occurred in the preseason training period, finals matches, or a different playing competition were included. These are excluded from the AFL database system. Thus our cohort probably had a larger number of athletes, in relative terms, with a history of previous injury than the AFL database and this is the possible reason for the higher relative risk rate seen in our study. It is also apparent that our cohort had an absolute higher risk of injury than the AFL database. A possible explanation is that we included injuries that occurred at training, injuries that occurred in the preseason training period, and injuries that may not have resulted in a player missing a competitive match. No data with respect to a past history of other injuries (apart from muscle strain injuries) or race were presented in the AFL study.

ANALYSIS OF THE COHORT

Comparison of AFL players with SANFL players

There were no significant differences between the two sets of players in terms of anthropometric variables and previous clinical characteristics despite playing in different competitions. Thus for the purposes of this study the two can be considered as a single group. This is not unexpected, as many of the state competition players had played previously at the national competition level.

Level of competition

Players in the AFL had significantly more PTIs than players at the lower level of competition. The AFL club is involved in longer and more frequent training sessions and plays in matches that are more intense. This is a possible explanation for the greater injury incidence seen in this higher level of competition.

ANALYSIS OF THE METHOD

Definition of back injury

Many Australian Rules footballers have episodes of or continual back pain. Most of this pain is of low intensity or is transient in nature and therefore is not usually investigated by radiological imaging. The definition adopted was an episode of back pain that had been previously investigated by radiological imaging so

that a specific clinical diagnosis could be made. Specific diagnoses were recorded as a result of positive or negative findings from the investigation. Investigation of back pain is not common in Australian Rules footballers unless the pain is severe, prolonged, or has clinical features to suggest a disc prolapse. Acute spinal injury is rare in Australian football. Both club doctors in this study were satisfied that this broad definition would include all athletes in their care who had incurred a previous serious back injury.

Definition of groin injury (osteitis pubis)

The diagnosis of the cause of groin pain in athletes is controversial. The most common diagnosis in Australian Rules footballers made by our group is osteitis pubis.[27] Other diagnoses were made if the athlete had missed playing time because of the injury but had negative findings with respect to bone marrow oedema on an MRI scan.

Statistics

Although the numbers in this study were small (114), the number of injuries detected was high (28% of the subjects had MRI scans for injury), and therefore significance was often reached with relatively small numbers of injured subjects. This should be remembered when interpreting results from this study.

CONCLUSION

PTIs, in particular hamstring muscle strain, are common in Australian Rules football and strongly associated with a past history of a PTI. This study prospectively establishes other risk factors for a hamstring muscle strain that are independent of a past history of PTI. These include increasing age, being of aboriginal descent, having a past history of serious knee injury, and having a past history of osteitis pubis. The mechanism of the increased risk is not known and further research is required. In addition, 19% of all PTIs investigated by MRI showed no evidence of hamstring muscle injury. A previous back injury was a significant risk factor for this type of injury.

In the provision of athletic care for professional sports teams, when programmes for the prevention of PTIs, in particular hamstring muscle strain, are being designed and implemented, these risk factors should be taken into account.

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Take home message

An increased risk of hamstring muscle strain injury exists, independently of a past history of posterior thigh injury, in athletes who are older, have a past history of serious knee injury, have a past history of osteitis pubis, and are of aboriginal descent.

Commentary

The pathophysiology and risk factors for muscle-tendon stretch injury are of interest to both clinicians and basic scientists. In this study, the authors have improved our understanding of risk factors for this common problem by analysis of a cohort of elite Australian football players. One particular advantage of this study is the use of MRI to confirm or refute the diagnosis. Multiple regression analysis shows that, in addition to previous injury, age and previous history of knee injury and osteitis pubis are independent risk factors for hamstring injury in this particular cohort. Future studies are recommended to determine whether the same risk factors are identifiable in different populations. Whether the possibility of intervention in athletes with these risk factors can reduce the incidence and severity of injury cannot be ascertained from this study.

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