Why are older Australian football players at greater risk of hamstring injury?

Belinda J. Gabbea∗, Kim L. Bennellb, Caroline F. Finchc

aDepartment of Epidemiology and Preventive Medicine, Monash University, Central and Eastern Clinical School, Alfred Hospital, Commercial Rd., Melbourne, Vict. 3004, Australia
bCentre for Health, Exercise and Sports Medicine, School of Physiotherapy, University of Melbourne, Australia
cNew South Wales Injury Risk Management Research Centre, University of New South Wales, Australia

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Cohort study; Risk factors; Sports injury; Muscle strain

Summary

Introduction: Increasing age is a commonly identified predictor of hamstring injury but is not modifiable to reduce injury risk. Why increasing age is a risk factor for hamstring injuries in athletes has not been studied to date. This study aimed to identify potentially modifiable age-related changes that predict hamstring injury in a population of Australian football players.

Methods: One hundred and one young (≤20 years), and 73 older (≥25 years), Australian football players, without a history of hamstring injury in the past 12 months were studied prospectively. Players underwent screening of anthropometric, flexibility and lower extremity range of movement tests during the pre-season period and were followed-up for a full season with respect to injury and match participation. Comparisons of the age groups were performed to identify differences related to age. Logistic regression analysis was undertaken to determine whether the observed differences were predictors of hamstring injury.

Results: There were significant differences between the age groups with 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 ≥25 years. None of the observed differences were predictors of injury in the younger age group.

Conclusions: There are age-related changes that are potentially modifiable to reduce injury risk in older athletes and these factors should be considered in the development of hamstring injury prevention programs for this high risk group.

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∗Corresponding author. Tel.: +61 3 9903 0951; fax: +61 3 9903 0576. E-mail address: belinda.gabbe@med.monash.edu.au (B.J. Gabbe).
Introduction

Hamstring injuries are common in sprinting sports such as Australian football and soccer where the incidence is reported to be 12–16% of all injuries in a season. Prevention of hamstring injuries is a key priority for sprinting sports due to the high incidence and rates of recurrence. An understanding of the risk factors for hamstring injury is crucial for the development of prevention strategies. The two most commonly identified risk factors for hamstring injury are a previous history of injury and increasing age. Unfortunately, neither of these factors is able to be modified to alter an athlete’s risk of hamstring injury.

Recent studies have compared athletes who have and have not previously sustained hamstring injuries to establish the differences between these two groups. In particular, strength, flexibility, posture, neural mobility and other aspects of muscle function have been studied. Unfortunately, the retrospective and cross-sectional nature of these studies do not allow conclusions to be drawn on whether the observed differences were present before injury or resulted from the injury. Similarly, studies that have used the uninjured leg for comparison assume that the measurements of the uninjured leg are independent of those on the injured leg which is not the case. As such, identifying modifiable factors associated with a previous history of hamstring injury is extremely difficult.

In contrast, increasing age, irrespective of past history, has been identified as a predictor of hamstring injury through five prospective cohort studies of Australian football and soccer players. Verrall et al. studied 114 elite Australian football players over one season and found that increasing age was an independent predictor of hamstring injury but did not define an age cut-off as age was analysed as a continuous variable. Arnason et al. demonstrated that the risk of hamstring injury increases by 10% per year in their study of 306 elite soccer players in Iceland. Orchard et al. investigated risk factors for lower extremity muscle strains over a 7 year period in the elite Australian Football League and found that players aged ≥23 years were at significantly elevated risk of hamstring injury. Similarly, elite Australian football players aged ≥25 years were over four times more likely to sustain a hamstring injury than those <20 years in the most recent prospective study involving 222 players. A prospective cohort study focusing on lower extremity injuries in community-level football found that players aged ≥23 years were almost four times more likely to sustain a hamstring injury during the season than players aged <23 years.

Why the risk of hamstring injury increases at 23–25 years of age is not understood and has not been investigated to date.

The aims of this study were therefore to:

i. Compare younger (≤20 years) and older Australian football players (≥25 years) to determine whether any differences identified predict hamstring injury in older players.

ii. Determine whether there are any differences in intrinsic factors associated with increasing age that could be modified to reduce hamstring injury risk.

Methods

This study relates to two larger studies undertaken to identify risk factors for lower extremity injuries in elite and community-level Australian football players. A summary of the methodology, which was consistent for both cohorts, is provided here and the detailed methodology is published elsewhere.

Study design and participants

Prospective cohorts of 126 community-level and 222 elite players were recruited from 10 Melbourne-based Australian football clubs during the 2000 and 2002 seasons, respectively. Community-level players were recruited from the Victorian Amateur Football Association which is an amateur league that prohibits payment of players for participation. The elite players were from Australia’s highest professional league, the Australian Football League (AFL). All players provided written informed consent prior to participation and ethics approval was obtained from the Human Research Ethics Committee at the University of Melbourne.

For the current study, information on players was extracted from the previous cohort studies if they met the following criteria:

i. Aged ≤20 years or ≥25 years.

ii. No self-reported history of a hamstring injury in the previous 12 months.

Procedures

All players underwent baseline measurements during the pre-season period, approximately 6 weeks prior to commencement of the playing season. Baseline testing was consistent across elite and community-level cohorts and included a self-report questionnaire and musculoskeletal screen. The questionnaire captured information about age and
Injuries sustained during the previous 12 months. The recall period was limited to 12 months because the investigators did not have access to player medical records and prior research has demonstrated the reliability of a 12 month recall. The musculoskeletal screen comprised of commonly used field tests with published test-retest and inter-tester reliability, and included:

i. Dorsiflexion lunge test to assess ankle joint dorsiflexion range of movement in a weight bearing position.

ii. Active internal and external hip joint rotation in supine with the hip in neutral.

iii. Sit and reach test to assess combined spinal and lower extremity flexibility.

iv. Active Knee Extension Test to assess hamstring muscle flexibility.

v. Modified Thomas Test (MTT) to assess hip flexor flexibility (range of hip flexion in the MTT position).

vi. Active slump test to assess neural mobility.

Musculoskeletal testing was performed after completion of a club training session warm-up program (community-level) or a structured warm-up of stationary cycling and lower extremity stretches (elite). All testing was completed using standardised protocols by qualified physiotherapists and postgraduate researchers trained to perform the protocols described by prior reliability studies. Players were allowed familiarisation attempts before two measures were recorded for each test, and leg, where bilateral tests were performed. All testing equipment (e.g. scales, goniometers, etc.) remained consistent across the cohorts.

Players were monitored for the season with respect to participation and injury. For the community-level cohort, the club physiotherapist or medical staff member completed a standardised form for each injury. Injury data for the elite cohort were extracted from the AFL Injury Database which captures information about every injury sustained by elite players that resulted in at least one missed game to ensure consistency across the elite and community-level cohorts. The diagnosis of hamstring injury was made by the club medical staff and only hamstring injuries with a sudden/acute onset were included, as determined by the information provided by the AFL Injury Database and contained on the data collection form of the community-level cohort. While many elite players undergo imaging, this was not contained on the AFL Injury Database at the time and was not provided to the investigators by the clubs. A backward stepwise logistic regression procedure, based on likelihood ratio tests was used. Variables demonstrating a p-value < 0.20 on group comparisons were considered eligible for inclusion into the multivariate model. Variables were eliminated if the p-value for a likelihood ratio (LR) test of their exclusion was >0.15. The criterion for re-inclusion of the predictor variables in the model was p < 0.05. To ensure that predictors identified were not due to the level of play or exposure, variables relating to the level of play (elite versus community-level) and participation (match hours for the season) were entered into the model as potential confounders. To determine whether observed differences between the age groups were also predictive in the younger age group, the multivariate modelling procedure was repeated with only the younger (<20 years) players included.

Statistical analysis

All data were analysed using the SPSS Version 12.0. As there was no significant difference in the measurements made on both limbs for the bilateral tests, the average of both legs was used. The body mass index (BMI) was categorised according to World Health Organisation (WHO) guidelines. As the number of players who met the obese criteria of the WHO was small, the “overweight” and “obese” categories were combined and no players were considered “underweight” according to the guidelines. Players were grouped as either young (<20 years) or older (≥25 years). Comparisons of the two groups were made using Chi-square tests for categorical data, and either Mann–Whitney U-tests or independent t-tests for continuous variables, depending on the distribution of the data (based on normality). For Chi-square tests, the relative risk (RR) of an outcome (e.g. injury or test result group) was calculated and 95% confidence intervals (CI) were also generated. For all tests, a p-value < 0.05 was considered significant. To assess whether differences between the age groups were predictors of hamstring injury in the older age group, a multivariate analysis was performed. Only players aged ≥25 years were analysed and the outcome of interest was a hamstring injury during the study season that resulted in at least one missed game to ensure consistency across the two age groups were also predictive in the younger age group included.

Results

One hundred and seventy four players were included in this study, 135 elite and 39 community-level. Of these, 101 (58.0%) were aged 20 years or less and the remainder (n = 73, 42.0%) were aged
Table 1 Comparison of the anthropometric characteristics, lower extremity range of movement and flexibility of younger (≤ 20 years) and older (≥ 25 years) Australian football players

<table>
<thead>
<tr>
<th>Variable</th>
<th>Younger group, n = 101</th>
<th>Older group, n = 73</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height (cm) Mean (S.D.)</td>
<td>186.2 (7.8)</td>
<td>187.1 (8.7)</td>
</tr>
<tr>
<td>Weight (kg) Median (range)</td>
<td>81 (69—105)</td>
<td>86 (69—117)</td>
</tr>
<tr>
<td>Body Mass Index BMI n (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Healthy weight (&lt;25)</td>
<td>84 (83.2)</td>
<td>30 (41.1)</td>
</tr>
<tr>
<td>Overweight/obese (≥ 25)</td>
<td>17 (16.8)</td>
<td>43 (58.9)</td>
</tr>
<tr>
<td>Ankle dorsiflexion ROM (cm)</td>
<td>Mean (S.D.)</td>
<td></td>
</tr>
<tr>
<td>Mean (S.D.)</td>
<td>12.3 (2.8)</td>
<td>10.3 (3.5)</td>
</tr>
<tr>
<td>Active hip internal ROM (◦)</td>
<td>Mean (S.D.)</td>
<td></td>
</tr>
<tr>
<td>Mean (S.D.)</td>
<td>25.0 (10.7—51.2)</td>
<td>21.7 (9.7—39.0)</td>
</tr>
<tr>
<td>Active hip external ROM (◦)</td>
<td>Median (range)</td>
<td></td>
</tr>
<tr>
<td>Median (range)</td>
<td>26.4 (6.1)</td>
<td>26.7 (7.8)</td>
</tr>
<tr>
<td>Active slump test (◦)</td>
<td>Median (range)</td>
<td></td>
</tr>
<tr>
<td>Median (range)</td>
<td>19.2 (0.7—46.2)</td>
<td>19.4 (8.0—43.1)</td>
</tr>
<tr>
<td>Sit and reach test (cm)</td>
<td>Mean (S.D.)</td>
<td></td>
</tr>
<tr>
<td>Mean (S.D.)</td>
<td>5.7 (9.5)</td>
<td>3.7 (8.4)</td>
</tr>
<tr>
<td>Modified Thomas Test (◦)</td>
<td>Median (range)</td>
<td></td>
</tr>
<tr>
<td>Median (range)</td>
<td>−0.8 (6.7)</td>
<td>−3.3 (5.6)</td>
</tr>
<tr>
<td>Active Knee Extension test (◦)</td>
<td>Median (range)</td>
<td></td>
</tr>
<tr>
<td>Median (range)</td>
<td>23.0 (6.0—32.5)</td>
<td>22.7 (7.2—53.5)</td>
</tr>
</tbody>
</table>

N.B. Italics represents variables for which a significant difference was found between the groups.

Table 2 Independent predictors of hamstring injury for Australian football players aged ≥ 25 years

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Risk ratio (95% CI)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight (in kg)</td>
<td>1.07 (1.01—1.15)</td>
<td>0.029</td>
</tr>
<tr>
<td>Modified Thomas Test (in hip flexion)</td>
<td>1.15 (1.01—1.31)</td>
<td>0.040</td>
</tr>
<tr>
<td>Dorsiflexion lunge (cm)</td>
<td>0.87 (0.71—1.05)</td>
<td>0.144</td>
</tr>
</tbody>
</table>

* Adjusted for level of play (elite vs. community-level) and match exposure (hours for the season).

25 years or more. The cohort sustained 21 hamstring injuries during the season; 7 in the younger group (6.9% of younger group) and 14 (19.2% of older group) by older players. The unadjusted RR of sustaining a hamstring injury during the season in older players, without a history of hamstring injury in the previous 12 months, compared to younger players, was 2.8 (95% CI: 1.2, 6.5).

Table 1 summarises the comparison of the age groups with respect to baseline measurements. Older players were heavier (z = −4.2, p < 0.001), and demonstrated less active hip internal rotation (z = −2.4, p = 0.017) and ankle dorsiflexion (t = 3.9, p = 0.001) than the younger players, but had greater hip flexor length (t = 2.5, p = 0.013) as measured by the MTT. Age group was associated with BMI (z = 33.2, p = 0.001), with older players twice as likely to have a BMI ≥ 25 as the younger players (unadjusted RR 2.0, 95% CI: 1.5, 2.7). There was no difference between the age groups with respect to hamstring flexibility (z = −0.1, p = 0.909), neural mobility (z = −0.2, p = 0.823), active hip external rotation (t = −0.3, p = 0.763) or sit and reach test (t = 1.4, p = 0.155) (Table 1).

Six variables met the stated criteria for inclusion in the multivariate analysis: BMI, sit and reach, MTT, dorsiflexion lunge, active hip internal rotation ROM and weight. Table 2 shows the independent predictors of hamstring injury for players aged 25 years or more. Body weight and hip flexor length were independent predictors of hamstring injury in this age group. For each kilogram increase in body weight, the risk of sustaining a hamstring injury increased by 7%. For each 1° increase on the MTT (i.e. decreasing hip flexor flexibility), the risk of hamstring injury increased 15%. While an increase in the dorsiflexion lunge test (i.e. increased dorsiflexion range of movement), was associated with a decreased risk of hamstring injury, this was not a significant predictor. When the multivariate analysis was repeated for the younger players, none of the variables were identified as independent predictors of hamstring injury (i.e. all variables were eliminated by the step-wise procedure).

Discussion

Hamstring injuries are the most common injury sustained by elite and community-level Australian football players. Previous studies have highlighted the importance of age as a predictor for hamstring injury.2,4–6 Whilst age itself is not modifiable to reduce risk of injury, factors associated with ageing athletes have not been explored and previous authors have not provided potential explanations.2,4–6 Previously, we have suggested age-related changes to muscle structure and innervation as potential explanations6 while Orchard et al. have suggested that age-related entrapment of
Hamstring injuries in older footballers

The L5/S1 nerve root due to hypertrophy of the lumbosacral ligament could be a factor. However, there has been no published evidence to support these theories. The findings of our study suggest that some of the changes related to age may be potentially modifiable. In particular, body weight and hip flexor flexibility were predictors of hamstring injury in the older age group and could be important in the development of prevention strategies for this group.

The finding of increasing weight as a risk factor for hamstring injury raises further questions and requires careful consideration. As 78% of the cohort were elite, professional Australian football players, it is likely that the increased weight and BMI noted is related to increased lean muscle mass, although body composition was not assessed in our study, a noted limitation of this study. The reason for a direct link with increased hamstring injury risk is not clear but could reflect differences in training, or the effect of training, across the age groups.

Consideration could be given to investigating the training content and loads to determine whether the weight gain is reflective of differences in weight or fitness training.

Our study found hip flexor flexibility, as measured by the MTT, to be an independent predictor of hamstring injury in the older age group. However, this has not been shown to be a predictor of hamstring injury across all ages of adult Australian football players or soccer players, and has not been investigated in other prospective cohort studies of hamstring injury risk factors in athletes. Although the older age group was significantly more flexible on this test than the younger age group, it appears that this factor is more important for the older age group as the results of the multivariate analysis clearly show that decreasing flexibility increases the risk of hamstring injury in the older players and hip flexor flexibility was not a predictor of hamstring injury in the younger age group.

Why tightness in the hip flexors would increase hamstring injury risk is not clear but could relate to a change in sprinting mechanics as the majority of hamstring injuries occur whilst accelerating or sprinting. The hamstrings reach peak length during terminal swing phase of sprinting just prior to ground contact. At this stage, the muscles are actively lengthening to control the rate of knee extension and to slow the swinging limb in preparation for ground contact before a rapid change to concentric action to begin to extend the hip at foot contact. At this point, hamstring injury risk is believed to be greatest. As sprinting speed increases, the range of hip flexion reached does not change but the knee becomes significantly more flexed, an observation also noted when the hamstring muscles are fatigued and proposed as a protective mechanism to prevent injury to the hamstrings. Greater tightness in the hip flexor group could assist in greater acceleration of the swinging leg which would need to be offset by an increase in the activity of the hamstring muscles, increasing their vulnerability to injury. Whether the ability of the hamstring muscles of older athletes have the capability to adapt to this increased load requirement is unknown but could explain the importance of hip flexor flexibility as a predictor of hamstring injury in this age group.

Alternatively, the reduction in hip flexor length could result in a restriction of hip extension in sprinting. Compensation with increased movement at the lumbar spine could be required to gain sufficient hip extension. Over time, reliance on lumbar spine movement to compensate for restricted hip extension could lead to joint hypermobility, irritation of the neural structures and activation problems with the hamstring muscles, resulting in increased vulnerability of the hamstring muscles to injury. In support of this hypothesis, the EMG onset of the hamstrings during locomotion has been shown to significantly differ for subjects with and without low back pain. Regardless of the mechanism, hip flexor flexibility is also a modifiable risk factor and warrants consideration in the development of hamstring injury prevention programs for this high risk group of athletes.

This study has identified differences in intrinsic factors between the highest and lowest risk groups of Australian football players for hamstring injury and explored these age-related differences as predictors of hamstring injury. Nevertheless, a number of study limitations must be acknowledged. While the number of study participants was high (n = 174) for the comparison of the age groups, the multivariate modelling of hamstring injury risk involved 73 older players with only 14 hamstring injuries, and 101 players with just seven injuries for the younger age group. A number of factors were found to be different across the age groups but were not predictors of hamstring injury risk, potentially due to insufficient power. These additional factors could contribute to injury risk and warrant further investigation in a larger cohort. Although we were able to adjust the multivariate modelling for match participation (exposure), time spent training was not captured for the elite participants due to the difficulties in capturing information about the frequency and content of training sessions at the elite level. While the vast majority of hamstring injuries occur during competition and match participation was captured by this study, training loads could be...
an important factor in hamstring injury risk and warrant investigation in the future.

The definition of hamstring injury used by this study was based on clinical rather than imaging findings as imaging is not yet established as routine clinical practice for the diagnosis of hamstring injuries and a prior study of soccer players has found that less than 5% of hamstring injury cases undergo imaging.2 As a previous imaging study has found that 90% of sudden onset posterior thigh pain cases show evidence of a muscle strain on MRI,26 it is unlikely that our study was over-inclusive of non-strain posterior thigh pain cases but potential diagnostic differences must be acknowledged as a limitation.

Our study established differences between the age groups with respect to intrinsic factors such as lower extremity range of movement, flexibility and anthropometric characteristics. Biomechanical assessment (e.g. 3D biomechanics) of the athletes running and sprinting was not performed. Similarly, strength or other measures of muscle function were not assessed due to the unavailability of a simple, inexpensive test that could be undertaken in the field setting. The investigation of age-related changes in running mechanics, muscle strength or function across all Australian football players and other groups of athletes warrants investigation to determine whether factors such as hamstring angle-torque curves,33 concentric or eccentric strength3,22 or muscle activation patterns contribute to the increased risk of hamstring injury with age.

Finally, potential causal relationships, rather than causality per se, were established. Whether alteration of the modifiable risk factors identified reduces hamstring injury risk in this group of athletes requires further study.

Conclusions

Older Australian football players, without a history of a hamstring injury in the previous 12 months, are at significantly elevated risk of hamstring injury. This group of athletes was found to be significantly different to the group at lowest risk (aged 20 years or less) with respect to body weight, BMI, ankle dorsiflexion range of movement, hip flexor flexibility and active hip internal rotation range of movement. Multivariate modelling, adjusting for the level of competition and match time as potential confounders, identified hip flexor flexibility and body weight as significant independent predictors of hamstring injury in older players. The findings show that there are age-related changes that are potentially modifiable to reduce injury risk in older athletes and these factors should be considered in the development of hamstring injury prevention programs for this high risk group.

Practical implications

- Older Australian football players have a significantly elevated risk of hamstring injury, irrespective of their past history of hamstring injury, but the reasons for this are not known.
- There are significant differences between players aged ≥ 25 years and those aged ≤ 20 years with respect to body weight, body mass index, hip flexor flexibility, hip rotation range of movement and ankle dorsiflexion range of movement.
- Body weight and hip flexor flexibility are significant predictors of hamstring injury players aged ≥ 25 years but not in the younger players (aged ≤ 20 years).
- Risk factors for hamstring injuries in older Australian football players are different from those in younger players and there are potentially modifiable changes that occur with age which could be important in reducing the risk of hamstring injury.

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References

Hamstring injuries in older footballers