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Original paper

Factors associated with increased propensity for hamstring injury in English Premier League soccer players

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Abstract

The aim of this study was to concurrently model the influence of a number of physical and performance parameters on subsequent incidence of hamstring injury in a squad of English Premier League soccer players. Thirty six healthy, male, elite, professional soccer players (age 22.6 ± 5.2 years, height 1.81 ± 0.08 m, mass 75.8 ± 9.4 kg, lean mass 69.0 ± 8.0 kg) were assessed during the first week of pre-season training for anthropometry, flexibility, lower limb strength and power, speed and agility. Over the subsequent 45 week competitive season all hamstring injuries were diagnosed and recorded. Multiple logistic regression analysis was performed to link individual physical and performance capabilities with propensity to sustain a hamstring injury. A model containing age, lean mass, non-counter movement jump (NCM) performance and active hip flexion range of movement (ROM) was significantly ($p < 0.05$) associated with increased propensity for hamstring injury. Odds for sustaining an injury increased ×1.78 for each 1 year increase in age, ×1.47 for each 1 cm increase in NCM and ×1.29 for each 1° decrease in active range of hip flexion. Older, more powerful and less flexible soccer players are at greater risk of sustaining a hamstring injury. Support staff should identify such individuals and make appropriate interventions to minimise risk without compromising performance capabilities.

Keywords: Fitness; Injury; Multifactorial; Age; Preventative strategies

1. Introduction

Over the past two decades, injury trends in elite-level soccer have changed[1,2] with the hamstring muscle group now recognised as the most frequently injured structure, accounting for more time lost than any other muscle group.[3,4] Indeed, the initial Football Association Audit of Injuries[5] found that over a period of two seasons, hamstring strains were the most prevalent injury, accounting for 12% of all injuries in the English Premier League. Additionally, injuries to the hamstring muscles have been shown to have the highest rates of recurrence[5–7] with premature return to play[7] and inadequate or inappropriate rehabilitation programs[8] suggested as contributing factors. Logically, injuries sustained by key players competing in elite team sports may result in a negative impact on team performance, success and inevitably, financial well being. Consequently, a fuller understanding of the mechanisms of hamstring injury and players most at risk will be of great benefit to those working in professional sport.

The relationship between the architecture of the hamstring muscle group, its contribution to human locomotion, and its propensity for injury is undeniably complex. Despite the fact that it is widely thought that in many instances the cause of hamstring injury may be multifactorial,[9] to our knowledge nearly all studies to date have modelled predictor variables in isolation.[1,10] Discussion of the contribution of proposed pre-disposing factors to hamstring injury is beyond the scope of this article, but has been extensively reviewed in previous literature.[7,11] To date, few investigators have attempted to simultaneously model combinations of intrinsic (both modifiable and non-modifiable) factors with incidence of hamstring injury to better understand any co-relationships which may exist. In an attempt to model multiple risk factors with propensity for muscle strain injury in soccer players,

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Bradley and Portas[12] identified flexibility via active hip flexion and knee flexion range of movement (ROM) as modifiable variables which were significant predictors.

Hence, the aim of this study was to investigate the combined influence of a range of physical characteristics and performance capabilities on propensity for hamstring injury over a period of one full season (10 months) in a squad of English Premier League soccer players.

2. Methods

Thirty six healthy, male, elite, professional footballers (mean ± SD; age: 22.6 ± 5.2 years; height 1.81 ± 0.08 m; mass 75.8 ± 9.4 kg; lean mass 69.0 ± 8.0 kg) from an English Premier League soccer club gave written informed consent to participate in the study. Prior to participating in this study, eleven (31%) subjects had experienced at least one incidence of previous hamstring injury. Ethical approval for this study was granted by the University Institutional Review Board.

Pre-season tests were conducted over a period of 2 days. All players had undertaken the tests on a minimum of two occasions previously. Tests were conducted in the same order, and at the same time of day to limit circadian influences on performance.

Following a standardised warm up (consisting of 10 min sub-maximal stationary cycling and light stretching), isokinetic strength for concentric knee flexion and extension was assessed (Biodex System 3; Biodex Medical Systems Inc., Shirley, NY). Peak torque was determined at angular velocities of 1.05, 3.14 and 5.24 rad s^{-1}. All values were corrected for the effects of gravity at 30° of knee flexion.[13] The test protocol consisted of three trial repetitions followed by 3, 5 and 7 recorded repetitions at 1.05, 3.14 and 5.24 rad s^{-1} respectively, with a 1 min rest period observed between sets.[14] Peak torque was recorded in absolute terms (N m) and relative to fat free mass (N m kg^{-1}).

Anaerobic fitness was assessed using previously validated tests of soccer specific agility and speed endurance.[15] Aerobic fitness was assessed using the Yo-Yo Intermittent Endurance Test (YIET, level 2).[16]

Explosive leg power was determined from standing vertical jump protocols. Maximum jump height was recorded both with and without counter-movement. For both techniques data were recorded using electric pressure mat apparatus (Newtest Powertimer Testing System, Newtest Oy, Kiviharjunte, Finland). Subjects stood on the mat with hands on hips and descended until knees were at 90° before explosively jumping for maximum height. For the non-counter-movement jump subjects held the 'crouch' position for 3 s prior to jumping.

Active and passive hip flexion ROM for dominant and non-dominant leg of each player was assessed via supine straight leg raise (SLR), according to the methods of Reese et al.[17] using 2-dimensional image-based analysis. Players were guided but not assisted by the researcher for the active SLR whilst the researcher moved the limb into position for the passive SLR. We clarified that restriction was at the hamstring muscle as players were only able to voluntarily flex the hip further by tilting the pelvis. Once the pelvis was repositioned with both PSIS in contact with the bed the natural end of range was restored. A stationary video camera (Panasonic SHM20, Matsushita Electric Corp of America, Secaucus, NJ) operating at a frame rate of 25 Hz was placed perpendicular to the plane of motion at a distance of 10 m. This capture technique has been previously validated by Selfe.[18] Active ROM was also reported relative to passive ROM (active/passive ROM (%)). To determine the reliability of the ROM protocol, measurements for 12 players were repeated 10 times. This resulted in a coefficient of variation of 1.5% for hip flexion ROM.

During the 45 weeks of the competitive season all injuries sustained and requiring medical attention were recorded. For the purposes of this study a hamstring injury was defined as one that would result in a player being unable to participate in general training for a period of 48 h or more. All injuries were diagnosed clinically by the doctor, physiotherapists and sports therapists employed at the club, and subsequently confirmed by MRI scan (T2 weighted images).

Descriptive statistics were performed on each variable to confirm the assumptions of normality. Comparisons for all independent variables between injured (injury to hamstring muscle sustained during the 45 weeks of the season) and non-injured players were performed using independent *t*-tests. Following removal of one subject as a significant outlier (studentised residual >±2, subsequent improvement in model accuracy >2%), forward stepwise logistic regression (block method) was performed to assess the impact of several factors collectively on the likelihood that subjects would sustain a hamstring injury. We chose to model data on injury propensity for the dominant limb only as there were enough data on this side to permit use of the statistic ($n = 10$). Independent variables (maximum 4) were entered according to logical criteria (based on previous work and deduction). This technique allows data to be modelled as continuous and categorical variables simultaneously and is considered to be the criterion statistical procedure for this kind of research problem.[10] Significance was accepted at the $p < 0.05$ level of confidence and all results reported as mean (SD). Data were analysed using SPSS for Windows (version 10; SPSS, Inc., Chicago, IL).

3. Results

A total of 104 injuries were recorded for all participants ($n = 36$), of which 14 (13.5%) were disruptions to the hamstring musculature (nine Biceps Femoris, five Semitendinosus; grade 1, 2 or 3). This is comparable to that reported by others[6] in previous work. Of the 14 incidences of hamstring injury recorded, three were sustained by the same player, the remaining 11 being single incidences for different players. Twelve injuries resulted in less than 14 training days missed

Table 1
Performance data on pre-season tests. Mean (SD).

Isokinetic data	Velocity (rad s^{-1})	Dominant		Non-dominant		Population norm
		Extension	Flexion	Extension	Flexion	
Peak torque (PT, N m^{-1})	1.05	263(37)	162(35)	262(46)	151(27)	
	3.14	193(28)	121(25)	201(30)	125(21)	
	5.24	157(23)	104(21)	159(24)	99(21)	
PT corrected for body mass (N m^{-1} kg^{-1})	1.05	3.52(0.65)	2.17(0.55)	3.49(0.69)	2.03(0.41)	
	3.14	2.59(0.52)	1.62(0.35)	2.69(0.55)	1.68(0.35)	
	5.24	2.11(0.43)	1.39(0.35)	2.13(0.42)	1.33(0.32)	
HQ ratio (%)	1.05	62(11)		58(7)		61
	3.14	63(10)		63(11)		72
	5.24	66(9)		62(10)		78

Hip flexion ROM	Dominant	Non-dominant
Active (°)	69.3(9.8)*	66.5(10.9)
Passive (°)	76.7(10.7)	75.1(11.1)

Field tests	
Agility run (s)	11.62(0.28)
YIET (level 2) (m)	2183(401)
Countermovement jump (cm)	40(5)
Non-countermovement jump (cm)	40(4)

* $p < 0.05$.

and 2 resulted in 14 or more (maximum 37 days missed). Ten of the 12 injuries were to the dominant (favoured kicking) leg. No relationship ($p > 0.05$) between prior injury and injury during this study was observed for either limb.

Subjects showed typical anthropometric profiles for professional soccer players[19] characterised by high relative lean mass (69 ± 8 kg) and low levels of body fat ($8.0 \pm 2.6\%$). Active hip flexion ROM was higher on the dominant limb than the non-dominant ($69.3 \pm 9.8°$ *vs.* $66.5 \pm 10.9°$, $p < 0.05$). No differences were observed for passive hip flexion ROM between dominant and non-dominant limbs ($76.7 \pm 10.7°$ *vs.* $75.1 \pm 11.1°$, $p > 0.05$; Table 1). Although non-significant ($p > 0.05$), both passive and active ROM demonstrated a trend for being higher in non-injured players than injured players (Table 2). No significant differences in active/passive ROM (%) were noted, although there was an observed trend towards higher values for dominant *vs.* non-dominant limbs (Table 2).

Performance in tests of endurance, agility and vertical jump power are detailed in Table 1. YIET scores are typical for adult professional soccer players.[20]

Comparison of performance on the agility and jump tests with externally validated norms is not possible due to the fact that protocols used were internally developed and validated.[15] Scores for the jump with counter movement did not differ from those with non-counter movement ($p > 0.05$).

No differences were found for any of the isokinetic measures of leg strength between dominant and non-dominant limbs for knee flexion or knee extension ($p > 0.05$). Data are similar to that reported from other studies on professional soccer players, both in absolute terms and when adjusted for body mass.[21] As expected, with increasing angular velocity, peak torque values decreased. Again, no differences between dominant and non-dominant limbs were observed ($p > 0.05$). Hamstring:quadriceps strength ratios remained constant, at around 60% with increasing angular velocity ($p > 0.05$). This is in contrast to normative values for the general population, where ratios have been shown to rise from 61% at 1.05 rad s^{-1} to 78% at 5.24 rad s^{-1},[22] and may represent a sport-specific adaptation for soccer players.

Due to the fact that 10 of 12 sustained hamstring injuries were to the dominant limb, and that many of the independent variables are unilateral in nature, it was decided to model data for those players experiencing a hamstring injury to the dominant limb only.

The age of injured players (InjDom; 26.7 ± 6.5 years) was higher than for non-injured players (Non-InjDom; 21.4 ± 3.4 years; $p < 0.05$). No differences were observed in any of the performance tests between InjDom and Non-InjDom (Table 2; $p > 0.05$).

The final regression model predicting propensity for hamstring injury on the dominant limb contained four independent variables (age, active range of movement on the dominant limb (ACTDOM), non-counter movement jump (NCMJUMP) and lean mass) and was statistically significant ($\chi^2(4, N = 35) = 4.38$, $p < 0.05$; Table 3) indicating that it could successfully discriminate between subjects who have a higher propensity for hamstring injury, and those who might have a lower propensity, correctly classifying 88.6% of cases.

Of the four variables in the model, only lean mass did not make a uniquely significant contribution ($p = 0.068$).

It would thus appear that propensity for hamstring injury in the dominant (kicking) leg is greater with increases in age and non-counter movement jump performance and decreases in active range of hip flexion.

Table 2
Comparison of performance data for injured *vs.* non-injured players on pre-season tests. Mean (SD).

Isokinetic data	Velocity (rad s^{-1})	InjDom ($n=10$)		Non-InjDom ($n=25$)		Population norm
		Extension	Flexion	Extension	Flexion	
Peak torque (PT, N m^{-1})	1.05	266(40)	160(23)	262(37)	163(39)	
	3.14	193(19)	123(15)	193(31)	121(28)	
	5.24	161(18)	107(19)	159(26)	102(22)	
PT corrected for body mass (N m^{-1} kg^{-1})	1.05	3.62(0.44)	2.18(0.24)	3.48(0.72)	2.18(0.63)	
	3.14	2.64(0.28)	1.68(0.17)	2.57(0.58)	1.61(0.40)	
	5.24	2.19(0.22)	1.47(0.27)	2.11(0.47)	1.37(0.37)	
HQ ratio (%)	1.05	60(9)		62(12)		61
	3.14	64(6)		63(11)		72
	5.24	67(10)		65(9)		78

Hip flexion ROM	InjDom ($n=9$)		Non-InjDom ($n=26$)	
	Dom	Non-Dom	Dom	Non-Dom
Active (°)	67(12)	64(9)	71(9)	68(12)
Passive (°)	74(13)	72(10)	78(9)	77(11)
Acive ROM/passive ROM (%)	91	89	91	88

Field tests		
Agility run (s)	11.7(0.3)	11.6(0.3)
YIET (level 2) (m)	2298(177)	2184(306)
Countermovement jump (cm)	41(6)	40(4)
Non-countermovement jump (cm)	42(4)	39(4)

InjDom: players sustaining a hamstring injury to the dominant limb; Non-InjDom: players not sustaining a hamstring injury to the dominant limb.

Table 3
Logistic regression model predicting likelihood to sustain a hamstring injury on the dominant limb.

	B	Sig.	Odds ratio	95% C.I. for odds ratio	
				Lower	Upper
Age	0.579	0.007	1.78	1.17	2.72
ACTDOM	−0.258	0.023	0.77	0.62	0.97
NCMJUMP	0.386	0.038	1.47	1.02	2.12
Lean mass	−0.166	0.068	0.847	0.71	1.01
Constant	−1.154	0.879	0.315		

4. Discussion

To the best of our knowledge, this study was the first to attempt to simultaneously model the effect of physical and performance characteristics on individual propensity for hamstring injury in elite level soccer players. Using multivariate techniques, a final model containing four independent variables (age, active ROM, explosive power and lean mass) demonstrated a strong combined influence on individual propensity for injury as the model had a capacity to correctly classify 88.6% of cases.

Of those contributory variables, three of four (active range of movement, non-countermovement jump and lean mass) can be considered as 'modifiable', although the model does present something of a paradox for non-countermovement jump performance, in that reduction in risk for less powerful athletes must be weighed against lower performance potential. Whilst lean mass did not make a statistically significant contribution to the overall model ($p=0.068$), on a practical level the 95% confidence limits for its inclusion were very close to unity (0.71–1.01) suggesting that players with lower lean mass are inherently more at risk of injury.

Age was the only variable to be independently related to propensity for injury, its inclusion as a significant predictor variable in our model seeming to be logical for a number of reasons. The population being assessed are professional athletes who expose themselves to extraordinary physical stresses on a daily basis. The likelihood of older athletes having suffered a previous hamstring injury could logically be assumed to be greater than for younger athletes through cumulative training exposure alone. It is therefore not surprising that with each additional year of age, the odds of sustaining an injury increase by ×1.78. These findings add to the already powerful body of evidence linking age with increased risk of hamstring injury.[5,23] The results were, however, in contrast to findings from Bradley and Portas[12] who, when modelling intrinsic predictor variables for generic muscle injury in professional soccer players, found age to be a non-significant factor. The difference in findings could be due to the fact that the age profile for the players in their study was more homogeneous than ours, giving less scope for any association to be identified. The significant contribution of active hip flexion ROM to the model supports the findings of a number of other investigators[1,10] yet is in contrast to those of others.[24] One possible explanation of the conflicting evidence could be the varying methodologies used to measure 'hamstring flexibility'. Orchard et al.[24] used sit and reach, a technique that has been criticised due to the role upper and lower limb length, scapular abduction and lumbar flexion can contribute to scoring in addition to hamstring length.[25,26] In this study we used the supine straight leg raise, often recognised as the criterion gold standard for measuring hamstring ROM,[27] and which allows for unilateral measurement. Results from this study add to existing knowledge by showing that for every 1° decrease in active straight leg raise, propensity for injury is increased ×1.29 (1/0.77).

We found that the odds of sustaining an injury increased ×1.47 with every 1 cm extra achieved in the non-counter movement jump test. These findings concur with those of previous work[28] in that explosive power makes a significant contribution to the final model, indicating that athletes who generate most power (those who jumped highest) are at greater risk of injury. On a practical level these results present something of a dilemma in that explosive power is an accepted pre-requisite for successful performance in elite soccer, yet increases in power would also appear to increase propensity for hamstring injury.

This study was performed on a group of 35 elite soccer players which is a typical sample size for work of this nature and is similar to that reported in previous work.[12] To avoid diluting the homogeneity of the group and the control we maintained over training and conditioning regimes, we purposefully avoided increasing the sample size by using youth players, or players from other clubs.

We suggest that practitioners can use the findings of this work to inform training interventions with soccer players. The structure of training programmes for older players should account for their increased susceptibility to hamstring injury and be structured around appropriate preventative elements. We would suggest that in order to minimise the inherent enhanced injury risk in more powerful players, conditioning programmes focus on increasing capacity to control activities where this power is expressed. Flexibility in itself is a complex issue with many interacting factors contributing to range of movement about a joint. We do provide evidence that improvements in active ROM could decrease injury risk, and recommend that limitations in less flexible athletes should be addressed through appropriate static stretching and strengthening regimes.[29] It may also be appropriate to incorporate postural assessment into screening programmes as it could help identify restricted range of movement and associated increased injury risk.[30]

5. Conclusion

These findings extend the existing knowledge in the area of injury prevention for those involved in the daily training of elite athletes, particularly soccer players and adds quantifiable support to the discussion that mechanisms of hamstring injury are indeed multifactorial. We have demonstrated that older, more powerful athletes with reduced range of motion are potentially at greater risk for hamstring injury. Reduced lean mass, although not significantly contributing to our model should also not be ignored by practitioners as another possible contributor to hamstring injury. Practitioners should consider these results when implementing physical training regimes with elite soccer players.

Practical implications

- Powerful, older soccer players with reduced active hip flexion range of motion are more susceptible to hamstring injury.
- Results from screening of players can be used to identify individual physical and performance limitations which could contribute to increased injury susceptibility.
- Individualised conditioning plans based on screening results should be used to help to minimise risk of hamstring injury.
- Training for older players should be adapted to allow time to perform activities which will minimise risk of injury.

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