

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

Running Head: Hamstring Injury in Soccer

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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 45 weeks of the subsequent 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 1.78X for every 1 year increase in age, 1.47 X for every 1cm increase in NCM and 1.29 X for every 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. Prehabilitation and conditioning strategies should target modifiable risk factors to minimise individual potential for injury.

Keywords: fitness, multifactorial, preventative strategies

INTRODUCTION

Over the past two decades, injury trends in elite-level soccer have changed [1,2,3], with the hamstring muscle now recognised as the most frequently injured structure, accounting for the most time lost [4,5]. Indeed, the initial Football Association Audit of Injuries [6] 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 [6,7,8] with premature return to play [9] and inadequate or inappropriate rehabilitation programs [10] 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 [11]. 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 [12], to our knowledge nearly all studies to date have modelled predictor variables in isolation [1,13]. In an attempt to model multiple 'intrinsic' risk factors with propensity for muscle strain injury, Bradley and Portas [14] identified flexibility as the only modifiable variable to be a significant predictor. To our knowledge, to date, no investigators have attempted to simultaneously model combinations of intrinsic and trainable factors with incidence of hamstring injury to better understand any relationships which may exist.

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.

METHODS

55 Thirty six healthy, male, elite, professional footballers (mean \pm S.D.; 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.

60 Pre season tests were conducted over a period of 2 days. All players were familiar with protocols used, having undertaken the tests on a minimum of 2 occasions previously. Tests were conducted in the same order, and at the same time of day to limit circadian influences on performance.

65 Following a standardised warm up (consisting of 10mins sub-maximal stationary cycling and light stretching), isokinetic strength for knee flexion and extension was assessed (Biodex System 3; Biodex Medical Systems Inc., Shirley, New York.). Peak torque was determined at angular velocities of 1.05, 3.14 and 5.24 $\text{rads}\cdot\text{sec}^{-1}$. All values were corrected for the effects of gravity at 30 degrees of knee flexion [15]. The test protocol consisted of three trial repetitions followed by 3, 5 and 7 recorded repetitions at 1.05, 3.14 and 5.24 $\text{rads}\cdot\text{sec}^{-1}$ respectively, with a 70 one minute rest period observed between sets [16]. Peak torque was recorded in absolute terms (N.m) and relative to fat free mass ($\text{N}\cdot\text{m}\cdot\text{kg}^{-1}$).

Anaerobic fitness was assessed using previously validated tests of soccer specific agility and speed endurance [17]. Aerobic fitness was assessed using the Yo-Yo Intermittent Endurance Test (YIET, level 2) [18].

75 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 degrees before explosively jumping for maximum height. For the non counter-
80 movement jump subjects held the 'crouch' position for 3 seconds prior to jumping.

Active and passive range of hip flexion ROM for dominant and non-dominant leg of each player
was assessed according to the methods of Reese *et. al.*, [19] using 2-dimensional image-based
analysis. 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
85 motion at a distance of 10 m. This capture technique has been previously validated by Selfe
[20]. 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
90 that would result in a player being unable to participate in general training for a period of 48
hours or more. All injuries were diagnosed clinically by the doctor, physiotherapists and sports
therapists employed at the club, and subsequently confirmed by MRI scan.

Descriptive statistics were performed on each variable to confirm the assumptions of normality.
Following removal of one subject as a significant outlier, forward stepwise logistic regression
95 (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 the 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
100 continuous and categorical variables simultaneously and is considered to be the criterion
statistical procedure for this kind of research problem [13]. 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).

105 **RESULTS**

A total of 104 injuries were recorded for all participants (n=36), of which 14 (13.5%) were disruptions to the hamstrings (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
110 resulted in less than 14 training days missed 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 [21] characterised by high relative lean mass (69 ± 8 kg) and low levels of body fat ($8.0 \pm 2.6\%$).
115 Active hip flexion ROM was lower on the dominant limb than the non-dominant (69.3 vs 66.5 degrees, $P<0.05$). No differences were observed for passive hip flexion ROM between dominant and non-dominant limbs (76.7° vs 75.1° $p>0.05$, Table 1). Performance in tests of endurance, agility and vertical jump power are detailed in Table 1. YIET scores are typical for adult professional soccer players [22].

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Table 1.

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

Isokinetic Data	Velocity (rads.sec ⁻¹)	Dominant		Non-dominant		'Target'
		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 (Deg)		69.3(9.8)*		66.5(10.9)		
Passive (Deg)		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)			

* dominant significantly different to non-dominant

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 [18]. Scores for the jump with counter movement did not differ from those with non-counter movement (p>0.05). When analysed independently, none of the performance measures in this study were found to be related to propensity for hamstring injury in the subsequent season (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 [23]. 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 remain relatively constant (Table 1), 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 1.05rads.sec⁻¹ to 78% at 5.24rads.sec⁻¹[24].

The resultant regression model predicting propensity for hamstring injury 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 (χ^2 (4, N=35) = 4.38, p<0.05, Table 2) indicating that it could successfully discriminate between subjects who have a higher propensity for hamstring injury in the dominant limb, and those who might have a lower propensity, correctly classifying 88.6% of cases.

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Table 2.

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		

Of the 4 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 attenuated with increasing age, increasing non-counter movement jump performance and a decrease in active range of hip flexion.

DISCUSSION

To 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. When modelled individually, no relationship between any of our variables and injury occurrence was noted. However, 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. Indeed, the model had a capacity to correctly classify 88.6% of cases.

Of those contributory variables, three of four (active range of movement, non-counter movement jump and lean mass) can be considered as modifiable. 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
200 with lower lean mass are inherently more at risk of injury.

The inclusion of age as a significant predictor variable in our model would seem 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
205 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 1.78X. These findings add to the already powerful body of evidence [6,8,25] linking age with increased risk of hamstring injury. The results were, however, in contrast to findings from Bradley and Portas [14] who, when modelling intrinsic predictor variables for generic muscle injury in professional soccer
210 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 for ours, giving less scope for any association to be identified. The significant contribution of hip flexion active range of motion to the model is supported by the findings of a number of other investigators [1,13,15]. Results from this study add to existing knowledge by showing that for
215 every 1° decrease in active straight leg raise, propensity for injury is increased 1.29X (1/0.77).

We found that the odds of sustaining an injury increased 1.47X with every 1cm extra achieved in the jump test. These findings concur with those of previous work [26] 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
220 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.

225 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 [14,27]. 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.

230 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, that conditioning programmes focus on increased 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 235 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 [28,29]. 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].

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CONCLUSION

245 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.

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PRACTICAL APPLICATIONS

- 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 minimize risk of hamstring injury.
- Training for older players should be adapted to allow time to perform activities which will minimize risk of injury.

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