Intrinsic risk factors of non-contact quadriceps and hamstring strains in soccer: a prospective study of 100 professional players

Konstantinos Fousekis,[1,2] Elias Tsepis,[2] Peter Poulmedis,[3] Spyros Athanasopoulos,[4] George Vagenas[1]

[1] Department of Physical Education and Sports Science, Quantitative Analysis & Kinesiology Research, University of Athens, Athens, Greece
[2] Department of Physiotherapy, Biomechanics and Sports Injuries Laboratory, Technological Educational Institute (TEI) of Patras, Branch Department of Aigion, Aigion, Greece
[3] Department of Physiotherapy, Sports Injuries Laboratory, Technological Educational Institute (TEI) of Athens, Athens, Greece
[4] Department of Physical Education & Sports Science, Laboratory of Sports Physical Theapy, University of Athens, Athens, Greece

Correspondence to
Mr Konstantinos Fousekis, 6 Psaron Street, Aigion 25100, Greece; konfousekis@yahoo.gr

Accepted 1 November 2010
Published Online First 30 November 2010

ABSTRACT

Objectives To identify the intrinsic risk factors of non-contact strains in the hamstrings and quadriceps muscles of professional soccer players via a cohort prospective design.

Methods A total of 100 professional soccer players (aged 19.4–27.8 years) from four professional teams underwent a composite musculoskeletal assessment at preseason. Intrinsic risk factors included dichotomies of asymmetries in muscle strength, flexibility, proprioception, anthropometry and knee joint stability, and of previous injuries. Muscle strains were prospectively monitored during the subsequent season using questionnaires. The data were analysed via binary logistic regression.

Results Thirty-eight percent of the players sustained one or more lower-extremity muscle strains. Sixteen (42.1 %) and seven (18.4 %) of them were clinically diagnosed as having non-contact muscle strains at their hamstrings and quadriceps, respectively. Players with eccentric hamstring strength asymmetries (OR=3.88; 95% CI 1.13 to 13.23), functional leg length asymmetries (OR=3.80; 95% CI 1.08 to 13.33) and no previous hamstrings injuries (OR=0.15; 95% CI 0.029 to 0.79) were at greater risk of sustaining a hamstring muscle strain. Players with eccentric strength (OR=5.01; 95% CI 0.92 to 27.14) and flexibility asymmetries (OR=4.98; 95% CI 0.78 to 31.80) in their quadriceps as well as heavier (OR=10.70; 95% CI 0.73 to 156.37) and shorter players (OR=0.08; 95% CI 0.00 to 1.35) were at greater risk of sustaining a strain in this muscle group.

Conclusions Professional soccer players with functional asymmetries possess a higher risk of sustaining hamstring strains. Previous injury seems not to constitute a risk factor. The systematic isokinetic evaluation of the lower extremities during the preseason period can provide therapists and trainers with valuable data regarding the predictive elements of non-contact hamstring strains in professional soccer players.

INTRODUCTION

Playing and practising in soccer requires players to cope with varying degrees of asymmetrical mechanical workloads imposed on the musculoskeletal structures of their lower extremities,[1 2] and this, consequently, leads to injury.[3 4] Epidemiological studies[5–9] show that injuries in soccer occur in relation to age, training level and gender, at a rate of 1.5–15.4 per 1000 h of training and 7.4–47.5 per 1000 h of playing.[10–12] In comparison with other team sports such as volleyball, handball and basketball, soccer presents higher rates of injuries.[13 14] The majority of these (68–88%) are lower-extremity injuries,[14 15] approximately 25% of which are non-contact thigh muscle strains.[9 16] These strains are primarily created by either a violent stretch of an eccentrically contracted muscle (the hamstring's case) or an explosive contraction of a muscle (the quadriceps's case), with prolonged functional disability and a strong tendency for recurrence being their major complications.[17 18]

Aetiologically, the risk of injury in soccer depends on both extrinsic (environment) and intrinsic (athletes) factors.[19–32] The physical contact between opponent players (contact injury) constitutes the main extrinsic factor, accounting for about 44–74% of the injuries,[20 21] whereas major sources of intrinsic aetiology are asymmetries in muscle strength,[20–28] flexibility[29–31] and proprioception,[32 33] as well as joint instability,[17] anatomical and anthropometric asymmetries,[22 23 28] age[20 21] and previous injury.[17 18] Although many studies have dealt with the investigation of these intrinsic factors in soccer, especially in relation to muscle strains, their specific impact on injury remains controversial.[19–33] As a general trend, the relevant studies were simply based on the assumption that muscle-strength asymmetries alter the kinetic patterns of the lower limbs of the players, and this predisposes the players to muscle strains.[4 22–24 26–28] For example, while some studies found a significant correlation between muscle-strength asymmetries and muscle injuries,[4 22–24] others failed to detect significance in this hypothetical association.[26–28] On the contrary, previous findings regarding asymmetries in muscle flexibility[29–31] and previous injuries[21 27] are more definite in terms of their connection to the occurrence of muscle strains in the lower limbs of the players.

Evidently, research on the intrinsic aetiology of muscle strains in soccer is limited to the study of separate factors (eg, strength, flexibility). No study has yet focused on the composite assessment of several factors simultaneously, such as asymmetries in the functional and somatometric profile of the lower limbs of the players. This aspect of the problem is crucial, since nearly every soccer player possesses some degree of functional footedness, which leads to consistent asymmetry in the neuromuscular patterns of the lower limbs.[1 2] Given the complex nature of aetiology in non-contact muscle strains, the purpose of this prospective study was to determine whether the composite effects of asymmetries in muscle strength, flexibility, proprioception, joint stability, physical characteristics and previous history of strains are connected with increased risk of non-contact lower-extremity muscle strains in professional soccer players.

METHODS

Study design and participants

This investigation was a prospective cohort study. The sample consisted of 100 professional soccer players free of injury for at least 6 months prior to testing, recruited from a total of 115 players from four teams of the 3rd National Soccer League division. The sample was grossly homogeneous in potential confounding variables, such as weight, height, age, training regime (one game and 6–7 days of training per week), climatic conditions, level of play, resting periods and professional experience (about at least 5 years). All players signed written informed consents. Based on a desired power level of 0.90 and a smallest detectable OR of 0.01 (in cases of OR<1 for predictors that decrease the odds of injury), the sample size was estimated to be 74.[34 35] The study was approved by the committee of Postgraduate Studies in Biology of Exercise, at the Physical Education and Sport Science Department of the University of Athens.

Procedures

All subjects underwent a preseasonal evaluation of lower-extremity isokinetic muscle strength, flexibility, joint stability, neuromuscular coordination and anthropometric traits. The measurements were carried out at the Biomechanics and Sports Injury Laboratory of the Physiotherapy Department, Technological Educational Institute of Patras. Table 1 provides an overview of the intrinsic risk factors, the anatomical elements, the variables and the corresponding experimental equipment in the procedures used. Previous injuries as well as lateral dominance-related characteristics were recorded for all players through questionnaires.[36]

Functional assessment

All tests were preceded by a 10–15 min warm-up consisting of pedalling on an ergometric bicycle and stretching exercises for the muscles of the lower limbs. Adequate familiarisation to each testing device and measurement was given to each subject. Three measurements were obtained and averaged per variable, muscle group and limb side, except for strength evaluation, where five repeated measurements were performed.

The isokinetic assessment was carried out on a Biodex-System III dynamometer (Biodex Medical, Shirley, New York) and included bilateral measurements of concentric and eccentric modes of muscle strength for the knee flexors and extensors and the ankle dorsal and plantar flexors as well as for the calculation of functional knee strength ratio at 180°/s. Flexibility was assessed with bilateral goniometric measurements for the knee and ankle flexors and extensors, according to the method described by Norkin *et al*.[37] Proprioception was assessed with bilateral kinaesthetic measurements using a Prokin-200 stabilometer (Prokin, Technobody, Dalmine, Bergamo).[38] In this test, the player had to cover a sequence of five traces of a circular route to the best of his ability by the movement of his lower limb using a cursor controlled by an electronic platform. The percentage deterioration from the circular route reflected the neuromuscular coordination of the lower extremities. Four anthropometric measurements were taken with the implementation of the International Society for the Advancement of Kinanthropometry method[39] by a level III accredited anthropometrist: weight, height, functional leg length, mid-thigh girth. The stability of the knee joint was assessed by the maximum anterior laxity (mm) produced after a maximum manual anterior displacement of the tibia using a KT-1000 arthrometer (Medmetric, San Diego, California).[40]

All non-contact muscle strains forcing players to miss at least one scheduled practise session or game were recorded by the club's physiotherapists for a period of 10 months following the initial testing, in accordance with the questionnaire proposed by Fuller *et al*.[36] To avoid any rehabilitative attempts of correcting functional asymmetries detected at the preseason testing, neither players nor their physiotherapists were informed about the results of the entire testing prior to the completion of the study.

A factor that would induce some variation was time of participation in games (exposure time). However, this factor is an extrinsic one (not within the scope of this study) and practically

Table 1 Tests and measurements of functional, somatometric characteristics and asymmetries of the lower limbs of professional soccer players (N=100)

Intrinsic risk factor	Anatomical elements*/property	Assessed variables	Experimental equipment—procedure
Isokinetic muscle strength	Knee extensors Knee flexors Ankle plantar flexors Ankle dorsal flexors	Con 60, 180, 300°/s; Ecc 60, 180°/s (Nm) Con 60, 180, 300°/s; Ecc 60, 180°/s (Nm) Con—Ecc 60°/s (Nm) Con—Ecc 60°/s (Nm)	Biodex System III[4]
Functional knee strength ratio	Eccentric knee flexors/concentric knee extensors	180°/s (Nm)	Biodex system III[4]
Muscle flexibility	Hamstrings Quadriceps Ankle plantar flexors	Range of motion (°)	Goniometric evaluation[37]
Proprioception	Neuromuscular coordination of the lower extremities	Percentage deterioration from ideal kinaesthetic rotation of the ankle joint	Kinaesthetic stabilometer Prokin-200 (Prokin-technobody Italy)[38]
Anthropometrics	WeightHeightMid-thigh girthLower limb functional length	Weight (kg) Height (cm) Mid-thigh girth (cm) Lower-limb functional length (cm)	International Society for the Advancement of Kinanthropometry method[39]
Joint stability	Knee joint	Anterior knee laxity (mm)	KT-1000 (medmetric)[40]
Previous injuries	Lower-extremity injuries	Non-contact muscle strains	Specific questionnaire[36]

*Measurements on both sides (left, right).
Con, concentric; Ecc, eccentric.

difficult to control. Previous studies do not examine exposure time as either a confounding or a controlled variable.

Data processing and analysis

Mean values and SDs for all outcome variables were computed. The independent variables (1) age, weight and height, which were used as dichotomies based on the median values (above or below median values), and (2) anatomical and functional asymmetries categorised as dichotomies (asymmetry, no asymmetry) according to established criteria (cut-off points): isokinetic strength asymmetries≥15%, [4 25] a functional isokinetic strength ratio (on at least one leg)<1, [4] flexibility asymmetries≥6°, [14 41] proprioception asymmetries (right–left)≥15% and knee stability asymmetries (right–left)≥2 mm.[42] The specific anthropometric characteristics (functional leg length, mid-thigh girth) were classified as asymmetrical if they were at least 1 SD above or below the average asymmetry value (right–left) on at least one measurement. The dependent variable was also a dichotomy reflecting the occurrence or not of a muscle strain.

The relationship between the independent variables and the dependent variable was examined by backward stepwise binary logistic regression (Wald, inclusion probability p≤0.10) with OR analysis been used as in previous studies[3 4 14 21] for estimating the simultaneous effects of several predictors instead of relative risk estimates.[43] Logistic regression function is logit $(p)=b_0+b_1X_1+b_2X_2+..+b_kX_k$ and predicts a logit transformation of the probability (p) of occurrence of an outcome of the form odds=p/(1−p), in our case of the probability of a non-contact muscle strain.

RESULTS

The players ranged from 19.4 to 27.8 years of age, 172.04 to 183.32 cm in height, 67.4 to 79.28 kg in weight and 5.90 to 11.52 years in professional training age. The distribution of the players in terms of their functional asymmetries is given in table 2. From the 100 players tested in 14 isokinetic variables, only 11 (11%) showed a normal isokinetic muscle strength profile (with asymmetries<15%). At least one clinically substantial (≥ 15%) muscle strength asymmetry was detected in 68% of the players for the concentric mode of isokinetic muscle contraction and in 73% of these for the eccentric. Thirty-two players (32%) presented asymmetries in mid-thigh girth and in functional leg length, and 34 (34%) in anterior knee laxity asymmetry. Thirty eight (38%) players had flexibility asymmetries in the hamstrings and 16 (16%) in the quadriceps. Previous strains were found in 33 of the players (33%) for the hamstrings and only in 13 of (13%) for the quadriceps.

Thirty-eight players (38%) sustained at least one muscle strain injury at their lower extremities, both contact and non-contact, which caused them to miss training and/or playing time during the period of the study. Twenty-eight players (28%) suffered non-contact muscle strains, from which seven (7%) occurred in the quadriceps, 16 (16%) in the hamstrings, three (3%) in the hip adductors and two (2%) in the gastrocnemius muscle. Based on the total number of injuries recorded, 16 injuries (43%) occurred on the right lower extremity and 21 (57%) on the left. In terms of lateral dominance, 21 (57%) injuries occurred on the dominant (kicking) leg and 16 (43%) on the non-dominant. Owing to the small number of strains reported for the hip adductors and the ankle plantar flexors, only the hamstrings and quadriceps strains were used in the logistic regression model. The baseline values for the respective independent variables are given in tables 3, 4, while the summary statistics of the logistic regression model are given in table 5.

Table 2 Percent (%) of players possessing functional asymmetries and previous strains (N=100)

Characteristics	No of variables	Players (%) with asymmetries
Specific somatometric asymmetries	2	32
Functional leg length (right–left≥1.8 cm)	1	29
Mid-thigh girth (right–left≥1.5 cm)	1	20
Knee laxity (right–left≥2 mm)	1	34
Proprioception asymmetries (right–left≥15%)	1	54
Myodynamic asymmetries (right–left≥15%)	14	89
Concentric strength	8	68
Eccentric strength	6	73
Quadriceps concentric strength	3	17
Quadriceps eccentric strength	2	20
Hamstrings concentric strength	3	34
Hamstrings eccentric strength	2	47
Functional isokinetic strength ratio (180°/s)	1	39
Flexibility asymmetries (right–left>6°)	3	49
Quadriceps flexibility	1	16
Hamstrings flexibility	1	38
Previous strains	3	49
Previous quadriceps strain	1	13
Previous hamstrings strain	1	33

This model revealed three significant predictors of hamstring muscle strain occurrence: eccentric hamstring strength asymmetries (OR=3.88; 95% CI 1.13 to 13.23, p=0.03), functional leg length asymmetries (OR=3.80; 95% CI 1.08 to 13.33, p=0.03), previous hamstring injuries (OR=0.15; 95% CI 0.029 to 0.79, p=0.02). The first two (OR>1) increase and the third (OR<1) decrease the odds of injury. None of the other intrinsic factors imposed a significant relative risk for hamstring strain (p>0.05). Regarding quadriceps, a trend was documented for heavier (OR=10.70; 95% CI 0.73 to 156.37, p=0.08) and shorter players (OR=0.08; 95% CI 0.00 to 1.35, p=0.08), as well as for players with eccentric strength (OR=5.01; 95% CI 0.92 to 27.14, p=0.06) and flexibility (OR=4.98; 95% CI 0.78 to 31.80, p=0.08) asymmetries in the quadriceps to be at greater risk for a strain in this muscle group. This trend was not significant at the 0.05 level, probably owing to the small number of players (seven) having this injury.

DISCUSSION

The present study hypothesised that anatomical and functional asymmetries increase the propensity of non-contact lower-extremity muscle strains in professional soccer players. A total of 100 professional players were examined at preseason and monitored for a total of 10 months to the end of the competition period. The results verified that the lower extremities of soccer players tend to be asymmetrical. Almost half of the players (49%) had flexibility asymmetries, and only 11% of the players had normal isokinetic strength symmetry. Additionally, 39 (39%) of the players had isokinetic strength imbalances in the knee joint, 22 (22%) presented somatometric asymmetries, while 34% presented anterior knee laxity asymmetries. A total of 28 non-contact muscle strains were recorded in the lower limbs of the players. Sixteen occurred in the hamstrings (57%) and seven in

Table 3 Descriptive statistics profile of functional and somatometric characteristics for players with injured and uninjured hamstrings (N=100)

		Hamstring injured soccer players (N=16)		Hamstring uninjured soccer players (N=83)	
Age (years)		22.94 (4.11)		23.00 (3.27)	
Weight (kg)		74.71 (3.64)		71.58 (5.96)	
Height (cm)		180.04 (4.97)		176.36 (6.19)	
		RightM (SD)	**LeftM (SD)**	**RightM (SD)**	**LeftM (SD)**
Hamstring isokinetic strength (Nm)	Con 60°/s	136.25 (22.57)	133.38 (23.49)	142.06 (30.51)	133.05 (23.46)
	Con 180°/s	108.47 (16.53)	101.72 (18.15)	109.32 (21.19)	103.07 (18.17)
	Con 300°/s	93.78 (15.64)	92.83 (18.63)	98.42 (21.00)	92.85 (20.52)
	Ecc 60°/s	189.90 (43.46)	187.49 (30.68)	192.51 (52.06)	191.80 (54.56)
	Ecc 180°/s	188.36 (46.74)	170.45 (44.40)	186.62 (47.02)	185.02 (46.26)
Knee functional strength ratio	Hamstrings/quadriceps 180°/s	1.11 (0.22)	1.03 (0.26)	1.14 (0.25)	1.11 (0.24)
Muscle flexibility (°)	Hamstrings flexibility	89.17 (15.00)	90 (11.89)	82 (14.37)	89.11 (14.19)
Proprioception (percentage deterioration)	Kinaesthesis	24.47 (10.57)	24.66 (11.60)	38.30 (16.91)	45.05 (28.99)
Anthropometrics (cm)	Mid-thigh girth*	53.14 (1.44)	52.52 (1.43)	52.34 (2.57)	52.08 (2.50)
	Lower-leg functional length*	92.07 (4.30)	92.25 (4.57)	91.44 (4.67)	91.61 (4.28)
Joint stability (mm)	Anterior knee laxity	7.29 (2.05)	8.17 (2.48)	7.82 (1.50)	8.35 (2.47)

*Intratester reliability (body sides): (1) technical error of measurements<1%; (2) intraclass correlation coefficient>0.98.
Con, concentric; Ecc, eccentric.

Table 4 Descriptive statistics profile of functional and somatometric characteristics for players with injured and uninjured quadriceps (N=100)

		Quadriceps injured soccer players (N=7)		Quadriceps uninjured soccer players (N=93)	
Age (years)		25.42 (5.28)		23.42 (2.76)	
Weight (kg)		72.35 (4.69)		73.42 (3.36)	
Height (cm)		176.41 (4.68)		180.81 (2.76)	
		RightM (SD)	**LeftM (SD)**	**RightM (SD)**	**LeftM (SD)**
Quadriceps isokinetic strength (Nm)	Con 60°/s	231.61 (29.46)	241.17 (29.99)	241.14 (2.48)	233.57 (27.33)
	Con 180°/s	160.20 (21.90)	168.41 (25.47)	167.50 (26.33)	167.94 (22.41)
	Con 300°/s	131.40 (16.23)	142.97 (18.98)	133.61 (19.40)	132.52 (11.97)
	Ecc 60°/s	324.94 (48.07)	305.25 (49.52)	269.64 (92.21)	269.14 (76.45)
	Ecc 180°/s	295.68 (62.44)	315.60 (55.84)	243.22 (79.95)	225.98 (79.43)
Knee functional strength ratio	Hamstrings/quadriceps 180°/s	1.15 (0.22)	1.13 (0.17)	1.35 (0.28)	1.08 (0.40)
Muscle flexibility (º)	Quadriceps flexibility	158.42 (1.51)	152.71 (5.58)	159.00 (2.6)	147.28 (7.01)
Proprioception (percentage deterioration)	Kinaesthesis	43.73 (12.63)	61.73 (35.18)	22, 19 (7.60)	23.57 (9.82)
Anthropometrics (cm)	Mid-thigh girth*	51.77 (3.13)	51.90 (2.91)	54.05 (1.06)	53.28 (0.76)
	Lower-leg functional length*	91.44 (3.92)	91.57 (4.03)	93.54 (5.57)	94.05 (5.48)
Joint stability (mm)	Anterior knee laxity	7.71 (1.88)	9.14 (2.67)	7.14 (1.34)	8.57 (3.20)

*Intratester reliability (body sides): (1) technical error of measurements<1%; (2) intraclass correlation coefficient>0.98.
Con, concentric; Ecc, eccentric.

the quadriceps (25%). This epidemiological incidence rate of non-contact muscle strains is in accordance with the findings of previous studies.[8 9]

The analysis of these data via logistic regression determined that for the development of hamstring strains in soccer players, two functional asymmetries of the lower limbs (isokinetic strength and leg length) are accountable, with previous history of strains in the same muscle group being rather reductive of the odds of this injury. Players with an eccentric isokinetic strength asymmetry of >15%, a functional leg length asymmetry of >1.8 cm and no previous injury (OR<1) were at greater risk of suffering a non-contact hamstring injury compared with those with lower or no asymmetries and hamstring strain history.

Regarding quadriceps, no significant risk factor of muscle strain was found, with this apparently being the result of the small number of cases with quadriceps strains (seven). This outcome leaves the definite answer about quadriceps to be answered by future studies analysing a sufficiently large number of strains. Despite this, the study offered a clear novel methodological approach by applying an assessment protocol on all intrinsic factors with a potential impact on the risk of non-contact muscle strains. Relevant research so far has concentrated on the analysis of single aetiological factors for soccer traumas, in spite of the rather complex (multivariable) structure of the phenomenon. In this respect, previous findings regarding muscle strength asymmetries[4 25] and imbalances,[22 24] flexibility asymmetries[29–31] and previous injuries[21 27] only

Table 5 Frequencies and logistic regression* results: intrinsic risk factors for hamstrings and quadriceps muscle strains in professional soccer players (N=100)

Intrinsic aetiological factors		Frequencies* (%)		Statistics		
		Low risk	High risk	OR	95% CI	p Value
Hamstrings muscle strains (16 vs 84)						
Eccentric hamstrings strength asymmetries	No strain	48	36	3.88	1.13 to 13.23	0.03
	Strain	5	11			
Functional leg length asymmetries	No strain	62	22	3.80	1.08 to 13.33	0.03
	Strain	9	7			
Previous hamstring strains	No strain	53	31	0.15†	0.029 to 0.79	0.02
	Strain	14	2			
Quadriceps muscle strains (7 vs 93)						
Weight	No strain	55	38	10.70	0.73 to 156.37	0.08
	Strain	3	4			
Height	No strain	42	51	0.08†	0.00 to 1.35	0.08
	Strain	4	3			
Quadriceps flexibility asymmetries	No strain	80	13	4.98	0.78 to 31.80	0.08
	Strain	4	3			
Eccentric quadriceps strength asymmetries	No strain	77	16	5.019	0.928 to 27.14	0.06
	Strain	3	4			

High risk (low risk): with (without): (1) preseason functional asymmetries, (2) previous muscle strains, (3) weight above (below) median and (4) height above (below) median.
Strain (no strain): with (without) muscle strain.
*Two separate models determined.
†OR<1: decreased odds of injury.

partially explained the potential risk for non-contact muscle strain that characterises soccer players. In our study, the use of logistic regression with several independent factors led to the identification of three significant predictors (functional leg length asymmetry, excessive isokinetic asymmetry, previous hamstring strains), which, combined together, provide a composite effect on the risk of muscle strain. Thus, the results of previous studies with soccer players are comparable only in terms of single explanatory variables—for example, the study by Croisier *et al.*,[4] with its primary finding that the incidence rate of hamstring strains is significantly increased in players with eccentric strength asymmetries (>15%); or the studies by Croisier *et al*[4] and Ascling *et al*,[44] in which this incidence rate was found to be significantly lower in players following a specific eccentric muscle-strengthening programme of the hamstrings, compared with those who did not.

Our findings clearly support the general hypothesis that symmetry in the myodynamic function of the lower extremities is crucial for the prevention of muscle injuries in athletes. Therefore, asymmetry in the hamstrings function may decrease the capability of the muscle to cope with the maximal forces created by the explosive contraction of knee extensors in the deceleration phase of the late forward swing in running, thus leading to muscle injury. On the other hand, the reduced risk for non-contact hamstring strains in players with a history of previous hamstring strains is opposite that of previous findings,[21 27] assuming an increase in the risk due to inadequate rehabilitation or neuromuscular adaptations[45] usually following a muscle strain. In ankle injuries, in which both passive and active elements of the joint structure are implicated, a similar finding (previous injury not connected to reinjury) was attributed to the type of rehabilitation, the compliance of the athlete to it and the quality of recovery.[46] In our view, this novel finding may also be at least partially attributed to improved contemporary rehabilitative techniques and to protective kinetic patterns adopted by the injured players to avoid reinjury.

A significant role in increasing the risk of muscle injury, especially in the hamstrings, seems to be played by the functional leg length inequality as well. It appears that this structural inequality alters the kinetic patterns of the lower-extremity function during the production of excessive and asymmetrical forces in explosive sports activities, such as kicking and cutting in soccer. Previous studies examining the role of anatomical characteristics in the risk of non-contact muscle strains in soccer players focused on only ligament injuries and their association with general joint laxity[28] and proprioceptive asymmetries.[32 33] Additionally, contrary to findings correlating muscle flexibility asymmetries[29–31] and isokinetic strength imbalances[22 24] with muscle strains, no such association was revealed in the present study. It is possible that potential asymmetries of muscle flexibility and knee strength ratios play a secondary role in the mechanisms that predispose the soccer player to quadriceps and hamstring strains.

The present study was not a randomised study, and this limitation is recognised by all other relevant prospective studies of professional soccer players. Other potential limitations are the conversion of continuous data into dichotomies, using the median as a control point, not controlling for exposure time and not using cluster analysis for examining the problem under study on an individual player level (not in the scope of the study). However, as reliability and validity of the preseason assessment are critical, the current study adopted a prospective design with controlled experimental conditions (same lab, identical conditions, same testers). Relevant studies assessing larger samples (>100) adopt insufficiently controlled experimental conditions (ie, different laboratories and different testers).[4 26–28] In that respect, our study substantially improved previously applied procedures, and, considering the use of multivariable logistic regression, our results are so far of the highest validity and, therefore, of better applicability regarding injury prevention and rehabilitation in soccer.

CONCLUSIONS

The presence of clinically significant isokinetic strength and functional leg length asymmetries in the lower limbs of soccer players increase the odds of non-contact hamstring strains. Previous hamstring strain seems to decrease the odds of injury recurrence. Other potential intrinsic factors, such as age, cross-sectional periphery of the thigh, muscle flexibility, functional knee strength ratio, knee-joint laxity and proprioceptive traits, proved to be irrelevant to the creation of quadriceps and hamstrings muscle strains. A preseasonal functional assessment similar to that used in the present study must lead to the detection of the major intrinsic risk factors connected with these strains. A strengthening protocol focusing on the reduction in lower-extremity strength asymmetries may then be developed, evaluated and employed for the purpose of reducing the risk of occurrence of non-contact muscle strains in soccer players.

Competing interests None.

Patient consent Obtained.

Ethics approval Ethics approval was provided by the committee of Postgraduate Studies in Biology of Exercise, at the Physical Education and Sport Science Department of the University of Athens.

Provenance and peer review Not commissioned; externally peer reviewed.

REFERENCES

1. **Fousekis K,** Tsepis E, Vagenas G. Lower limb strength in professional soccer players:profile, asymmetry, and training age. *JSSM* 2010;**9**:364–73.
2. **Masuda K,** Kikuhara N, Demura S, *et al.* Relationship between muscle cross-sectional area and strength in various isokinetic movements among soccer players. *J Sports Sci* 2003;**21**:851–8.
3. **Dauty M,** Potiron-Josse M, Rochcongar P. Consequences and prediction of hamstring muscle injury with concentric and eccentric isokinetic parameters in elite soccer players. *Ann Readapt Med Phys* 2003;**46**:601–6.
4. **Croisier JL,** Ganteaume S, Binet J, *et al.* Strength imbalances and prevention of hamstring injury in professional soccer players: a prospective study. *Am J Sports Med* 2008;**36**:1469–75.
5. **Baumhauer JF,** Alosa DM, Renstrom AF, *et al.* A prospective study of ankle injury risk factors. *Am J Sports Med* 1995;**23**:564–70.
6. **Bjordal JM,** Arnly F, Hannestad B, *et al.* Epidemiology of anterior cruciate ligament injuries in soccer. *Am J Sports Med* 1997;**25**:341–5.
7. **Junge A,** Dvorak J, Graf-Baumann T, *et al.* Football injuries during FIFA tournaments and the Olympic Games, 1998–2001: development and implementation of an injury-reporting system. *Am J Sports Med* 2004;**32**(1 Suppl):80S–9S.
8. **Woods C,** Hawkin RD, Maltby S, *et al.* The football association medical research programme: an audit of injuries in professional football. Analysis of hamstring injuries. *Br J Sports Med* 2004;**38**:36–41.
9. **Hawkins RD,** Hulse MA, Wilkinson C, *et al.* The association football medical research programme: an audit of injuries in professional football. *Br J Sports Med* 2001;**35**:43–7.
10. **Ekstrand J,** Tropp H. The incidence of ankle sprains in soccer. *Foot Ankle* 1990;**11**:41–4.
11. **Peterson L,** Junge A, Chomiak J, *et al.* Incidence of football injuries and complaints in different age groups and skill-level groups. *Am J Sports Med* 2000;**28**:S51–7.
12. **Dvorak J,** Junge A. Football injuries and physical symptoms. A review of the literature. *Am J Sports Med* 2000;**28**:S3–9.
13. **Yde J,** Nielsen AB. Sports injuries in adolescents' ball games: soccer, handball and basketball. *Br J Sports Med* 1990;**24**:51–4.
14. **de Loës M.** Epidemiology of sports injuries in the Swiss organization 'Youth and Sports' 1987–1989. Injuries, exposure and risks of main diagnoses. *Int J Sports Med* 1995;**16**:134–8.
15. **Junge A,** Dvorak J, Graf-Baumann T, *et al.* Football injuries during FIFA tournaments and the Olympic games, 1998–2001: development and implementation of an injury-reporting system. *Am J Sports Med* 2004;**32**(Suppl 1):S80–9.
16. **Junge A,** Cheung K, Edwards T, *et al.* Injuries in youth amateur soccer and rugby players–comparison of incidence and characteristics. *Br J Sports Med* 2004;**38**:168–72.
17. **Ekstrand J,** Gillquist J. Soccer injuries and their mechanisms: a prospective study. *Med Sci Sports Exerc* 1983;**15**:267–70.
18. **Ekstrand J,** Gillquist J. The avoidability of soccer injuries. *Int J Sports Med* 1983;**4**:124–8.
19. **Warrel TW.** Factors associated with hamstrings injuries: an approach to treatment and preventive measures. *Sports Med* 2003;**17**:338–45.
20. **Nielsen AB,** Yde J. Epidemiology and traumatology of injuries in soccer. *Am J Sports Med* 1989;**17**:803–7.
21. **Arnason A,** Sigurdsson SB, Gudmundsson A, *et al.* Risk Factors for Injuries in Football. *Am J Sports Med* 2004;**32**(1 Suppl):5S–16S.
22. **Devan MR,** Pescatello LS, Faghri P, *et al.* A Prospective Study of Overuse Knee Injuries Among Female Athletes With Muscle Imbalances and Structural Abnormalities. *J Athl Train* 2004;**39**:263–7.
23. **Söderman K,** Alfredson H, Pietilä T, *et al.* Risk factors for leg injuries in female soccer players: a prospective investigation during one out-door season. *Knee Surg Sports Traumatol Arthrosc* 2001;**9**:313–21.
24. **Poulmedis P.** Muscular imbalance and strains in soccer. In: Van der Togt CR, Kemper AB, eds. *Proceedings 3rd Meeting Council of Europe: Sports Injuries and Their Prevention.* Oosterbeek: National Institute for Sports Health Care 1988:53–7.
25. **Knapik JJ,** Bauman CL, Jones BH, *et al.* Preseason strength and flexibility imbalances associated with athletic injuries in female collegiate athletes. *Am J Sports Med* 1991;**19**:76–81.
26. **Grace TG,** Sweetser ER, Nelson MA, *et al.* Isokinetic muscle imbalance and knee-joint injuries. A prospective blind study. *J Bone Joint Surg Am* 1984;**66**:734–40.
27. **Bennell K,** Wajswelner H, Lew P, *et al.* Isokinetic strength testing does not predict hamstring injury in Australian Rules footballers. *Br J Sports Med* 1998;**32**:309–14.
28. **Ostenberg A,** Roos H. Injury risk factors in female European football. A prospective study of 123 players during one season. *Scand J Med Sci Sports* 2000;**10**:279–85.
29. **Witvrouw E,** Danneels L, Asselman P, *et al.* Muscle flexibility as a risk factor for developing muscle injuries in male professional soccer players. A prospective study. *Am J Sports Med* 2003;**31**:41–6.
30. **Bradley PS,** Portas MD. The relationship between preseason range of motion and muscle strain injury in elite soccer players. *J Strength Cond Res* 2007;**21**:1155–9.
31. **Ibrahim A,** Murrell GA, Knapman P. Adductor strain and hip range of movement in male professional soccer players. *J Orthop Surg (Hong Kong)* 2007;**15**:46–9.
32. **Mandelbaum BR,** Silvers HJ, Watanabe DS, *et al.* Effectiveness of a neuromuscular and proprioceptive training program in preventing anterior cruciate ligament injuries in female athletes: 2-year follow-up. *Am J Sports Med* 2005;**33**:1003–10.
33. **Caraffa A,** Cerulli G, Projetti M, *et al.* Prevention of anterior cruciate ligament injuries in soccer. A prospective controlled study of proprioceptive training. *Knee Surg Sports Traumatol Arthrosc* 1996;**4**:19–21.
34. **Demidenko E.** Sample size determination for logistic regression revisited. *Stat Med* 2007;**26**:3385–97.
35. **Demidenko E.** Sample size and optimal design for logistic regression with binary interaction. *Stat Med* 2008;**27**:36–46.
36. **Fuller CW,** Ekstrand J, Junge A, *et al.* Consensus statement on injury definitions and data collection procedures in studies of football (soccer) injuries. *Scand J Med Sci Sports* 2006;**16**:83–92.
37. **Norkin C,** White D. *Measurement of Joint Motion: A Guide to Goniometry.* F A Davis Company, Philadelphia, USA. 2003:181–241.
38. **Felicetti G,** Chiappano G, Molino A, *et al.* Preliminary study of the validity of an instrumental method of evaluating proprioception in patients undergoing total knee arthroplasty. *Eura Medicophys* 2003;**39**:67–94.
39. **Norton K,** Olds T. *Anthropometrica: A Textbook of Body Measurement for Sports and Health Courses*. Sydney: University of New South Wales 1996:172–98.
40. **Arneja S,** Leith J. Review article: Validity of the KT-1000 knee ligament arthrometer. *J Orthop Surg (Hong Kong)* 2009;**17**:77–9.
41. **Agre JC,** Baxter TL. Musculoskeletal profile of male collegiate soccer players. *Arch Phys Med Rehabil* 1987;**68**:147–50.
42. **Fortser I,** Orster I, Waoren-Smith CD, *et al.* Is the KT1000 knee ligament arthrometer reliable? *J Bone Joint Surg* 1989;**71**:843–7.
43. **Deeks J.** When can odds ratios mislead? Odds ratios should be used only in case–control studies and logistic regression analyses. *BMJ* 1998;**317**:1155–6.
44. **Ascling C,** Karlsson J, Thorstensson A. Hamstring injury occurrence in elite soccer players after preseason strength training with eccentric overload. *Scand J Med Sci Sports* 2003;**13**:244–50.
45. **Brocket CL,** Morgan DL, Proske U. Predicting hamstring strain injury in elite athletes. *Med Sci Sports Exerc* 2004;**36**:379–87.
46. **Beynnon BD,** Murphy DF, Alosa DM. Predictive factors for lateral ankle sprains: a literature review. *J Athl Train* 2002;**37**:376–80.

Intrinsic risk factors of non-contact quadriceps and hamstring strains in soccer: a prospective study of 100 professional players

Konstantinos Fousekis, Elias Tsepis, Peter Poulmedis, Spyros Athanasopoulos and George Vagenas

Br J Sports Med 2011 45: 709-714 originally published online November 30, 2010
doi: 10.1136/bjsm.2010.077560