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Intrinsic risk factors for hamstring injuries among male soccer players – a prospective cohort study

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Key terms: Hamstring injuries; football; risk factors; prospective cohort study; previous injuries.

Abstract

Background: Strain injuries of the posterior thigh are common in soccer. It seems that previous injury and age are important risk factors, but the literature is limited. This study was conducted to see if we could identify intrinsic risk factors for hamstring injuries among male soccer players.

Hypothesis: We hypothesized that previous hamstring injuries, reduced function scores, abnormalities on a clinical examination, high maximum sprint speed, poor hamstring strength or low hamstring/quadriceps ratio can predict increased risk of new hamstring injuries.

Study design: Prospective cohort study.

Methods: A total of 508 players representing 31 amateur teams were tested during the 2004 preseason for potential risk factors for hamstring injury through a questionnaire on previous injury and function score (Hamstring Outcome Score; HaOS), a clinical examination of the hamstring and specific hamstring relevant tests. Generalized estimating equations were used in univariate analyses to identify candidate risk factors, and factors with a p-value of <0.10 were then examined in a multivariate model.

Results: During the soccer season, 76 hamstring injuries, affecting 65 legs (61 players), were registered. Univariate analyses revealed previous acute hamstring injury (yes/no) (OR: 2.62, 95% CI 1.54 to 4.45), HaOS function score with all sub-scores except "Soreness" (OR for a 10-point difference in total score: 1.29; 95% CI, 1.08-1.54), age (OR: 1.25, 95% CI 0.96 to 1.63) and player position (p=0.09) as candidate predictors of high injury risk.

In a multivariate analysis the most important risk factor for injuries to the hamstring was previous acute hamstring injury (yes/no) (adjusted OR: 2.19 [1.19-4.03], P=0.01).

Conclusions: In a multivariate analysis previous acute hamstring injury was found to be a significant risk factor for new hamstring injuries. Previously injured players have more than twice as high risk of sustaining a new hamstring injury.

Introduction

Strain injuries of the posterior thigh are among the most common injuries in soccer and account for 10% to 23% of all acute injuries.[2, 10, 18, 21, 22, 29, 30] Also, a vicious circle with recurrent hamstring injuries is not uncommon, resulting in a chronic problem with significant morbidity in terms of symptoms, reduced performance and time loss from sports. Hence, prevention of the first as well as repeated hamstring injuries is important.

To prevent new injuries, the specific intrinsic and extrinsic risk factors for hamstring injury in soccer players must be identified.[24] Regarding intrinsic risk factors, it seems that previous hamstring injury, especially when rehabilitation is inadequate, places an athlete at increased risk of suffering an injury to the hamstring.[3] Also, age has been shown to be a risk factor, independent of history of previous injury.[3] The same risk factors have been identified in other sports as well.[14]

Although studies examining whether low hamstring strength is a significant risk factor have produced conflicting results, a recent intervention study has shown a preventive effect of the specific eccentric strength exercise “Nordic Hamstring lowers”.[1] In a pilot study, another eccentric exercise was also shown to be useful.[4]

A multivariate approach should be used to examine the contribution of various risk factors for injuries and explore their interrelationship.[24] Among male soccer players, there are few risk factor studies which have included multivariate analyses. We therefore planned the present prospective cohort study on soccer players to screen for several potential risk factors for hamstring injuries, some of which have not been studied in depth earlier.

Elite players only constitute a small portion of all soccer players, and advanced resources for screening tests are not available for the majority of players. Therefore, one goal of this study was to investigate if simple screening tests, which are easy to do and not require advanced equipment, can be used to identify individuals at risk. In this way, if the questionnaire and simple strength and sprint tests in this study prove useful, teams and players with minimal resources can test themselves in the pre-season to find out whether they have an increased risk of injuries.

We hypothesized that previous acute hamstring injuries, reduced function scores, abnormalities on a clinical examination, high maximum sprint speed, short hamstring muscles, poor hamstring strength or a low hamstring/quadriceps strength ratio can predict increased risk of new hamstring injuries. In addition, we included player information such as age, height, weight, BMI and player position to investigate if there were any correlations between these variables and injury risk.

Hence, the aim of this study was to examine potential intrinsic risk factors for injuries to the hamstrings in a prospective cohort study among subelite male soccer players.

Methods

Design and participants

This study is based on data from a randomized trial on male amateur soccer players examining the effect of a training program designed to prevent injuries. The design, the intervention program, and the results of the study have previously been described in detail in a separate paper.[12] Because no differences were seen in injury rates between the intervention and control groups,[12] the entire cohort could be used to examine the effect of a number of risk factors assessed at baseline.

A total of 35 teams (n=769 players) from the Norwegian 1st, 2nd or 3rd division of soccer for men, geographically located in the proximity of Oslo, were invited to participate in the study.

In Norway there are several different 3rd division conferences, and the 3rd division teams included either won their conference or finished as first runners up the previous season, resulting in a relatively homogenous group of teams, even if the 35 teams competed in three different divisions. Three of the teams (n=60 players) declined the invitation to participate, 177 players did not report for testing, three players did not speak Norwegian and could therefore not complete the questionnaire and four players were excluded for other reasons (Figure 1). Hence, 244 of the players invited could not be included. In addition, one team (n=17 players) was later excluded because the physiotherapist did not record injuries, resulting in a final sample of 508 players representing 31 teams from three divisions (1st division, n=7, 122 players; 2nd division, n=16, 260 players; and 3rd division, n=8; 126 players).

Risk factor screening

The teams were tested for potential risk factors for hamstring injuries during the 2004 pre-season, January through March, at the Norwegian School of Sport Sciences. Every player capable (not injured at the time) completed three counter movement jumps, two 40 m sprint tests, a Nordic hamstring strength test, a clinical examination including hamstring length measurement and a questionnaire.

The counter movement jump test was performed on a force plate (AMTI LG6-4-1, Advanced Mechanical Technology, Inc., Watertown, MA, USA), with hands held at the hips as described by Lian et al.[23] From a standing position with straight knees the player squatted down to at least 90° before jumping as high as he could. All three tests were scored as the maximal height of rise of the center of gravity in centimeters, calculated based from data on body weight and ground reaction forces on the force plate during the jump. The best result was used for the analysis.

The 40 m sprint test was performed with time cells at the Norwegian Olympic Training Center, measuring the time from when the front foot left the floor to the time sensor at 40 m.

The Nordic hamstring strength test was developed for this study based on the Nordic hamstring exercise.[1, 25] The player was instructed to lower his upper body towards the floor in a slow and controlled manner, always keeping his back and hips straight, until the point where he had to let go with his hamstrings, thereby falling towards the ground (Figure 2a and 2b). The test was done twice; the best result was used and scored in two categories according to whether the player could hold the position beyond 30° of forward flexion (strong) or not (weak). The choice of 30° as cut-off point was arbitrary, as this test has never before been used for screening. However, based on results from a pilot study, 30° was believed to be a relevant cut-off to separate players with reasonably strong hamstrings from weaker players.

The clinical testing of the players was performed by a group of ten sports physical therapists and sports physicians who were blinded to injury history. The players were examined for hip range of motion and determined to be tender on palpation of the hamstrings, iliopsoas and psoas major muscles (yes/no). In addition, hamstring length was measured in degrees using the Passive Knee Extension test, as described in detail by Árnason et al.[3]

The players also completed a questionnaire in two parts, where the first part covered general player information (age, height, body mass index, position on the field, number of junior or senior national team matches played, level of play this season, and level of play the previous season), and history of previous injuries (number, severity, nature and number of months since the most recent hamstring injury, and if the most recent injury had caused the player to miss matches). The second part was a function score for the hamstrings (Hamstring Outcome Score; HaOS), which was developed as a screening tool.[12] This form has a similar outline as the KOOS form,[27] which consists of five major parts (symptoms and stiffness, pain, function in daily living, function in sports and recreational activities and quality of life) and is scored by calculating the mean value of the five parts in percent of the total possible score, where 100% is the maximal and 0% the lowest score. For the HaOS score, we replaced the category “function in daily living” with a category on muscle soreness resulting in five categories (symptoms, pain, soreness, function in sports and quality of life).

In addition, a similar screening was done for risk factors for ankle, knee and groin injuries. The data from these tests are reported in separate papers.

Injury reporting

An injury was defined as any physical complaint sustained by a player that made him seek medical assistance and that resulted from a soccer match or soccer training, forcing him to miss or being unable to take full part in future soccer training or match play (“time-loss” injury). Acute injuries were defined as injuries with a sudden onset associated with a known trauma, whereas overuse injuries were those with a gradual onset without any known trauma. Two of the authors were blinded to all other information regarding risk factors and categorized all injuries based on the injury reports from the physiotherapist. For the purpose of the present paper, an injury was classified as hamstring strain if it was recorded as either an acute or an overuse muscle injury of the posterior thigh. Injuries were classified into three severity categories according to the time it took until the player was fully fit to take part in all types of organized soccer play: minor (1-7 days), moderate (8-28 days) and major (>28 days). Overuse injuries where there was no time loss were included to incorporate small repeated strain injuries, as some players still elect to play despite discomfort in the posterior thigh. The head coach for every team registered each player’s participation in training and the number of minutes played in matches.

The team physical therapist was responsible for reporting injuries on their team throughout the preseason and the season. Most of the teams from the 1st and 2nd division already had a physical therapist working with the team. In case there was no physical therapist involved, we assigned one for the team. However, the physical therapist was not required to be present at every training session and match; the degree of follow-up therefore varied from team to team participating in the study.

Reliability testing

Inter-test reliability tests were carried out for both the clinical examination of hamstring muscle length and the Nordic hamstring strength test by having the same player repeat the same test with different personnel after he had completed the first test. Each examiner was blinded to the other's results. The same scoring system/clinical forms were used at both stations. Inter-test reliability for the categorical variables in the interpretation of the Nordic hamstring strength tests was computed using kappa statistics, while the coefficient of variation for the continuous variable hamstring muscle length was calculated as the standard deviation of the difference between the first and second test as a percentage of the average test results for both tests.

Statistical methods

Exposure to matches and training was calculated by adding the individual duration of all training and match play during the season.

For the continuous dependent variable risk factor analyses, where each leg was the unit of analysis, generalized estimating equations (STATA, version 8; STATA, Texas, U.S.A.) were used, accounting for individual exposure during the soccer season, any within-team correlations and the fact that the left and the right leg belonged to the same player. Logistic regression analyses were used to analyze the relationships between per subject calculated dichotomous injury variables and their risk factors.

All risk factor variables were examined in univariate analyses, and those with a P value <0.10 were investigated further in a multivariate model.

Results

A total of 505 injuries were reported, sustained by 283 (56%) of the 508 players included in the study. The total incidence of injuries during the season was 4.7 injuries per 1000 playing hours (95% CI 4.3 to 5.1). 12.1 (227 injuries) (95% CI 10.5 to 13.7) for match injuries and 2.7 (243 injuries) (95% CI 2.4 to 3.1) for training injuries (in 35 cases it was not reported whether the injury occurred during a match or training). The total exposure to match play (19008 hours) and training (89103 hours) was 108 111 player hours. A total of 76 hamstring injuries were reported, affecting 65 legs and 61 (12.0%) of the 508 players in the study. Of these, there were 51 acute and 25 overuse injuries. The total incidence of hamstring injuries was 0.7 injuries per 1000 playing hours (95% CI 0.5 to 0.9), 0.3 injuries per 1000 training hours (95% CI 0.2 to 0.4) and 1.8 injuries per 1000 match hours (95% CI 1.2 to 2.5). A total of 48 players sustained one hamstring injury, 11 sustained two injuries, and two players sustained three injuries. Of the 76 injuries, 40 occurred on the right side and 36 were on the left side. There were 25 minor injuries (time loss 1 to 7 days), 31 moderate injuries (8 to 28 days) and 10 severe injuries (>28 days), while information on the duration of time loss was missing in five cases. In five overuse injuries, there was no time loss.

Inter-test reliability computed using kappa statistics was 0.24 for the Nordic hamstring strength test. The coefficient of variation for the continuous variable hamstring muscle length was 9.1%.

Univariate analyses revealed previous acute hamstring injury (yes/no), total HaOS function score and the four of five sub-scores symptoms, pain, function in sports and quality of life as potential leg-dependent risk factors for hamstring injuries (Table 1). Of the player-dependent factors, age and player position were identified as potential predictors of increased injury risk (Table 2). Because this study is based on data from a randomized trial, separate analyses controlling for group assignment (intervention or control group) were performed; however, with no change in the results. Also, a Poisson model approximating multinomial logistic regression analyses was used, in order to compare players who sustained no injuries versus those who sustained one injury versus those who sustained more than one injury. Again, the results did not differ from the original analyses.

Risk factors with a p-value of <0.10 were then considered as candidates to predict which players are more prone to sustain an injury to the hamstring. Because these factors may be inter-correlated or confounded by each other, a multivariate analysis was performed and history of previous acute hamstring injury was found to be a significant risk factor for new hamstring injuries (adjusted OR: 2.19 [1.19-4.03], P=0.01) (Table 3). Out of a total of 1016 cases, the final multivariate analysis was based on 893 cases after cases with missing data were excluded.

Discussion

The main finding of this cohort study investigating potential risk factors for hamstring injuries in soccer was that a history of previous acute hamstring injury is a significant risk factor. Previously injured players have more than twice as high risk of sustaining a new hamstring injury. Other candidates for identification of players with increased risk of hamstring injuries were age, player position and hamstring function score. However, none of these proved significant in the multivariate analysis. Among other potential predictors of increased risk such as clinical examination, hamstring muscle length measurement, counter movement jump test, Nordic hamstring strength test, 40 meter sprint test, level of play or other player characteristics, none were associated with increased risk in this study.

Several authors have found previous acute hamstring strains to be a significant risk factor for new injuries, both in male soccer[3, 16] and among male athletes in other sports.[14, 15] This is in correspondence with the present findings, showing that the injury risk is doubled among previously injured players. Although the results were not significant, the risk seems to increase gradually with the number of previous injuries and decrease with time since the previous injury.

The rationale for the high rate of recurrent strain injuries is not fully known, but may be the result of scar tissue formation or other structural changes[20, 26] or that full function has not been restored. In that case, the results serve to underline the importance of adequate rehabilitation before return to full participation. Also, the increased risk associated with a history of previous injury implicates that preventing the first injury should be a high priority, to keep players from entering the vicious cycle of repeated injuries to the same body part. The Nordic hamstring exercise is the best documented preventive exercise for hamstring injuries,[1, 4] and has been shown to increase muscle strength and does not require advanced equipment.[25] It therefore seems reasonable to suggest that all soccer players, especially players with a history of previous hamstring injury, use this exercise regularly.[1, 4] Because the compliance with preventive exercises is low,[12] we recommend that they are done during team practices under supervision.

Strength deficits or imbalances have been suggested to increase hamstring injury risk,[8] although the relationship between advanced isokinetic testing and injury risk is not fully resolved. [7] Isokinetic tests have been criticized for their lack of specificity and the fact that eccentric strength training can prevent strains made us hypothesize that the Nordic hamstring exercise could be used as a simple screening test to identify players at risk. However, there was no association between the test and injury risk. The most likely explanation for this is that the reliability for the Nordic hamstring strength test is low, with a kappa value of only 0.24. This shows that the same player will not necessarily be scored the same way on two separate tests, a factor which clearly influences the ability to identify players with poor hamstring strength. It could also be that the cut-off angle was set too high or low. Another factor may be that the test examines the combined strength of both sides, which means that side-to-side imbalances or weakness related to previous injury on one side therefore will be difficult to detect.

In addition to previous injury, Árnason et al. [3] found age to be significant risk factors for a new strain injury, independent of injury history. In the present study, age was associated with injury risk in the univariate analysis but not in the multivariate analysis.

Among other potential risk factors mentioned in the literature, reduced flexibility has been suggested as a risk factor for hamstring strains.[31] It has also been shown that soccer players are less flexible than a control group [9] and that soccer players often do not pay sufficient attention to stretching exercises.[2, 11, 17, 19] A study from Australian rules football examining a simple way of measuring hamstring flexibility – the toe touch test – did not find it useful as a predictor of increased risk of hamstring strains in Australian rules footballplayers.[6] The test used to measure hamstring muscle length in this study has been used in different studies.[3, 13] Árnason et al.[3] did not find hamstring muscle length to be a significant predictor of injury risk, which is in correspondence with the present findings. The coefficient of variation for the measurements from the passive knee extension test in this study was 9%, which means that the accuracy of the test is quite good. In other words, it seems that there is no association between hip flexion range of motion flexibility and hamstring injury risk, which may explain why stretching programs do not seem to influence injury risk.[1, 28]

From a biological perspective, it seems reasonable to suggest that explosive athletes with a dominant fast muscle fiber type would be more prone to sustain strain injuries. In this study, however, neither the 40 m sprint test nor the counter movement jump test was associated with injury risk.

No registration of contact and non-contact injuries was made in this study. However, to a player, the important issue is whether he is injured or not, and in this study the main goal was to look at simple ways of measuring potential risk factors for injuries, not injury mechanisms. Hence, the injury report form was simplified to possibly improve compliance from the physiotherapists. One can not eliminate the risk of contact and thereby contact injuries in soccer, and the risk factors tested in this study were therefore evaluated independently of contact or non-contact in the injury situation.

We did not record the mechanism of injury, and therefore we do not know whether injuries resulted from contact with other players, although this is rarely the case with hamstring strains. Contact injuries may be a more heterogeneous group with respect to risk factors and most of the risk factors studied are believed to be relevant primarily for non-contact injuries. If there were a number of contact injuries among the hamstring injuries recorded, these would presumably serve to dilute the effect of the risk factors studied. However, we can not correct for this, as the mechanism of injury in each case is not known.

The present study is one of the largest cohort studies on risk factors for hamstring injuries to date, with as many as 76 injuries. Still, the statistical power is limited for multivariate tests. Nevertheless, the strength of the candidate risk factors studied does not indicate that any of these would be helpful as screening tools. As pointed out by Bahr & Holme [5] in their review, the present number of injuries should be sufficient to detect clinically relevant risk factors. In this study, overuse injuries where no time-loss had occurred were also included as hamstring injuries. As MRI or ultrasound examinations were not readily available we did this to include small repeated strain injuries, as some players still elect to play despite discomfort in the posterior thigh. We can not be sure that all of these represented true strain injuries to the hamstring muscles, but a separate statistical analysis using solely acute time-loss injuries as end point (data not shown) did not change the main findings.

One limitation of the current study is that we had to rely on the coaches for the exposure registration. We had no way to check their figures, but there should be no reason to misreport. If a game or practice session was missed, it would affect all players on the team, which is unlikely to influence the analysis regarding any specific risk factor. A more critical error would occur if the team physiotherapists were to misreport injuries and this was related somehow to the risk factors under study. However, there should be no reason for the physiotherapist to intentionally misreport, and even if cases have been missed or misclassified it may be expected that these would be unrelated to player characteristics. Also, there is a low injury incidence in this study compared to other studies, most of them from the highest level of soccer.[2,10, 18, 29, 30] This could partly be explained by the lower level of play, but it could also be that our recording system did not capture all injuries. If that were the case, this may be expected to have influenced all risk factors, not any specific factor. Therefore, the greatest consequence of missing cases would be loss of statistical power.

Conclusions

In a multivariate analysis, a history of a previous acute hamstring injury was found to be a significant risk factor for new hamstring injuries. Previously injured players have more than twice as high risk of sustaining a new hamstring injury. Other potential risk factors such as clinical findings, hamstring muscle length, jumping ability, a simple eccentric strength test or running speed were not associated with increased risk in this study.

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Fig 1. Flow chart showing movement of numbers of players participating.

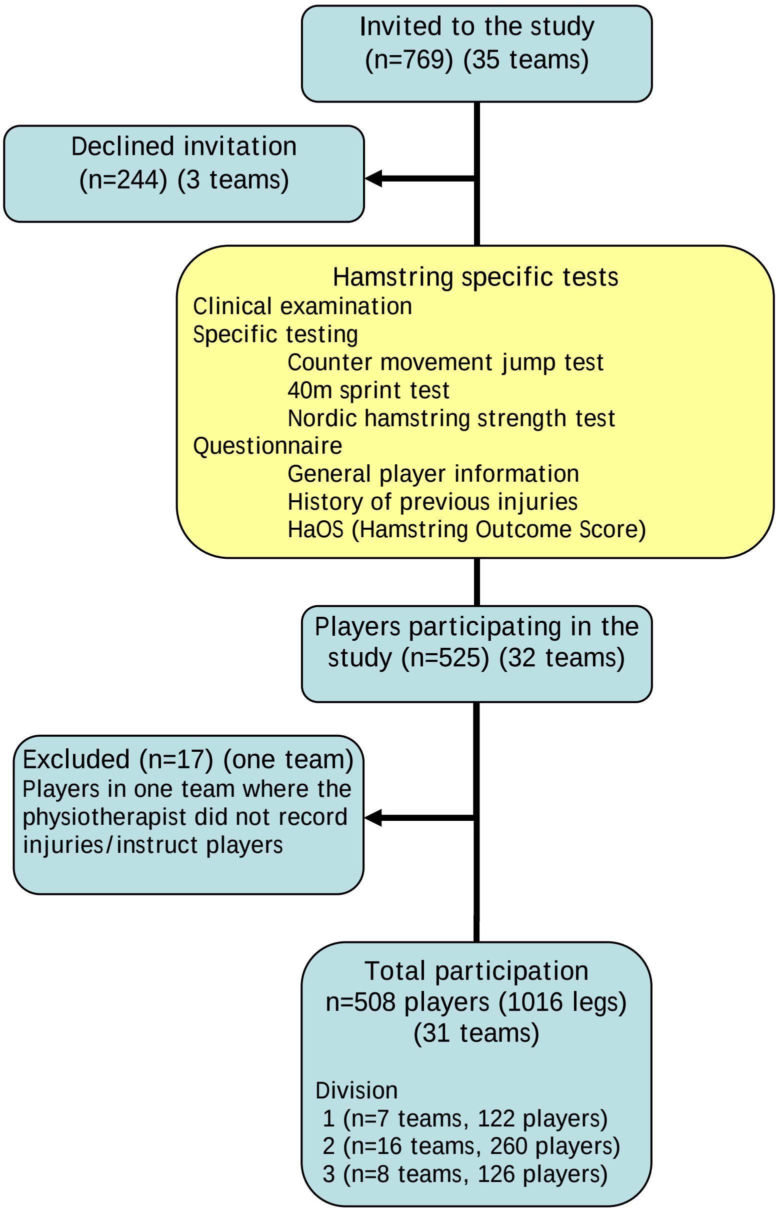

Fig 2a and 2b. The Nordic hamstring strength test. The player was instructed to lower his upper body towards the floor in a slow and controlled manner, always keeping his back and hips straight. The test was scored in two categories (weak or strong) according to whether the player could hold the position beyond 30° or not.

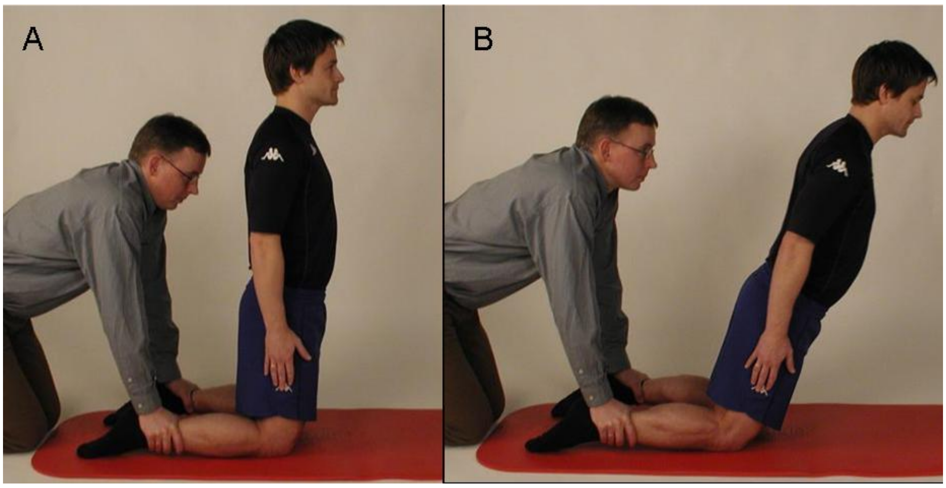

Table 1. Odds ratios for the risk of hamstring injury, calculated from generalized estimating equations taking into account the individual exposure and the fact that the left and the right leg belonged to the same player. Each leg was the unit of analysis, including both continuous (mean ± SEM) and categorical (yes/no) independent variables.

	Current injury							
		Uninjured (n=945)	Injured (n=65)					
	n	n/Mean ± SEM	n/Mean ± SEM	% injured	SD	OR	95% CI	p-value
Previous acute hamstring injury								
Yes	315	282	33	10.5%		2.62	[1.54-4.45]	<0.001
No	695	663	32	4.6%		1.00		
Missing	6							
Number of previous acute injuries								
No previous injury	695	663	32	4.6%		1.00		
1 injury	155	143	12	7.7%		1.42	[0.73-2.77]	0.30
2 injuries	75	68	7	9.3%		1.56	[0.65-3.74]	0.32
3 injuries	34	30	4	11.8%		1.91	[0.61-6.00]	0.27
4 injuries	13	11	2	15.4%		2.49	[0.50-12.5]	0.27
5 injuries	5	4	1	20.0%		3.04	[0.30-31.2]	0.35
>5 injuries	33	26	7	21.2%		4.65	[1.83-11.8]	0.001
Time since previous injury (n=1016)								
Never	695	663	32	4.6%		1.00		
0-6 months	66	57	9	13.6%		1.61	[0.70-3.67]	0.26
6-12 months	64	55	9	14.1%		1.52	[0.66-3.50]	0.32
1-2 years	83	74	9	10.8%		1.06	[0.47-2.40]	0.90
>2 years	101	95	6	5.9%		0.42	[0.16-1.05]	0.06

Missing	7							
HaOS function score[1]								
Total score	964	88.8 ± 0.4	83.3 ± 2.1		13.0	1.29	[1.08-1.54]	0.005
Symptoms	996	82.3 ± 0.8	74.2 ± 3.5		23.6	1.13	[1.02-1.25]	0.03
Soreness	994	86.6 ± 0.5	83.1 ± 1.9		14.0	1.15	[0.97-1.38]	0.12
Pain	996	91.2 ± 0.4	85.9 ± 1.9		11.8	1.33	[1.11-1.60]	0.003
Function in sports	1000	95.1 ± 0.4	91.2 ± 1.9		11.9	1.21	[1.02-1.43]	0.03
Quality of life	1001	89.1 ± 0.6	81.4 ± 2.6		17.9	1.21	[1.07-1.37]	0.003
Tender hamstrings (n=893)								
Yes	17	16	1	5.9%		1.08	[0.12-9.41]	0.95
No	876	822	54	6.2%		1.00		
Hamstring length (degrees)	1005	117.3 ± 0.5 (940)	116.8 ± 2.1 (65)		16.2	0.96[2]	[0.81-1.13]	0.63

[a] The number of legs in the uninjured and injured groups reflect the number of legs that completed each of the tests.

[1] All results (OR and 95% CI) are presented for a reduction of 10 in hamstring function score (HaOS).

[2] Per decrease of one standard deviation

Range (mean, min-max) of continuous variables: HaOS (Total score: 88.5, 30.6-100.0), (Symptoms: 81.8, 0.0-100.0), (Soreness: 86.4, 25.0-100.0), (Pain: 90.9, 34.4-100.0), (Sport: 94.9, 25.0-100.0), (Quality of Life: 88.6, 12.5-100.0), Hamstring muscle length (117.2, 64.0-172.0).

Table 2. Odds ratios for the risk of hamstring injury, calculated by logistic regression analyses. Each player was the unit of analysis, including both continuous (mean ± SEM) and categorical (yes/no) independent variables.

	Current injury							
		Uninjured (n=447)	Injured (n=61)					
Factor	n	Mean ± SEM	Mean ± SEM	% injured	SD	OR	95% CI	p-value
Age (years)	500	23.9 ± 0.2 (439)	24.8 ± 0.6 (61)		4.2	1.25[1]	[0.96-1.63]	0.09
Height (cm)	497	181.4 ± 0.3 (436)	181.5 ± 0.7 (61)		6.3	1.01[1]	[0.77-1.33]	0.92
Weight (kg)	493	77.9 ± 0.4 (433)	78.2 ± 0.9 (60)		9.3	1.05[1]	[0.77-1.43]	0.76
BMI (kg * m^{-2})	486	23.7 ± 0.1 (426)	23.7 ± 0.2 (60)		2.1	1.02[1]	[0.72-1.43]	0.91
Player position	485							0.09
Forward	84	72	12	14.3		1.00		
Winger	70	64	6	8.6		0.56	[0.20-1.59]	0.28
Attacking midfielder	62	55	7	11.2		0.76	[0.28-2.07]	0.60
Central midfielder	66	63	3	4.5		0.29	[0.08-1.06]	0.06
Wingback	87	71	16	18.4		1.35	[0.60-3.06]	0.47
Center back	71	59	12	16.9		1.22	[0.51-2.92]	0.65
Goalkeeper	45	43	2	4.4		0.28	[0.06-1.31]	0.11
Level of play	508							0.82
1st division	119	106	13	10.9		1.00		
2nd division	256	223	33	12.9		1.21	[0.61-2.39]	0.59
3rd division	133	118	15	11.3		1.04	[0.47-2.28]	0.93
Level of play last season								0.88
Elite division	4	3	1	25.0		1.00		
1st division	126	110	16	12.7		0.44	[0.04-4.45]	0.48

2nd division	154	136	18	11.7		0.40	[0.04-4.02]	0.43
3rd division or lower	201	177	24	11.9		0.41	[0.04-4.07]	0.44
Junior or senior national team matches								
Yes	92	81	11	12.0		0.99	[0.50-1.99]	0.99
No	416	366	81	19.5		1.00		
Specific tests								
Counter movement jump test	423	37.7 ± 0.2 (376)	37.6 ± 0.6 (47)		4.7	0.99[1]	[0.73-1.34]	0.95
Nordic hamstring strength test (n=452)	452							
Weak	173	157	16	9.3		1.00		
Strong	279	244	35	12.5		1.41	[0.75-2.63]	0.28
40 m sprint test	398	5.20 ± 0.01 (355)	5.20 ± 0.03 (43)		0.18	0.99[1]	[0.72-1.35]	0.95

[a] The number of players in the uninjured and injured groups reflect the number of players who completed each of the tests.

[1] Per increase of one standard deviation.

Range (mean, min-max): Counter movement jump test (37.7, 25.9-56.8) and 40 meter sprint test (5.20, 4.71-5.81).

Table 3. Multivariate analysis of the candidate risk factors with $p<0.10$ in univariate analyses. Adjusted odds ratio (OR) and 95% confidence interval (CI) of age, player position (central midfielder or not), previous hamstring injury (yes/no) and HaOS (Hamstring Outcome Score) total score. P-values are the results from analysis in STATA using generalized estimating equations.

Risk factors	Adjusted OR	95% CI	p-value
Player dependent factors			
Age	1.05[1]	[0.77-1.42]	0.77
Player position	0.96	[0.82-1.12]	0.61
Leg dependent factors			
Previous acute hamstring injury (yes/no)	2.19	[1.19-4.03]	0.01
HaOS total score	1.16[2]	[0.95-1.42]	0.14

[1] OR and 95% CI are presented for a change of one standard deviation, 4.2 years.

[2] OR and 95% CI are presented for a reduction of 10 in HaOS (Hamstring Outcome Score).

REFERENCES

1. Arnason A, Andersen TE, Holme I, et. al.: Prevention of hamstring strains in elite soccer: an intervention study. *Scand J Med Sci Sports 18:* 40-48, 2008

2. Arnason A, Gudmundsson A, Dahl HA, et. al.: Soccer injuries in Iceland. *Scand J Med Sci Sports 6:* 40-45, 1996

3. Arnason A, Sigurdsson SB, Gudmundsson A, et. al.: Risk factors for injuries in football. *Am J Sports Med 32:* 5S-16S, 2004

4. Askling C, Karlsson J, Thorstensson A: Hamstring injury occurrence in elite soccer players after preseason strength training with eccentric overload. *Scand J Med Sci Sports 13:* 244-250, 2003

5. Bahr R, Holme I: Risk factors for sports injuries--a methodological approach. *Br J Sports Med 37:* 384-392, 2003

6. Bennell K, Tully E, Harvey N: Does the toe-touch test predict hamstring injury in Australian Rules footballers? *Aust J Physiother 45:* 103-109, 1999

7. Bennell K, Wajswelner H, Lew P, et. al.: Isokinetic strength testing does not predict hamstring injury in Australian Rules footballers. *Br J Sports Med 32:* 309-314, 1998

8. 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 36:* 1469-1475, 2008

9. Ekstrand J, Gillquist J: The frequency of muscle tightness and injuries in soccer players. *Am J Sports Med 10:* 75-78, 1982

10. Ekstrand J, Gillquist J: Soccer injuries and their mechanisms: a prospective study. *Med Sci Sports Exerc 15:* 267-270, 1983

11. Ekstrand J, Gillquist J, Moller M, et. al.: Incidence of soccer injuries and their relation to training and team success. *Am J Sports Med 11:* 63-67, 1983

12. Engebretsen AH, Myklebust G, Holme I, et. al.: Prevention of injuries among male soccer players: a prospective, randomized intervention study targeting players with previous injuries or reduced function. *Am J Sports Med 36:* 1052-1060, 2008

13. Fredriksen H, Dagfinrud H, Jacobsen V, et. al.: Passive knee extension test to measure hamstring muscle tightness. *Scand J Med Sci Sports 7:* 279-282, 1997

14. Gabbe BJ, Bennell KL, Finch CF, et. al.: Predictors of hamstring injury at the elite level of Australian football. *Scand J Med Sci Sports 16:* 7-13, 2006

15. Gabbe BJ, Finch CF, Bennell KL, et. al.: Risk factors for hamstring injuries in community level Australian football. *Br J Sports Med 39:* 106-110, 2005

16. Hagglund M, Walden M, Ekstrand J: Previous injury as a risk factor for injury in elite football: a prospective study over two consecutive seasons. *Br J Sports Med 40:* 767-772, 2006

17. Hawkins RD, Fuller CW: A preliminary assessment of professional footballers' awareness of injury prevention strategies. *Br J Sports Med 32:* 140-143, 1998

18. Hawkins RD, Fuller CW: A prospective epidemiological study of injuries in four English professional football clubs. *Br J Sports Med 33:* 196-203, 1999

19. Inklaar H: Soccer injuries. II: Aetiology and prevention. *Sports Med 18:* 81-93, 1994

20. Jarvinen TA, Kaariainen M, Jarvinen M, et. al.: Muscle strain injuries. *Curr Opin Rheumatol 12:* 155-161, 2000

21. Juma AH: Outline of sport injuries in the V World Youth Championship for FIFA Cup in Saudi Arabia. *Indian J Med Sci 52:* 433-437, 1998

22. Junge A, Dvorak J: Soccer injuries: a review on incidence and prevention. *Sports Med 34:* 929-938, 2004

23. Lian O, Engebretsen L, Ovrebo RV, et. al.: Characteristics of the leg extensors in male volleyball players with jumper's knee. *Am J Sports Med 24:* 380-385, 1996

24. Meeuwisse WH. Assessing causation in sport injury: A multifactorial model. *Clin J Sport Med 4*, 166-170. 1994.

25. Mjolsnes R, Arnason A, Osthagen T, et. al.: A 10-week randomized trial comparing eccentric vs. concentric hamstring strength training in well-trained soccer players. *Scand J Med Sci Sports 14:* 311-317, 2004

26. Noonan TJ, Garrett WE, Jr.: Injuries at the myotendinous junction. *Clin Sports Med 11:* 783-806, 1992

27. Roos EM, Roos HP, Lohmander LS, et. al.: Knee Injury and Osteoarthritis Outcome Score (KOOS)--development of a self-administered outcome measure. *J Orthop Sports Phys Ther 28:* 88-96, 1998

28. Thacker SB, Gilchrist J, Stroup DF, et. al.: The impact of stretching on sports injury risk: a systematic review of the literature. *Med Sci Sports Exerc 36:* 371-378, 2004

29. Walden M, Hagglund M, Ekstrand J: Injuries in Swedish elite football--a prospective study on injury definitions, risk for injury and injury pattern during 2001. *Scand J Med Sci Sports 15:* 118-125, 2005

30. Walden M, Hagglund M, Ekstrand J: UEFA Champions League study: a prospective study of injuries in professional football during the 2001-2002 season. *Br J Sports Med 39:* 542-546, 2005

31. 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 31:* 41-46, 2003