Risk Factors for Lower Extremity Muscle Injury in Professional Soccer: The UEFA Injury Study

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RISK FACTORS FOR LOWER EXTREMITY MUSCLE INJURY IN PROFESSIONAL SOCCER: THE UEFA INJURY STUDY

ABSTRACT

Background: Muscle injury is the most common injury type in professional soccer players. Still, risk factors for common lower extremity injuries remain elusive.

Purpose: To evaluate the effects of various player and match related risk factors on the occurrence of lower extremity muscle injury in male professional soccer.

Study Design: Cohort study.

Methods: Between 2001 and 2010, 26 soccer clubs (1401 players) from 10 European countries participated in the study. Individual player exposure and time loss muscle injuries in the lower extremity were registered prospectively by the club medical staffs during nine consecutive seasons. Hazard ratios (HRs) were calculated for player related factors from simple and multiple Cox regression, and odds ratios (ORs) were calculated for match related variables from simple and multiple logistic regression, presented with 95% confidence intervals (CIs).

Results: There were 2123 muscle injuries documented in the major lower extremity muscle groups; adductors (n=523), hamstrings (n=900), quadriceps (n=394), and calf (n=306). Injuries to the adductors (56%, $P = .015$) and quadriceps (63%, $P < .001$) were more frequent in the kicking leg. Based on multiple analysis, having a previous identical injury in the preceding season increased injury rates significantly for adductor (HR 1.40, 95% CI 1.00-1.96), hamstring (HR 1.40, 95% CI 1.12-1.75), quadriceps (HR 3.10, 95% CI 2.21-4.36), and calf injuries (HR 2.33, 95% CI 1.52-3.57). Older players (above mean age) had an almost two-fold increased rate of calf injury (HR 1.93, 95% CI 1.38-2.71), but no association was found in other muscle groups. Goalkeepers had reduced injury rates in all four muscle groups. Match play on away ground was associated with reduced rates of adductor (OR 0.56, 95% CI 0.43-0.73) and hamstring injuries (OR 0.76, 95% CI 0.63-0.92). Quadriceps injuries were more frequent during preseason, while adductor, hamstring and calf injury rates increased during the competitive season.

Conclusion: Intrinsic factors found to increase muscle injury rates in professional soccer were previous injury, older age, and kicking leg. Injury rates varied during different parts of the season, and also depending on match location.

Key Terms: adductor, hamstring, quadriceps, calf, muscle strain

What is known about the subject: Muscle injury is the most common injury type in professional soccer players, and lower extremity injuries comprise more than 90% of muscle injuries. Several intrinsic risk factors have been suggested in the literature, but results are conflicting, and extrinsic risk factors have scarcely been investigated.

What this study adds to existing knowledge: Previous identical injury was consistently found to be a risk factor for lower extremity muscle injury. In addition, previous injury to other muscle groups also increased injury rates, a finding not previously reported in soccer. This study also identified significant extrinsic risk factors for injury including part of the season, and match characteristics, with varying injury rates depending on match location and type of competition.

INTRODUCTION

Muscle injuries are very common in soccer, representing up to 37% of all time loss injuries at men's professional level.[1,10,20,24] In a recent study in European professional soccer it was shown that a club with a 25 player squad can expect 15 muscle injuries each season and that muscle injuries accounted for more than one-fourth of all lay-off time from injuries.[9] Injuries to four major muscle groups of the lower extremity - adductors, hamstrings, quadriceps, and calf - comprise more than 90% of all muscle injuries in professional soccer.[9]

In order to establish prevention programs it is important to identify risk factors associated with the occurrence of injury, preferably using analysis accounting for the multifactorial etiology of injury.[33] Some, but not all, intrinsic risk factors identified for lower extremity muscle injury include previous injury,[1,13,14,21] older age,[1,21,26] poor flexibility,[1,3,15,26,27,42] and decreased muscle strength or strength imbalances,[7,8,13,15] but results from different studies are contradictory. Extrinsic risk factors have only been scarcely investigated, but match play has consistently been associated with an increased rate of muscle injury.[9,13,14,21] Fatigue may be a component in the occurrence of muscle injury, since some studies have found that muscle injuries occur more frequently towards the end of matches.[9,23] Finally, it has been shown that various match factors, such as the type of match, match location (home or away) and match result may influence general injury rates in professional soccer,[5,12,22] but sub-analyses of lower extremity muscle injuries have not been reported.

The purpose of this study was to evaluate the effects of various player (intrinsic) and match related (extrinsic) risk factors on the occurrence of lower extremity muscle injury in male professional soccer.

METHODS

Study design and participants

The present study is a sub-study of a larger injury surveillance study carried out in European professional soccer in collaboration with the Union of European Football Associations (UEFA).[10] The study had a prospective design and comprised nine full soccer seasons, between July 2001 and June 2010. The cohort included 26 professional soccer clubs from ten European countries. All players contracted to the first team were invited to participate in the study. Players who left the club during the season, e.g. due to transfer, were included until leaving the club. Written informed consent was collected from all included players.

Study procedure

The study design underwent an ethical review and was approved by the UEFA Football Development Division and the UEFA Medical Committee. The full methodology and the validation of the study design has been reported previously,[19] and data collection and definitions harmonize with the consensus statement for soccer injury surveillance.[16] All clubs were provided with a study manual containing definitions and describing how to record data, including explanatory examples. Reports were checked monthly by the study group and feedback was sent to the clubs in order to correct any missing or unclear data. Player baseline data were collected annually, at the start of each new season or upon joining the club. Individual player participation (minutes) in training and matches was registered by the club contact person on an exposure form and sent to the study group on a monthly basis. All club exposures with the first team, as well as any national team or second team exposure for included players, were registered. The club medical staffs recorded injuries on an injury form that was sent to the study group each month. The first team physician was responsible for injury diagnostics. The injury form gave information about the diagnosis, nature and circumstances of injury occurrence. All injuries resulting in a player being unable to fully participate in training or match play (i.e. time loss injuries) were recorded, and the player was considered injured until the club medical staff allowed full participation in training and availability for match selection. Injuries were categorized under four degrees of severity based on lay-off time from soccer; slight/minimal (0-3 days), mild (4-7 days), moderate (8-28 days), and severe (>28 days). Recurrent injury was defined as an injury of the same type and at the same site as an index injury occurring after a player's return to full participation from the index injury, and a reinjury within two months after return to play was considered an early recurrent injury.

In the present sub-study, only lower extremity muscle injuries to the adductors, hamstrings, quadriceps and calf muscle groups were included. The registration of a muscle injury was based on a clinical examination by the club medical staff, often with additional radiological examinations performed, but no specific criteria for examination procedures were sent out to clubs a priori. A muscle injury was defined as "a traumatic distraction or overuse injury to a muscle leading to a player being unable to fully participate in training or match play".[9] Contusions, haematomas, tendon ruptures and chronic tendinopathies were excluded. Injuries with a sudden onset and known cause were categorized as traumatic, and those with a gradual onset and no known trauma as overuse injuries.

Statistical analyses

Data are presented as means ± standard deviations (SDs) and absolute or relative frequencies. Unpaired Student's t-test was used for group comparisons of continuous normally distributed data and the χ^2 test for categorical data. One sample proportional test was used for analysis of proportions of limb dominance and injury occurrence (ambidextrous players excluded from analysis). Injury rates are reported as the number of injuries per 1000 player hours, and compared between preseason and competitive season with rate ratios (RRs) with 95% confidence intervals (CIs), and significance tested using z-statistics.

For the analysis of player related risk factors, hazard ratios (HRs) with 95 % CIs are presented for all independent variables based on simple Cox regression using player as the unit for analysis. Continuous variables were converted to categorical variables (below or above mean) for the analyses. The player related independent variables were: age, stature, body mass, playing position (goalkeeper, defender, midfielder, or forward), and previous muscle injury (adductor, hamstrings, quadriceps, or calf muscle groups) during the preceding season. To reduce the risk of recall bias, previous injury history included only prospectively recorded injuries from the preceding season, meaning that this was not calculated during a player's first season of participation in the study. All independent variables were then included in a multiple Cox regression analysis, and in this analysis we also adjusted for the players' match exposure ratio (match hours/total hours of exposure) since injury rates are higher in matches than in training.[9,13,14,21]

For the analysis of match related risk factors, odds ratios (ORs) with 95 % CIs are presented for all independent variables based on simple logistic regression using each first team competitive match (friendly matches excluded) as the unit for analysis. The match related independent variables were type of match [national league play, UEFA Champions League (UCL), UEFA Europa League (EL; including former UEFA Cup), or other cup (mainly domestic cup matches)], match venue (home or away match), period of season [preseason (July-August), fall (September-November), winter (December-February), or spring (March-May)], and climate region. Climate region was determined according to the updated Köppen-

Geiger climate classification system[30] and teams were divided into a “northern” (predominately marine west coast climate) and a “southern” group (Mediterranean climate).[41] All independent variables were then included in a multiple logistic regression analysis.

All player (Cox regression) and match related (logistic regression) independent variables were tested for association with the occurrence of muscle injury to the hamstrings, quadriceps, adductors, and calf, in separate analyses for each muscle group. Significance level was set at $P < .05$.

RESULTS

Player and exposure characteristics

There were 1401 players included, participating in mean 2.3 ± 1.7 seasons (range 1-9, total 3207 player seasons). Mean age was 25.8 ± 4.5 years, stature 182.3 ± 6.3 cm, and body mass 77.9 ± 7.0 kg. Seventy-six percent (n=1065) were right footed, 21% (n=295) left footed, and 3% (n=41) were ambidextrous. Playing positions included 140 goalkeepers (10%), 433 defenders (31%), 514 midfielders (37%), and 314 forwards (22%). Players had as a mean 247 ± 87 hours of total exposure during a season, with 207 ± 73 training hours and 40 ± 24 match hours.

Nature of lower extremity muscle injuries

There were 6140 injuries recorded in total, 2123 (35%) of which were muscle injuries located to the adductors (n=523), hamstrings (n=900), quadriceps (n=394), and calf (n=306). The nature and circumstances of these injuries are presented in Table 1. Thirty-four percent (n=728) were overuse injuries, and overuse injury was more frequent among adductor injuries than in other injury locations (P = .001). Twenty-seven percent (n=564) of injuries were reinjuries with a preceding identical injury during the study period. Hamstring (30%) and adductor (29%) injuries had a higher reinjury rate than quadriceps (21%) and calf (21%) injuries (P < .001), while no difference was found in early recurrence rates (within 2 months) between injury locations (P = .720). A lower rate of adductor, hamstring, and calf injury was found during preseason compared to the competitive season, while quadriceps injury rates were higher during preseason (Figure 1).

Risk factors for adductor injury

Adductor injuries were more common in the dominant (kicking) leg (56%, $P = .015$). Simple analysis of player related factors identified two significant variables: being a goalkeeper, and previous adductor injury (Table 2), and these remained significant in the multiple analysis (Table 3). Simple analysis showed that match related factors associated with adductor injury were other cup match and playing the match away (Table 4); away match was significant also in the multiple analysis (Table 3).

Risk factors for hamstring injury

No influence from leg dominance was found on hamstring injury (dominant leg 50%, $P = .889$). According to simple analysis, taller players and goalkeepers were less likely to suffer a hamstring injury, while players with previous injury to the hamstrings, quadriceps, and calf muscles were more prone to injury (Table 2). Goalkeeper and previous hamstring injury remained significant in the multiple analysis (Table 3). Simple analysis showed that match related factors associated with hamstring injury were away match, and playing a match in the fall, winter, or spring periods as compared to preseason (Table 4). The same variables were significant also in the multiple analysis (Table 3).

Risk factors for quadriceps injury

Quadriceps injuries were more frequent in the dominant leg (63%, $P < .001$). According to simple analysis, goalkeepers had a decreased rate of quadriceps injury, while a previous injury to the quadriceps, adductors or calf muscles increased the rate of injury (Table 2). The same variables were significant in the multiple analysis (Table 3). Simple analysis identified no significant match related risk factors (Table 4), while, according to multiple analysis, playing UCL matches were associated with a lower odds of quadriceps injury (Table 3).

Risk factors for calf injury

Calf injuries were evenly distributed between the legs (dominant leg 52%, P = .521). Simple analysis showed that goalkeepers had a lower rate of calf injury, whereas a higher rate was observed among older players, and for players with a previous calf injury, adductor injury and hamstring injury (Table 2). Multiple analysis identified the same significant variables (Table 3). Of the tested match related variables, match play in the UCL had a higher odds that a calf injury would occur according to simple (Table 4) and multiple analysis (Table 3).

DISCUSSION

This study consistently identified previous identical injury as an intrinsic risk factor for muscle injury in male professional soccer players. In addition, previous injury to other muscle groups in the lower extremity also increased injury rates, a finding not previously reported in soccer. Goalkeepers had decreased rate of injury in all four muscle groups, and older age was associated with an increased rate of calf injury. Match related factors that influenced injury occurrences included playing a match away (for adductor and hamstring injuries), match play in the competitive season (for hamstring injury), and the type of competition played (for quadriceps and calf injuries).

Player related risk factors

It has been suggested that player related factors are most important in the occurrence of muscle injury.[35] One of the most cited risk factors for lower extremity muscle injury in soccer is a previous identical injury,[1,13,14,21] and this was found also in the present study. Players with a muscle injury in the preceding season had increased injury rates of up to three-fold compared to previously uninjured players. This suggests that preseason evaluation of previously injured players could be of value to reduce injury rates. In 21-30% of registered muscle injuries, the player had suffered an identical injury previously during the study period, with 12-14% being early recurrences (occurring within 2 months of return to play). The specific risk factors involved in the recurrence of muscle injury have not been clearly established, but may be related to the same extrinsic and intrinsic factors that were associated with the initial injury. In addition, factors related to modifications following the initial muscle injury (tightness or weakness, presence of scar tissue, biomechanical alterations, neuromuscular inhibition, etc.), as well as questionable treatment options (incomplete or aggressive rehabilitation, underestimation of an extensive injury, etc.) may further predispose an athlete to reinjury.[6,7,32,34] Recurrent muscle injuries tend to cause longer lay-off than the index injury[9] and this highlights the need for careful rehabilitation. However, even though structured tests and progressions to determine safe return to play from muscle injury have been suggested,[2,25] these remain to be scientifically evaluated.

Another interesting finding was that a history of previous injury to other lower extremity muscle groups increased the rate of quadriceps and calf injury in the present study by 68-91%. Although not previously shown in soccer, similar findings have been demonstrated in two previous studies in Australian football.[35,40] Orchard reported that hamstring injury was associated with past calf injury, calf injury was associated with past quadriceps injury, and quadriceps injury was associated with past hamstring injury, and hypothesized that altered running biomechanics due to the initial injury may be a predisposing factor.[35] Similarly, Verrall et al. found that a past history of knee and groin injury increased the risk of hamstring muscle injury, and postulated that the biomechanical properties of the lower extremities may change, thereby increasing the risk for further injury.[40] Although speculative, these findings may suggest that inadequate compensations after an initial injury could predispose a player to further injury, and highlights the importance for clinicians to evaluate injury causation thoroughly, and to monitor factors other than pure tissue healing (such as biomechanical evaluation) before allowing a player to return to play after a lower extremity muscle injury. It should also be pointed out that some players may be more injury prone in general, owing to genetic, physiological or psychological factors. It has previously been observed in Swedish elite soccer that injury rates in general increased with the number of injuries a player had sustained in the preceding season.[21] Psychosocial factors, such as risk taking behavior, life event stress, and trait anxiety should probably be considered here.[28,29] Finally, unknown factors contributing to the initial injury event may also influence subsequent injury occurrences irrespective of any increased risk due to the initial injury itself.

Several studies have shown that older players are more susceptible to muscle injury, particularly to the hamstrings.[1,21,26,40] We observed a two-fold increased rate of calf injury for older players in the present study, whereas no association was seen for adductor, quadriceps, and, perhaps surprisingly, for hamstring injury. This inconsistency with previous studies with regards to age and hamstring injury rates could possibly be explained by different study cohorts, i.e. highest professional level in the current study compared to semi-professional or elite level in two previous studies.[1,21] The reason why older players may be at risk for muscle injury is unclear, but it has been suggested that age-related changes in older athletes, such as increased body weight and a loss of flexibility, may partially explain the risk increase.[17] We found no influence of body mass or stature on injury rates in the present study in a multiple regression model.

Quadriceps and adductor injuries were more common in the kicking leg, most probably due to a greater volume of shooting and passing/crossing actions with the dominant leg resulting in injury, that is, a greater exposure to high risk actions. However, it has also been suggested that specific limb preference in soccer players may result in lingering muscle imbalances that could lead to an increased propensity for injury, and altered strength characteristics between the dominant and non-dominant leg has been found in soccer players.[39] Correction of muscle imbalances at preseason has been found to decrease hamstring injury rates in soccer players,[8] but its preventive effects needs to be verified also for other muscle injuries.

Finally, goalkeepers had reduced rates of all four muscle groups with approximately half to one-third in the present study, a finding that remained when adjusting for possible confounders such as player age, stature and body mass, while no apparent differences were seen between outfield playing positions. Although muscle injury rates for different playing positions are seldom reported, our data are consistent with two previous studies.[4,38] In a study of one French professional club a slight increase in the rate of muscle injury recurrences was found in forwards and defenders compared to defenders and goalkeepers.[4] Data may not be directly comparable to ours, however, since we included both first time and recurrent muscle injuries in our analyses. Another study reported a lower frequency of hamstring injuries in goalkeepers compared to outfield players in Danish elite players, but injury rates based on actual exposure times were not presented.[38]

Match related risk factors

Match related factors, such as match type, playing at home or away, and match result have been found to influence general injury rates in soccer,[5,12,22] but showed only marginal associations with lower extremity muscle injury in the present study. Hamstring and adductor injuries were more likely to occur in matches played at home than away, and, possibly, differences in playing style could explain this finding. For instance, a higher degree of ball possession, and time situated in the attacking zone of the field, has been documented in the home team compared to the away team.[31] Still, it is not clear whether this is linked to an increase in playing intensity or in actions such as number of sprints or passes, and there may be other underlying factors involved, for example higher levels of anxiety at home matches. Influence of match type on injury rates showed inconsistent findings in the present study, with UEFA Champions League matches being associated with an increase in calf injuries, and a decrease in quadriceps injuries. No association with adductor and hamstring injuries was observed. The reason for this discrepancy is unclear, but could possibly be related to differences in intensity and playing style in different types of competitions. In contrast, a previous study on one French club reported no difference in general injury rates in domestic matches compared to European cup matches, while data on muscle injuries were not reported.[5] Overall, match injury rates in soccer are several-fold increased compared to training,[9,13,14,21] but other factors than evaluated here may be of importance. For instance, it has been suggested that fatigue may play a role in the etiology of muscle injury in matches, with an observed increase in injury rates towards the end of each half, and in the second compared with the first half,[9] which corresponds with a decrease in eccentric hamstring strength as a function of time, and after the halftime interval, found in a laboratory study.[18]

Finally, in a previous study it was shown that professional soccer teams from northern Europe had a higher overall injury rate than teams from the southern parts of Europe,[41] but we found no influence of climate region on the rate of lower extremity muscle injury during matches in the present study. This is in contrast to a previous study from Australian football where an association between climate factors and muscle injuries was reported in that teams from the northern (warmer) parts of Australia had an increased rate of quadriceps and calf strains.[36] Differences in sport characteristics, as well as climate and/or cultural differences, between the study cohorts could explain this discrepancy.

Other extrinsic risk factors

An increase in quadriceps muscle injury rate (by 40%) was apparent during preseason, which is in line with a previous study from professional soccer.[43] Quadriceps injuries are related to kicking[35] and an increased number of kicking actions during preseason could possibly explain this finding. Implementation of eccentric training protocols for the quadriceps complex and a gradual increase in the volume of kicking actions during preseason could possibly help reduce the rate of injury. In contrast, injury rates in the other three major muscle groups were increased during the competitive season, and for hamstring injuries this trend was evident also in matches. A previous study on English professional soccer players concur with our data for hamstring injuries, while gastrocnemius, adductor and iliopsoas injuries were evenly distributed between pre- and competitive season in that study.[43] Hamstring injuries in soccer are typically high-speed running injuries[9,34] and occur more frequently in matches,[9] which could explain the rate increase in the competitive season. The association between season planning and muscle injury was not evaluated in the present study and should be studied further. Eccentric training has shown positive preventive effect of new and recurrent hamstring injuries,[37] and may be considered both during pre- and competitive season.

Methodological considerations

A few limitations with the present study should be acknowledged. First, muscle injury, according to our inclusion criteria, constitute a heterogeneous group including many types of injuries, both structural (partial or total muscle fibre ruptures) and functional (no macroscopic muscle fibre disruption). We used a pragmatic approach to record injuries, and the fact that many different club medical staffs were involved in injury diagnosis, that no specific criteria for examination procedures were sent out to clubs a priori, and that radiological verification of muscle injury was not required may decrease the reliability of injury recording. Still, our data from professional soccer clubs rely on clinical data reported by experienced sports medicine practitioners, and was often verified with radiological examinations. Muscle injuries with an acute or gradual onset may have different etiology, and this was not considered in the present study. In addition, injuries were of different severity (radiological grade), size (of muscle pathology and/or oedema), and location (within the muscle, as well as different muscle groups, e.g. biceps femoris) and this was not taken into account in our analyses. A further sub-grouping of injuries according to type, location and dimension of pathology may help in prognosticating lay-off time from sports and reinjury risk,[11] but may also be useful when studying risk factors for lower extremity muscle injury. Second, several suggested intrinsic (e.g. strength, flexibility, race) and extrinsic risk factors (e.g. fatigue, warm-up) for muscle injury were not evaluated in the present study, and may interact with the factors identified here. For instance, strength deficits and/or imbalances, and decreased flexibility may explain the increased risk from previous injury.[6,34] Similarly, fatigue may be a factor related to variations in injury rates over the season. Third, in the analyses of match related factors no attention was given to player line-ups. Many top-level clubs rotate squad rosters from one match to the other, and this could contribute to a difference in injury occurrence between different match types. Finally, most of the risk factors examined in the present study were non-modifiable, for instance previous injury, age, part of season, and match type. However, knowledge of such factors may still be of value to identify subgroups of players at increased risk of injury, as well as to recognize parts of a season and types of exposures where injury is more likely to occur, in order to implement proper preventive measures.

CONCLUSIONS

Consistent with most previous studies, we identified previous injury as an important risk factor for lower extremity muscle injury. Interestingly, previous injury to other muscle groups in the lower extremity also increased injury rates, a finding not previously reported in soccer. Even though intrinsic factors may be more important in the occurrence of lower extremity muscle injury, we identified significant extrinsic risk factors for injury including part of the season, and match characteristics, with varying injury rates depending on match location and type of competition. More studies on other potential extrinsic risk factors such as fatigue, match load, season planning, etc., as well as on modifiable intrinsic risk factors, would be of great value to develop further preventive measures, and to reduce the overall burden of muscle injury in soccer.

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TABLE AND FIGURE LEGENDS

Table 1. Nature and circumstances of lower extremity muscle injuries in professional soccer players.

	Adductors	Hamstrings	Quadriceps	Calf
Injuries	523 (100)	900 (100)	394 (100)	306 (100)
Severity				
Slight/minimal (0-3 days)	76 (15)	105 (12)	49 (12)	41 (13)
Mild (4-7 days)	151 (29)	203 (23)	94 (24)	59 (19)
Moderate (8-28 days)	240 (46)	478 (53)	182 (46)	151 (51)
Severe (>28 days)	56 (11)	114 (13)	69 (18)	51 (17)
Part of season				
Preseason (July-August)	83 (16)	95 (11)	100 (25)	37 (12)
Fall (September-November)	174 (33)	290 (32)	111 (28)	90 (29)
Winter (December-February)	134 (26)	281 (31)	103 (26)	101 (33)
Spring (March-May)	132 (25)	234 (26)	80 (20)	78 (25)
Side				
Right	290 (55)	436 (48)	225 (57)	166 (54)
Left	216 (41)	463 (51)	160 (41)	138 (45)
Bilateral	17 (3)	1 (<1)	9 (2)	2 (1)
Circumstance				
Training	110 (21)	183 (20)	139 (35)	95 (31)
Match	199 (38)	433 (48)	117 (30)	119 (39)
Gradual onset	214 (41)	284 (32)	138 (35)	92 (30)
Situation				
Club first team	485 (93)	835 (93)	372 (94)	291 (95)
Club reserve team	11 (2)	20 (2)	10 (3)	2 (1)
National team	27 (5)	45 (5)	12 (3)	13 (4)
Recurrent injury during study	150 (29)	270 (30)	81 (21)	63 (21)
Early recurrence (<2 months)	75 (14)	118 (13)	49 (12)	36 (12)

Values are n (%)

Table 2. Simple analysis of player related risk factor variables for lower extremity muscle injuries from Cox regression.

	Adductors			Hamstrings			Quadriceps			Calf		
Variable	HR	95% CI	*P* Value	HR	95% CI	*P* Value	HR	95% CI	*P* Value	HR	95% CI	*P* Value
Age (above mean)*	1.24	0.96-1.59	.094	1.02	0.84-1.23	.881	1.06	0.79-1.41	.710	2.02	1.45-2.82	<.001
Stature (above mean)*	0.97	0.75-1.24	.792	0.82	0.68-1.00	.049	0.88	0.66-1.17	.367	1.04	0.76-1.43	.819
Body mass (above mean)*	1.08	0.84-1.38	.559	0.87	0.72-1.06	.169	0.91	0.68-1.21	.500	1.19	0.87-1.64	.282
Playing position												
Goalkeeper	0.58	0.33-0.99	.048	0.11	0.06-0.23	<.001	0.46	0.23-0.90	.023	0.43	0.20-0.96	.038
Defender	1.19	0.83-1.70	.345	0.80	0.61-1.04	.094	0.95	0.62-1.43	.791	1.31	0.83-2.07	.242
Midfielder	1.10	0.77-1.58	.591	0.97	0.75-1.25	.792	1.18	0.62-1.43	.418	1.16	0.73-1.85	.524
Forward†	1.0			1.0			1.0			1.0		
Previous injury‡												
Adductors	1.48	1.06-2.06	.020	1.22	0.93-1.62	.154	1.88	1.31-2.69	.001	1.87	1.26-2.77	.002
Hamstrings	1.25	0.94-1.68	.131	1.64	1.32-2.04	<.001	1.25	0.89-1.76	.202	2.10	1.51-2.54	<.001
Quadriceps	1.31	0.89-1.91	.170	1.44	1.08-1.93	.014	3.47	2.49-4.84	<.001	1.09	0.65-1.83	.742
Calf	1.01	0.63-1.64	.959	1.40	1.00-1.95	.050	2.08	1.37-3.17	.001	2.83	1.86-4.31	<.001

* Reference group below mean.

† Reference group in analysis.

‡ Previous injury refers to injury during the preceding season.

HR denotes hazard ratio; CI denotes confidence interval

Table 3. Significant risk factors for lower extremity muscle injury from multiple Cox regression and logistic regression analyses.

Injury	Variable	HR/OR*	95% CI	*P* Value
Adductors	*Player related factors*			
	Previous adductor injury	1.40	1.00-1.96	.047
	Goalkeeper†	0.51	0.29-0.91	.022
	Match related factors			
	Away match‡	0.56	0.43-0.73	<.001
Hamstrings	*Player related factors*			
	Previous hamstring injury	1.40	1.12-1.75	.003
	Goalkeeper†	0.11	0.06-0.24	<.001
	Match related factors			
	Away match‡	0.76	0.63-0.92	.004
	Fall period (September-November)€	2.16	1.29-3.60	.003
	Winter period (December-February)€	2.55	1.53-4.24	<.001
	Spring period (March-May)€	2.49	1.49-4.17	<.001
Quadriceps	*Player related factors*			
	Previous quadriceps injury	3.10	2.21-4.36	<.001
	Previous adductor injury	1.68	1.16-2.41	.006
	Previous calf injury	1.91	1.24-2.93	.003
	Goalkeeper†	0.41	0.20-0.82	.012
	Match related factors			
	UCL match§	0.48	0.24-0.97	.040
Calf	*Player related factors*			
	Previous calf injury	2.33	1.52-3.57	<.001
	Previous adductor injury	1.71	1.15-2.55	.008
	Previous hamstring injury	1.74	1.24-2.44	.002
	Goalkeeper†	0.36	0.16-0.82	.015
	Older player (age above mean)	1.93	1.38-2.71	<.001
	Match related factors			
	UCL match§	2.72	1.78-4.14	<.001

* Hazard ratios (HR) are given for player related factors from Cox regression analysis (adjusted for match exposure ratio: match exposure/total exposure); Odds ratios (OR) are given for match related factors from logistic regression analysis.

† Reference group for playing position: forward

‡ Reference group for match venue: home match

§ Reference group for match type: league match

€ Reference group for period of season: preseason (July-August)

Previous injury refers to injury during the preceding season.

Table 4. Simple analysis of match related risk factor variables for lower extremity muscle injuries from logistic regression.

	Adductors			Hamstrings			Quadriceps			Calf		
Variable	OR	95% CI	*P* Value	OR	95% CI	*P* Value	OR	95% CI	*P* Value	OR	95% CI	*P* Value
Match type												
League*	1.0			1.0			1.0			1.0		
UCL	1.17	0.83-1.64	.374	1.05	0.81-1.37	.703	0.51	0.25-1.01	.053	2.43	1.61-3.67	<.001
EL	1.05	0.59-1.87	.865	0.72	0.43-1.18	.190	1.19	0.55-2.60	.656	1.23	0.53-2.84	.636
Other cup	0.60	0.37-0.97	.035	0.77	0.56-1.06	.106	1.36	0.83-2.22	.227	0.89	0.47-1.68	.708
Match venue												
Home*	1.0			1.0			1.0			1.0		
Away	0.56	0.43-0.73	<.001	0.75	0.62-0.91	.003	1.02	0.71-1.47	.901	0.90	0.63-1.28	.544
Part of season												
Preseason (July-August)*	1.0			1.0			1.0			1.0		
Fall (September-November)	1.39	0.81-2.38	.237	2.24	1.34-3.74	.002	0.97	0.50-1.90	.936	0.88	0.42-1.86	.745
Winter (December-February)	1.13	0.65-1.96	.660	2.56	1.54-4.26	<.001	0.95	0.48-1.85	.870	1.13	0.55-2.35	.740
Spring (March-May)	1.43	0.83-2.47	.201	2.56	1.54-4.28	<.001	0.67	0.33-1.37	.270	1.34	0.65-2.77	.429
Climate region†												
Northern group*	1.0			1.0			1.0			1.0		
Southern group	1.04	0.77-1.40	.803	1.08	0.87-1.35	.474	0.87	0.55-1.36	.528	0.89	0.57-1.39	.614

* Reference group in analysis

† Climate region according to Köppen-Geiger climate classification system[30]: Northern group (predominately marine west coast climate), Southern group (Mediterranean climate).

OR denotes odds ratio; CI denotes confidence interval; UCL denotes UEFA Champions League; EL denotes UEFA Europa League (including former UEFA Cup).

Figure 1. Seasonal distribution of lower extremity muscle injury rates (injuries/1000 h of total exposure). A lower rate was found during preseason (July-August) compared to the competitive season (September-May) for adductor (rate ratio [RR] 0.78, 95% CI 0.61-0.98, *P* = .03), hamstring (RR 0.48, 95% CI 0.39-0.60, *P* < .001), and calf injuries (RR 0.57, 95% CI 0.40-0.80, *P* = .001), while quadriceps injury rates were higher during preseason (RR 1.40, 95% CI 1.11-1.75, *P* = .004).