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Risk factors for lower extremity injuries in elite female soccer players

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ABSTRACT

Background: The incidence of lower extremity injuries in female soccer players is high, but the risk factors for injury are unknown.
Purpose: To investigate risk factors for lower extremity injuries in elite female soccer players.
Study design: Cohort study.
Methods: Players in the Norwegian elite female soccer league (N=12 teams) participated in baseline screening tests prior to the 2009 competitive soccer season. The screening included tests assessing maximal lower extremity strength, dynamic balance, knee valgus angles in a drop jump landing, knee joint laxity, generalized joint laxity and foot pronation. We also included a questionnaire to collect information on demographic data, elite level experience and injury history. Time-loss injuries and exposure in training and match were recorded prospectively in the subsequent soccer season using weekly text messaging. Players reporting an injury were contacted to collect data regarding injury circumstances. Univariate and multivariate regression analyses were used to calculate odds ratios (OR) and 95% confidence intervals (CI) for one standard deviation change.
Results: In total, 173 players provided complete screening tests and registrations of injuries and exposure throughout the season. A total of 171 injuries in 107 players (62%) were recorded, and ligament and muscle injuries were most frequent. Multivariate analyses showed that greater BMI (OR 1.51, CI 1.00-1.90, $p \leq 0.001$) was the only factor significantly associated with new lower extremity injuries. Greater BMI was associated with new thigh injuries (OR 1.51, CI 1.08-2.11, $p=0.01$), lower knee valgus angles in a drop jump landing was associated with new ankle injuries (OR 0.64, CI 0.41-1.00, $p=0.04$) and a previous knee injury with new lower leg and foot injuries (OR 3.57, CI1.27-9.99, $p=0.02$), whereas neither of the factors investigated influenced the risk of new knee injuries.
Conclusion: Greater BMI was found to be a risk factor for lower extremity injuries in elite female soccer players.
Clinical relevance: Increased knowledge on risk factors for lower extremity injuries enables more targeted prevention strategies with the aim of reducing injury rates in female soccer players.
Keywords: female; football; soccer; injury; risk; screening
What is known about the subject: The incidence of lower extremity injuries in female soccer players is high, but the knowledge regarding risk factors for injury is limited.

What this study adds to existing knowledge: Using comprehensive screening tests and a multivariate approach the current study provide documentation of intrinsic risk factors for lower extremity injuries in female soccer players.

INTRODUCTION

Injuries to the lower extremities are common in female soccer, accounting for 60% to 85% of all time-loss injuries in senior female players.[1-8] Existing reports have documented that the knee is the body part most frequently injured (16% to 32% of all time-loss injuries), and ligament sprains account for 19% to 46% of time-loss injuries in female players.

Only three studies have investigated risk factors for injuries in senior female soccer players;[9-11] only one of these included elite players.[9] Increased knee hyperextension and generalized joint laxity,[10,11] as well as high performance on balance tests[11] and during single leg hopping[10] were factors found to increase the risk of sustaining a lower extremity injury. In addition, the dominant leg seemed to be more vulnerable to injury.[9] Anthropometric characteristics and muscle strength have been suggested as potential predictors for new lower extremity injuries, but no associations have been found or the results are contradictory.[9-11] One study showed an increased injury risk for taller players,[9] whereas another study found no relationship between height, body weight or body mass index (BMI) and lower extremity injuries.[10] Isokinetic quadriceps and hamstring muscle strength have not been associated with injury risk,[10] but a low concentric hamstring-to-quadriceps ratio (H:Q) has been found to increase the risk of acute lower extremity injuries.[11] Previous ligament injuries have not been found to increase the risk of a new injury to the same location,[9] which is in contrast to findings among female adolescents[12,13] and male soccer players for lower extremity injuries in general.[14-20]

To develop effective injury prevention strategies, an understanding of the multifactorial risk factors and causes of injury is essential, and frameworks have been outlined to describe the preferred approach for identifying and preventing injuries in sports.[21-24] Injuries likely result from an interaction between intrinsic and extrinsic risk factors, and there is a need to identify and take all relevant factors into account by using a multivariate statistical approach.[21,25] We therefore included a series of neuromuscular and anatomical screening tests, as well as demographic data, to assess potential predictors of injuries to the lower extremity.

The main purpose of this prospective cohort study was to investigate intrinsic risk factors for lower extremity injuries in elite female soccer players using a comprehensive screening battery and a subsequent registration of injuries and exposure. Secondly, we wanted to assess potential predictors for new injuries to the thigh, knee, ankle and lower leg/foot.

MATERIALS AND METHODS

Study design and participants

The current study is a part of a prospective cohort study aimed at investigating risk factors for non-contact anterior cruciate ligament (ACL) injuries in female elite soccer players. We invited all players in the Norwegian female elite league (Toppserien) to a comprehensive baseline screening examination. Players with an A-team contract who were expected to play in the elite league during the 2009 season were eligible for participation. Data were collected from preseason risk factor screening tests and from prospective injury registration throughout the subsequent season (Figure 1).

[*Figure 1 near here*]

The risk factor screening tests

The screening tests were conducted at the Norwegian School of Sport Sciences in February and March, during the 2009 preseason. The test order was randomised and each player spent about eight hours in total to complete the test sessions, which also included information, warm-up trials on all stations and a lunch break. We used a comprehensive test battery to assess potential demographic, neuromuscular and anatomical risk factors for injury, and data from the following tests were included in the current study:

Questionnaire

We asked all players to complete a questionnaire to collect data on demographics, elite soccer experience and history of previous injuries to the ACL, knees, ankles or hamstrings. A history of ACL injury refers to any previous ACL injury, whereas previous knee, ankle or hamstring injuries refer to time-loss injuries occurring within one year prior to the screening tests.

Quadriceps and hamstrings strength

Maximal isokinetic quadriceps and hamstrings strength was tested in a Technogym REV 9000 dynamometer (Gamboletta, Italy). The test range of motion was 90° through 15° of knee flexion, with an angular velocity of 60°/s. After a 5-min warm-up with moderate load on a cycle ergometer, the dynamometer was adjusted individually and we used two belts for fixation of the pelvis and upper body. We used a standardized test protocol and recorded the peak torque (Nm) for concentric quadriceps and hamstrings strength on both legs. Isokinetic muscle strength testing is a method widely used in clinical practice and has been established as a reliable tool for assessing muscle force, with intraclass correlation coefficients (ICC) ranging from 0.81-0.97).[26]

Hip abductor strength

We measured maximal hip abductor strength with a handheld dynamometer (Hydraulic Push-Pull Dynamometer, Baseline® Evaluation instruments, White Plains, NY, USA) with the player in a supine position on an examination table. The pelvis was fixed and the players held the arms across the chest to avoid hand support. We placed the dynamometer 2 cm proximally to the lateral malleolus and applied resistance in a fixed position for 3-5 s until a maximal isometric contraction had been reached. The players were allowed two trials and the best trial was recorded (kg). Similar procedures have been established as reliable for assessing hip abductor strength (ICC=0.84-0.97).[27,28]

1 RM leg press
To assess the combined maximal strength of the gluteal, quadriceps and hamstrings muscles, we used a seated custom-made leg press machine, with good reliability reported for interrater measurements (ICC=0.83) in a separate investigation from the same cohort (2013, unpublished data). From the starting position, the back of the seat was declined 30° relative to the floor, with the hips flexed to 45°. The feet were placed shoulder width apart on a foot plate used to lower the weights to 100° of knee flexion before pushing back to the starting position. To ensure the correct range of motion, a bar was placed at the point where the knees reached a flexion angle of 100°, measured with a goniometer. Based on a standardized test protocol with gradually increasing load, we recorded one repetition maximum (1 RM, kg).

The Star Excursion Balance Test
To assess dynamic balance of the lower extremities, we used the Star Excursion Balance Test (SEBT), which has been found reliable for investigating balance and potential ankle stability deficits (ICC 0.67-0. 87).[29,30] From a center point identified as a vertical line, three tape measures were attached to the floor in the anterolateral, mediolateral and posterolateral direction. The mediolateral direction was perpendicular to the starting line, and relative to this tape measure, the anterolateral and posterolateral directions were at a 45° angle. The test was performed without shoes, always starting with balancing on their preferred kicking leg. While maintaining single-leg stance, the players were asked to reach as far as possible with the contralateral leg in all three directions, starting anteriorly and moving posteriorly, while the test leader marked their maximal distance (cm). The trial was judged invalid if they failed to maintain balance on the stance leg or moved from the starting point; if they touched the floor with the contralateral leg; or if they were unable to move their contralateral leg back to the starting position. They were allowed one practice trial in all directions for each leg. We recorded three trials for all three directions bilaterally, and the results from their best trials were included in the analyses.

Knee valgus in a vertical drop jump landing
We assessed maximal knee valgus angles in the landing of a vertical drop jump using three-dimensional (3D) motion analysis. This method is considered the gold standard for assessing knee joint kinematics in a drop jump landing, with good to excellent reliability reported (ICC=0.62-0.99),[31] and has been found to correlate well to real-time assessment of frontal plane knee control.[32] We used an optical tracking system with eight 240 Hz infrared cameras (ProReflex, Qualisys, Gothenburg, Sweden) for motion capture. The players wore shorts, a sports bra and indoor soccer shoes, and we attached 35 reflective markers to the torso and lower extremities over anatomical landmarks.[33] One research assistant (medical student) palpated the anatomical landmarks and placed the markers on all players to ensure standardization. To estimate inertia parameters, we obtained anthropometric measures of all players.

Starting on the top of a 30 cm high box with their feet 30 cm apart, the players were instructed to drop off the box with a two-feet symmetrical landing, immediately followed by a maximal vertical jump. They were allowed up to three practice trials and at least three valid trials were collected for each player. The trial was valid when the markers stayed firmly on the skin and were visible for all cameras throughout the jump.

Marker trajectories were tracked with the Qualisys Track Manager (Qualisys, Gothenburg, Sweden), and these were filtered and interpolated with a 15 Hz cubic smoothing spline.[34] We determined the anatomical coordinate systems of the thigh and shank from a static calibration trial. The vertical axis was defined in the direction from distal to proximal joint center, the antero-posterior axis was defined perpendicular to the vertical axis, and the third axis was the cross product of the vertical and antero-posterior axis.[33] Peak knee valgus angles during the contact phase were calculated in custom Matlab scripts (Mathworks Inc., Natick, MA, USA), using the Joint Coordinate System convention.[35] The zero posture was defined as zero degrees, and the contact phase was defined as the period where the unfiltered vertical ground reaction force exceeded 20 N. The static calibration trial from the 3D motion analysis was used to extract player height and the length of the femur and tibia, and their body mass was recorded from two adjacently placed 960 Hz force platforms (AMTI LG6-4-1, Watertown, Massachusetts, USA).

Knee joint laxity
Anterior-posterior knee joint laxity was measured using a KT-1000 arthrometer (MEDmetric Corp, San Diego, California, USA) with the players in a supine position on an examination table. With the knees flexed to 25 ±5°, posterior directed forces were applied to the tibia to establish a zero reference point, followed by an anterior directed force of 134 N to measure anterior knee joint laxity (mm). The maximal value out of two trials was recorded for both legs. The reliability of KT-1000 measurements by experienced raters has been shown to be good (ICC=0.79).[36]

Generalized joint laxity
Hypermobility was assessed using the 9-point Beighton scale,[37] which has been utilized extensively for quantifying hypermobility and with good to very good reliability reported within and between raters (Spearmans rho: 0.81-0.86 and 0.75-0.87, respectively).[38] Players were assessed for excessive joint laxity at the trunk, and bilaterally at the fifth finger, thumb, elbow and knee. Each joint received a score of 1 for each criteria met, giving a potential maximal score of 9. The threshold for hypermobility was defined as a score at or above 4, which indicated increased joint laxity.

Foot pronation
The navicular drop test was included to assess foot pronation. Navicular drop was defined as the difference in navicular height (mm) from standing with the subtalar joint in neutral position to the standing relaxed foot position. The players were barefoot, standing with the feet shoulder-width apart on a hard and elevated ground, and we marked the most prominent aspect of the navicular bone. The distance from the navicular bone to the floor in neutral and relaxed position was measured with a ruler, and we used procedures similar to those described by Shultz el al,[39] where intrarater and interrater reliability has been reported as moderate to very good (0.56-0.76 and 0.91-0.97, respectively).[40]

Injury registration
We recorded all injuries occurring throughout the 2009 competitive soccer season (April-November). An injury was recorded if the player was unable to fully participate in soccer training or match play for at least one day beyond the day of injury.[41] The player was considered injured until declared fit for full participation in training and available

for match selection by the medical staff. The players individually reported all injuries and exposure throughout the season using text messaging (SMS), and injuries were verified through a standardized telephone interview. The registration was conducted on a weekly basis with three text messages sent to the player at the end of each week with questions related to match exposure, training exposure and time-loss injuries. If an injury was reported, the player was contacted by telephone to complete the injury form and collect information regarding the injury circumstances, such as the injured body part, location and type of injury, the type of activity and playing surface, the specific diagnosis and the number of days of absence. The data collection procedure has been described in detail and validated in a previous report.[6]

Ethics approval

The study was approved by the Regional Committee for Medical Research Ethics; South-Eastern Norway Regional Health Authority, and by the Norwegian Social Science Data Services, Norway. All players signed a written informed consent form. Players under the age of 18 needed written consent from their parents to be eligible for participation.

Statistical analyses

Data were analysed using SPSS for Windows, version 18 (SPSS Inc., Chicago, IL, USA), and descriptive data are presented as means ± standard deviations (SD). Individual exposure data were calculated as the total hours of training and match play during the season, and injury rates are reported as the number of injuries per 1000 player hours with 95% confidence intervals (CI) using *z* statistics. Their preferred kicking leg was regarded as the dominant leg. For the analyses, we included new injuries only, excluding all injuries reported as re-injuries (n=6). We also excluded injuries located to the head, trunk or upper extremities (n=39), and all muscle and bone contusions (n=23).

Strength measures were adjusted for body mass and are presented as relative values. For the Star Excursion Balance Test, the players' maximal reaching distance in all three directions was adjusted for leg length (calculated from the 3D motion analyses), and we calculated the mean relative score for the three directions for further analyses. From the 3D motion analyses we calculated the average peak valgus angles across three trials for both the right and left knee and analysed the legs separately."

Demographic data and screening test scores were compared between players with and without any new lower extremity injury during the study period using Student`s t-test for continuous variables and chi-square tests for categorical data. To further investigate the risk factors for injuries, we used any lower extremity injury as the main outcome variable, and separate analyses were performed for injuries to the thigh, knee, ankle and lower leg/foot. Injuries to the hip and groin were excluded from these analyses due to the low number (n=14) and therefore a limited ability to establish associations.

For the dependent variable risk factor analyses, we followed a three-step model with similar procedures for all outcome variables. First, with each leg as the unit of analysis, we used generalized estimating equations (STATA, version 12.0; StataCorp, College station, Texas, USA) to calculate odds ratios (OR) per one SD unit of change with 95% confidence intervals (CI) for all potential player-related risk factors for the outcome variables. For candidate risk factors with a *P*-value of <0.05, these findings were verified using binary logistic regression, allowing for repeated measurements across legs using robust estimation of standard errors. Following the univariate analyses, all factors with a p-value of <0.20 were investigated further in a multivariate model. To account for a potential over-optimism in the multivariate model estimates, we used the bootstrap method to estimate regression coefficients. For the final analyses the significance level was set at p <0.05.

RESULTS

Player and injury characteristics

The total sample included 173 players who provided complete data sets from both the preseason screening tests and the prospective injury registration (age 21.5 ± 4.1 years, height 167 ± 5 cm, body weight 62 ± 6 kg). Of these, 107 (62%) sustained at least one injury to their lower extremities during the season, and a total of 171 lower extremity injuries were reported. The total player exposure in training and match play was 44831 hours throughout the season, giving an overall injury incidence of 3.8 injuries per 1000 player hours [95% CI 3.2 to 4.4]. For match and training injuries, the incidence was 12.9 [95% CI 9.9 to 15.9] and 2.6 [95% CI 2.1 to 3.1] per 1000 player hours, respectively.

The majority of injuries occurred during training (59%; n=101). The knee was the body part most frequently injured, and ligament and muscle injuries dominated (Table 1). Nearly one-third of the injuries were severe, leading to absence from soccer training and match play for ≥4 weeks. Most players (88%; n=152) were right-leg dominant, but there was no difference in injury rate between the dominant and non-dominant leg (p=0.86).

[*Table 1 near here*]

Risk factors for lower extremity injury

Players suffering a lower extremity injury during the season were heavier and had a greater BMI compared to players with no injuries (Table 2). Table 3 presents the univariate odds ratios for a new lower extremity injury. Players with higher foot pronation were more likely to sustain a lower extremity injury with a 23% higher injury risk per SD increase. Neither of the neuromuscular factors, nor the history of a previous lower extremity injury were candidate risk factors for new injuries. Multivariate analyses identified greater BMI as the only factor associated with increased lower extremity injury risk (see Table 8).

[*Table 2 and 3 near here*]

Risk factors for thigh injury

A total of 32 legs were affected by a thigh injury during the season, and 35 injuries were recorded (Table 4). The majority of injuries affected the hamstrings muscles (80%; n=28), whereas seven were located in the quadriceps. A history of a hamstring injury within the previous 12 months had no influence on the risk of a new thigh injury. None of the demographic, neuromuscular or anatomical factors was associated with a new injury. From the multivariate analyses (see Table 8), BMI was found to increase the risk of thigh injury by 51% per SD increase.

[*Table 4 near here*]

Risk factors for knee injury
We recorded a total of fifty-three injuries in 45 knees, of which five were non-contact ACL injuries. A previous ACL injury and low knee valgus angles were the only factors associated with a new knee injury (Table 5). Nineteen previous ACL injuries were reported (18 non-contact), and a previous ACL injury in the right knee gave a nine-fold increased risk of sustaining a new knee injury in the same leg (OR 9.08, CI 1.90-43.44, p=0.006), whereas this relationship was not found for the left knee (OR 1.87, CI 0.37-9.38, p=0.45). Neither the demographic-, neuromuscular- or anatomical factors, nor the history of a previous knee injury was associated with new knee injuries. In the multivariate model, neither of the candidate factors included were found to increase the risk of a new knee injury (see Table 8).

[*Table 5 near here*]

Risk factors for ankle injury
Thirty-two ankles were affected by at least one injury, and younger players were more likely to sustain an ankle injury compared to older players (Table 6). Higher maximal lower extremity strength in a leg press machine gave a 47% increased injury risk per SD increase of relative strength, whereas players with greater maximal knee valgus angles in a vertical drop jump landing or less foot pronation were less likely to suffer an injury. In the multivariate model knee valgus angles was the only candidate factor significantly associated with a new ankle injury (see Table 8).

[*Table 6 near here*]

Risk factors for lower leg and foot injury
Age was associated with the 29 leg and foot injuries recorded, with older players being more prone to injury (Table 7). A history of knee injury within the previous year increased the risk of an injury to the lower leg or foot more than three-fold, but when investigating the potential limb differences, the finding was only confirmed for the right leg (OR 3.69, CI 1.04-13.12, p=0.04). Previous knee injury was also a significant predictor for new leg and foot injuries in the multivariate analyses (see Table 8).

[*Table 7 and 8 near here*]

DISCUSSION
This is the first study using a series of comprehensive screening tests and subsequent injury registration through text messaging to assess potential intrinsic risk factors for lower extremity injuries in elite female soccer players. The main finding was that greater BMI was identified as a risk factor for a new lower extremity injury, whereas no association was found for neither of the neuromuscular nor anatomical factors. BMI was associated with thigh injuries, lower knee valgus in a drop jump landing was associated with ankle injuries and a previous knee injury influenced the risk of new injuries to the leg and foot, whereas neither of the candidate factors in the multivariate model was associated with new knee injuries.

Demographic variables and injury risk

Among the intrinsic factors associated with new lower extremity injury, BMI was the strongest factor, increasing the injury risk by 51% per one SD increase. Higher body mass may stress joint and ligament structures of the lower extremities to a greater extent, and thereby influence injury risk. More than half of the body mass is located in the upper body,[42] and a link has already been established between trunk and upper body kinematics and lower extremity loading during sport specific tasks.[43,44] However, although significant, the difference in BMI between injured and non-injured players was relatively small (22.6 versus 21.8, respectively, corresponding to 1.6 kg), and the clinical relevance may be limited. In contrast to our findings, neither studies among female senior players,[9,10] nor youth players[12,13] found any influence of BMI. On the other hand, these studies included all types of injury affecting the lower extremities, and the investigations among youth players also included injuries located in the trunk, head and upper extremities, and are therefore not directly comparable to our findings.

Although higher age has been suggested as a predictor for lower extremity injury and shown to increase injury risk in Swedish female elite players,[10] we found no association between age and lower extremity injury risk in general, nor with new injuries to any of the specific locations. This corresponds to the findings reported in two cohort studies on female senior players.[9,11]

Neuromuscular factors and injury risk

Frontal plane knee control

This is the first study to objectively measure knee valgus in a sport specific task to assess potential intrinsic risk factors among female soccer players. We found no difference in peak knee valgus angles in a drop jump landing between players sustaining a lower extremity injury compared to non-injured players. In contrast, players with lower knee valgus angles had a 36% higher risk of sustaining an ankle injury. This was somewhat surprising, considering that high knee valgus angles in a drop jump landing have been found to predict ACL injuries in a mixed-sport cohort of female athletes.[45] Moreover, lower extremity injury rates in females have been reduced after neuromuscular training aiming to increase frontal plane knee control and thus reducing dynamic knee valgus.[46-48] A plausible explanation for our finding could be that players with low valgus angles in drop jump landings, and thus proper frontal plane knee control, are better soccer players being more involved in game situations that entail a higher risk of injury. However, we acknowledge that the clinical relevance of a difference of 2.3 degrees of valgus may be little,[31] as well as potential sources of error in different steps of the 3D analysis, including landmark palpation, skin movement artefacts, joint center estimation and definition of joint axes.[49-51]

Functional balance

Proper functional lower extremity balance and control is essential for both technical and tactical performance as a soccer player, and one would assume that such attributes contribute to being less prone to injuries. The performance of the SEBT is dependent on multiple neuromuscular characteristics and has been found to identify youth athletes with increased risk for lower extremity injury.[30] However, we found no association between SEBT scores and injury. One explanation may be that the SEBT used in the current study was based on three out of the original eight reaching directions, which were different from those selected in other studies.[30,52] Furthermore, in contrast to previous studies investigating each direction separately, we calculated a mean score for all three directions. Separate analyses could potentially reveal differences.

Controversely, in a Swedish investigation,[11] female players with lower postural sway in single leg stance, i.e. better balance, had a higher risk of injury. Similar findings were demonstrated by Östenberg & Roos,[10] who found that players performing better in a functional performance task had a four-fold increased risk for sustaining a new lower extremity injury. These conflicting results suggest that dynamic balance is a complex functional skill influenced by numerous factors when being challenged, and is therefore difficult to capture with one single test. On the other hand, as shown in a study among youth female players,[53] highly skilled players may be more exposed to potential injury situations, thus leaving them more vulnerable to injury compared to less skilled players.

Muscle strength
Muscle strength deficits may represent a potential predictor for lower extremity injury, and increased muscle strength will likely improve dynamic stability and hence reduce injury risk. Interestingly, we found no differences in lower extremity muscle strength between players sustaining a lower extremity injury and those who did not. Yet, a limitation to our findings is that we only measured their maximal strength and have no information on muscle recruitment or timing, which is of interest with respect to how these factors could assist in avoiding injuries.

Anatomical factors and injury risk
We could not identify any associations between anatomical factors and injury risk. Although univariate analyses revealed that players with increased foot pronation were more likely to sustain a lower extremity injury in general or an ankle injury, these findings were not confirmed in the multivariate model. In contrast, some studies have found greater foot pronation in subjects with a history of an ACL tear.[54-57] Considering that the foot represents the base of support upon which the body maintains balance, it seems reasonable that even small changes in foot alignment could influence stability and movement strategies and hence injury risk. However, there is a lack of evidence supporting a cause-and-effect relationship between excessive foot pronation and lower extremity injury.[58]

Neither measures of knee laxity nor generalized joint laxity could identify players sustaining a lower extremity injury. In contrast, increased knee hyperextension and generalized joint laxity were predictors of lower extremity injury in two of the previous studies among senior female players[10,11] where the latter increased the risk more than three-fold. However, due to methodological differences between these studies and the current investigation, such a direct comparison should be interpreted with caution.

Injury history and injury risk
Interestingly, univariate analyses revealed a nine-fold increased risk for a knee injury in players with previous ACL injury in the same knee, although not confirmed in the multivariate model. This is in accordance with previous findings among male soccer players, documenting an increased risk for new knee injuries after an ACL rupture.[20] Furthermore, a previous knee injury gave a more than three-fold increased risk for a lower leg or foot injury. Contradictory, previous injuries did not influence the risk of ankle injuries, nor injuries to the lower extremities in general. This could be explained

by their access to medical treatment and rehabilitation, which likely influences the rate of recurrences. Investigations among senior female players at different levels revealed no association between injury history and new injuries,[9,11] whereas an increased risk was found for youth female players with a previous injury.[12,13] Corresponding findings have consistently been reported among male soccer players, both for injuries to the knees,[14,20] ankles,[16] as well as for specific lower extremity muscle injuries.[15,17-19] However, the definition of previous injury and for how long preceding the screening these injuries have been recorded differ among the studies, which affects the interpretation of their findings.

Methodological considerations
A major strength of this study was the method of injury and exposure registration, which was conducted individually with weekly reports throughout the season,[6] eliminating the potential recall bias. In contrast, existing studies assessing risk factors among female football players based their injury reports on medical staff registrations, which have been found to underestimate the true burden of injuries by 50%.[6] If previous injury reports were invalid, this would also affect the conclusions drawn from the risk assessments. Furthermore, in contrast to previous studies assessing risk factors in female players, we excluded all muscle and bone contusions, as they result from contact situations that are unlikely to be fully explained by intrinsic demographic, neuromuscular or anatomical factors. Furthermore, studies on injury risk have traditionally used the player as the unit of analysis. However, individual factors such as muscle strength, balance and stability, as well as lower extremity alignment, may be more related to the injured limb rather than the player. We therefore used the leg as the unit of analysis, and believe that this represent a strength of the study.

Despite of the strengths of the current investigation, there are some limitations to consider when interpreting the results. First, when conducting a risk factor study, a key component is the selection of screening tests and measurement tools. As this study was part of a cohort study aimed to investigate risk factors for ACL injuries, the screening test battery was therefore originally designed for this purpose and not for identifying lower extremity injury risk in general. For this reason, other potentially useful tests to enable even better descriptions of lower extremity characteristics and function, such as functional movement screening tests and core stability, have not been included. On the other hand, the tests included have previously been used for lower extremity assessment, and we believe that these comprise a broad and useful description of neuromuscular and anatomical characteristics. Secondly, we only assessed intrinsic factors and could not provide information on any external risk factors, such as the influence of playing surface, weather conditions, equipment, nor exposure other than playing soccer. As injuries likely result from a complex interaction of multiple factors, our study cannot provide a complete description of injury risk in female soccer players. Thirdly, psychological factors and life stressors, as well as lack of energy, illness or motivational barriers may have influenced the injury risk in these players and these were factors not captured through our preseason screening tests. Finally, although our sample size was larger than previous risk factor studies among senior female players and enabled a description of injuries to the thigh, knee, ankle and lower leg or foot in particular, we acknowledge that the limited number of injuries within each category reduced statistical power for such subgroup analyses. This may have affected the conclusions drawn, and potential associations may have been masked.

CONCLUSION

In conclusion, greater BMI was the only factor associated with new lower extremity injuries in elite female soccer players. Greater BMI was associated with thigh injuries and players with lower peak knee valgus angles in a drop jump landing were more likely to sustain a new ankle injury. The history of a previous knee injury was associated with new injuries to the lower leg/foot, whereas neither of the intrinsic factors assessed were associated with knee injuries. Future studies investigating intrinsic risk factors for injury and how psychological factors interact with physiological factors, as well as external factors, would be of great value to improve preventive measures and reduce the rate of injuries in female soccer.

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Figure 1
The flow of players participating in the study

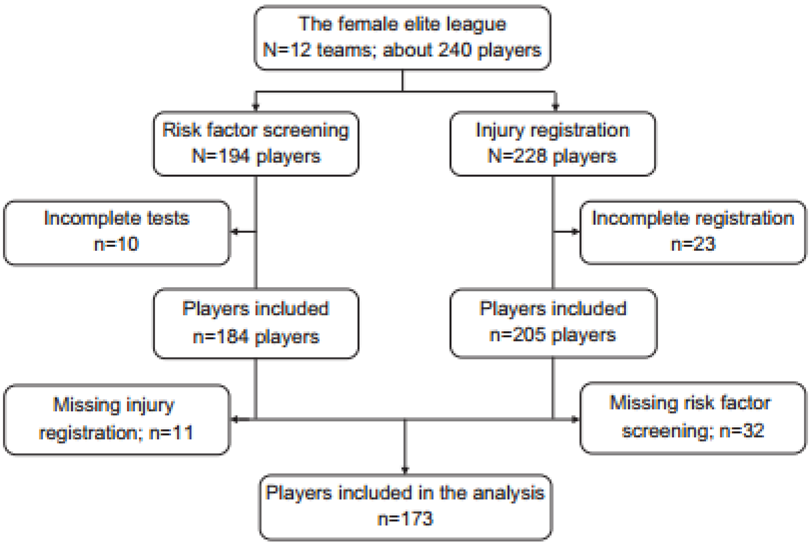

Table 1
Characteristics of Injuries (N = 171)

Injury Classification	Injuries, n (%)
Injury location	
Hip/groin	14 (8)
Thigh	35 (21)
Knee	53 (31)
Ankle	40 (23)
Leg/foot	29 (17)
Injury type	
Ligament sprain	63 (37)
Muscle injury	58 (34)
Meniscus/cartilage lesion	10 (6)
Tendon	31 (18)
Fracture	5 (3)
Other	4 (2)
Injury severity	
Minimal (1-3 days)	24 (14)
Mild (4-7 days)	32 (19)
Moderate (8-28 days)	64 (37)
Severe (>28 days)	51 (30)
Injured leg	
Dominant	96 (56)
Nondominant	75 (44)

Table 2
Risk Factors for Lower Extremity Injuries: Injured Versus Noninjured Players[a]

Player-Related Factors	Injured Players (n = 107)	Noninjured Players (n = 66)	Odds Ratio (95% CI)	*P* Value
Age, y	22.1 ± 4.3	20.4 ± 3.7	1.21 (0.99-1.47)	.06
Height, cm	166.6 ± 5.0	167.2 ± 5.7	0.93 (0.75-1.15)	.51
Weight, kg	62.8 ± 5.9	61.2 ± 6.3	1.34 (1.07-1.68)	.01
BMI, kg/m^2	22.6 ± 1.7	21.8 ± 1.7	1.55 (1.24-1.94)	≤.001
Seasons at elite level, y	3.6 ± 3.5	3.2 ± 3.3	1.00 (0.83-1.21)	.96
Match and training exposure, h	249.1 ± 69.9	275.4 ± 79.4	0.86 (0.64-1.15)	.21

[a]Comparison calculated using generalized estimating equations. Results are presented as mean ± standard deviation unless otherwise indicated. The risk for new injuries is reported as the odds ratio per standard deviation unit of change in player-related factors (95% confidence intervals [CIs]) and *P* values. BMI, body mass index.

Table 3
Multivariate Analyses Including All Candidate Risk Factors Achieving *P* < .20 in Univariate Analyses for All Dependent Variables[a]

Intrinsic Factors	Odds Ratio (95% CI)	*P* Value
Lower extremity		
BMI	1.51 (1.21-1.90)	.001
Foot pronation	1.25 (0.99-1.59)	.06
Age	1.24 (1.00-1.54)	.09
Knee valgus angles	0.90 (0.71-1.15)	.46
Previous ACL injury	1.55 (0.42-5.68)	.51
Thigh		
BMI	1.51 (1.08-2.11)	.01
Hamstring strength	1.45 (0.98-2.16)	.06
Previous hamstring injury	1.35 (0.42-4.38)	.62
Knee		
Previous ACL injury	3.30 (0.82-13.3)	.09
Knee valgus angles	0.12 (0.01-1.30)	.18
Foot pronation	1.28 (0.87-1.90)	.26
Previous ankle injury	1.46 (0.64-3.31)	.37
Knee laxity	1.12 (0.84-1.51)	.47
Ankle		
Knee valgus angles	0.64 (0.41-1.00)	.04
Foot pronation	1.55 (0.99-2.41)	.07
1 repetition maximum leg press	1.41 (0.97-2.06)	.07
Age	0.65 (0.40-1.05)	.08
Leg/foot		
Previous knee injury	3.57 (1.27-9.99)	.02
Age	1.47 (0.98-2.20)	.06
BMI	1.40 (0.90-2.17)	.14

[a]The odds ratios per standard deviation unit of change in test scores are presented with 95% confidence intervals (CIs) and *P* values and result from generalized estimating equations including the bootstrap method. ACL, anterior cruciate ligament; BMI, body mass index.