Risk Factors for Lower Extremity Injuries in Elite Female Soccer Players

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Background: The incidence of lower extremity injuries in female soccer players is high, but the risk factors for injuries are unknown.

Purpose: To investigate risk factors for lower extremity injuries in elite female soccer players.

Study Design: Cohort study; Level of evidence, 3.

Methods: Players in the Norwegian elite female soccer league (N = 12 teams) participated in baseline screening tests before 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. Also included was a questionnaire to collect information on demographic data, elite-level experience, and injury history. Time-loss injuries and exposure in training and matches 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 (ORs) and 95% confidence intervals (CIs) for standard deviation of change.

Results: In total, 173 players underwent complete screening tests and registration of injuries and exposure throughout the season. A total of 171 injuries in 107 players (62%) were recorded; ligament and muscle injuries were the most frequent. Multivariate analyses showed that a greater body mass index (BMI) (OR, 1.51; 95% CI, 1.21-1.90; P = .001) was the only factor significantly associated with new lower extremity injuries. A greater BMI was associated with new thigh injuries (OR, 1.51; 95% CI, 1.08-2.11; P = .01), a lower knee valgus angle in a drop-jump landing was associated with new ankle injuries (OR, 0.64; 95% CI, 0.41-1.00; P = .04), and a previous knee injury was associated with new lower leg and foot injuries (OR, 3.57; 95% CI, 1.27-9.99; P = .02), whereas none of the factors investigated influenced the risk of new knee injuries.

Conclusion: A greater BMI was associated with 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

Injuries to the lower extremities are common in female soccer players, accounting for 60% to 85% of all time-loss injuries in senior female players. Existing reports have documented that the knee is the body part most frequently injured (16%-32% of all time-loss injuries), and ligament sprains account for 19% to 46% of time-loss injuries in female players. Only 3 studies have investigated the risk factors for injuries in senior female soccer players, only 1 of these included elite players. Increased knee hyperextension and generalized joint laxity, as well as high performance on balance tests and during single-legged hopping, 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. Anthropometric characteristics and muscle strength have been suggested as potential predictors for new lower extremity injuries.
injuries, but no associations have been found, or the results are contradictory.20,42,47 One study showed an increased injury risk for taller players,20 whereas another study found no relationship between height, body weight or body mass index (BMI), and lower extremity injuries.42 Isokinetic quadriceps and hamstring muscle strength have not been associated with injury risk,47 but a low concentric hamstring-to-quadriceps ratio has been found to increase the risk of acute lower extremity injuries.47 Previous ligament injuries have not been found to increase the risk of a new injury to the same location,20 which is in contrast to findings among female adolescents14,50 and male soccer players for lower extremity injuries in general.2,15-17,27,28,55

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.4,21,38,54 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.3,4 We therefore included a series of neuromuscular and anatomic 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 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 part of a prospective cohort study aimed at investigating risk factors for noncontact anterior cruciate ligament (ACL) injuries in female elite soccer players. We invited all players in the Norwegian female elite soccer league (Toppserien) to participate in 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).

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 randomized, and each player spent about 8 hours in total to complete the test sessions, which also included information gathering, warm-up trials on all stations, and a lunch break. We used a comprehensive test battery to assess potential demographic, neuromuscular, and anatomic risk factors for injury, and data from the following tests were included in the current study.

Figure 1. The flow of players participating in the study.

Questionnaire. We asked all players to complete a questionnaire to collect data on demographics, elite soccer experience, and 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 1 year before the screening tests.

Quadriceps and Hamstring Strength. Maximal isokinetic quadriceps and hamstring strength were tested with a Technogym REV 9000 dynamometer (Gambettola, Italy). The test range of motion was 90° through 15° of knee flexion, with an angular velocity of 60 deg/s. After a 5-minute warm-up with a moderate load on a cycle ergometer, the dynamometer was adjusted individually, and we used 2 belts for fixation of the pelvis and upper body. We used a standardized test protocol and recorded the peak torque (N·m) for concentric quadriceps and hamstring 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 (ICCs) ranging from 0.81 to 0.97.10

Hip Abductor Strength. We measured maximal hip abductor strength with a handheld dynamometer (hydraulic push-pull dynamometer, Baseline Evaluation Instruments, White Plains, New York, USA) with the player in a supine position on an examination table. The pelvis was fixed, and the players held their 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 to 5 seconds until a maximal isometric contraction had been reached. The players were allowed 2 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).52,53

One Repetition Maximum Leg Press. To assess the combined maximal strength of the gluteal, quadriceps, and hamstring 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 (unpublished data). From the starting position, the back of the seat was declined 30° relative to

Incomplete tests
n=10

Incomplete registration
n=23

Players included
n=184 players

Players included
n=205 players

Missing injury registration; n=11

Missing risk factor screening; n=32

Players included in the analysis
n=173

The female elite league
N=12 teams; about 240 players

Risk factor screening
N=194 players

Injury registration
N=228 players

n=11

n=23

n=173

n=194

n=228

n=12

n=11
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 a gradually increasing load, we recorded 1 repetition maximum (kg).

**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). From a center point identified as a vertical line, 3 tape measures were attached to the floor in the anterolateral, mediolateral, and posterolateral directions. 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 the preferred kicking leg. While maintaining a single-legged stance, the players were asked to reach as far as possible with the contralateral leg in all 3 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 1 practice trial in all directions for each leg. We recorded 3 trials for all 3 directions bilaterally, and the results from the 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 3-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), and has been found to correlate well with real-time assessment of frontal-plane knee control. 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 anatomic landmarks and placed the markers on all players to ensure standardization. To estimate inertia parameters, we obtained anthropometric measures of all players.

Starting at the top of a 30 cm–high box with their feet 30 cm apart, the players were instructed to drop off the box and land symmetrically on both feet, immediately following this with a maximal vertical jump. They were allowed up to 3 practice trials, and at least 3 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, and these were filtered and interpolated with a 15-Hz cubic smoothing spline. We determined the anatomic coordinate systems of the thigh and shank from a static calibration trial. The vertical axis was defined as the direction from the distal to proximal joint center, the anteroposterior axis was defined perpendicular to the vertical axis, and the third axis was the cross-product of the vertical and anteroposterior axes. Peak knee valgus angles during the contact phase were calculated in custom Matlab scripts (MathWorks Inc, Natick, Massachusetts, USA) using the joint coordinate system convention. The zero posture was defined as 0°, and the contact phase was defined as the period in which 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 2 adjacently placed 960-Hz force platforms (AMTI LG6-4, 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 from 2 trials was recorded for both legs. The reliability of KT-1000 arthrometer measurements by experienced raters has been shown to be good (ICC, 0.79).

**Generalized Joint Laxity.** Hypermobility was assessed using the 9-point Beighton scale, which has been utilized extensively for quantifying hypermobility and has good to very good reliability reported within and between raters (Spearman ρ = .81-.86 and .75-.87, respectively). 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 criterion met, giving a potential maximal score of 9. The threshold for hypermobility was defined as a score of ≥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 a neutral position to the standing position with a relaxed foot. The players were barefoot, standing with the feet shoulder width apart on a hard and elevated surface, and we marked the most prominent aspect of the navicular bone. The distance from the navicular bone to the floor in a neutral and relaxed position was measured with a ruler, and we used procedures similar to those described by Shultz et al in which intrarater and interrater reliability have been reported as moderate to very good (0.91-0.97 and 0.56-0.76, respectively).

**Injury Registration.** We recorded all injuries that occurred 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 1 day beyond the day of injury. 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. Registration was conducted on a weekly basis with 3 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, the 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.40

Ethics Approval

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

Statistical Analyses

Data were analyzed using SPSS for Windows (v 18, SPSS Inc, Chicago, Illinois, USA), and descriptive data are presented as the mean ± standard deviation (SD). Individual exposure data were calculated as the total number of 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 (CIs) using Z statistics. The preferred kicking leg was regarded as the dominant leg. For the analyses, we included new injuries only, excluding all injuries reported as reinjuries (n = 6). We also excluded injuries 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 SEBT, the players' maximal reaching distance in all 3 directions was adjusted for leg length (calculated from the 3D motion analyses), and we calculated the mean relative score for the 3 directions for further analyses. From the 3D motion analyses, we calculated the mean peak valgus angles across 3 trials for both the right and left knees and analyzed 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 the Student t test for continuous variables and χ² 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 because of the low number (n = 14) and therefore a limited ability to establish associations.

For the risk factor analyses of dependent variables, we followed a 3-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 (ORs) per a single SD unit of change with 95% CIs for all potential player-related risk factors for the outcome variables. For candidate risk factors with a P value of <.05, these findings were verified using binary logistic regression, allowing for repeated measurements across legs using a robust estimation of standard errors. After the univariate analyses, all factors with a P value of <.20 were investigated further in a multivariate model. To account for potential overoptimism 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 < .05.

RESULTS

Player and Injury Characteristics

The total sample included 173 players who provided complete data sets for both the preseason screening tests and the prospective injury registration (age, 21.5 ± 4.1 years; height, 167 ± 5 cm; weight, 62 ± 6 kg). Of these, 107 (62%) sustained at least 1 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 44,831 hours throughout the season, giving an overall injury incidence of 3.8 injuries per 1000 player hours (95% CI, 3.2-4.4). For match and training injuries, the incidence was 12.9 (95% CI, 9.9-15.9) and 2.6 (95% CI, 2.1-3.1) 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>
<thead>
<tr>
<th>Injury Classification</th>
<th>Injuries, n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injury location</td>
<td></td>
</tr>
<tr>
<td>Hip/groin</td>
<td>14 (8)</td>
</tr>
<tr>
<td>Thigh</td>
<td>35 (21)</td>
</tr>
<tr>
<td>Knee</td>
<td>53 (31)</td>
</tr>
<tr>
<td>Ankle</td>
<td>40 (23)</td>
</tr>
<tr>
<td>Leg/foot</td>
<td>29 (17)</td>
</tr>
<tr>
<td>Injury type</td>
<td></td>
</tr>
<tr>
<td>Ligament sprain</td>
<td>63 (37)</td>
</tr>
<tr>
<td>Muscle injury</td>
<td>58 (34)</td>
</tr>
<tr>
<td>Meniscus/cartilage lesion</td>
<td>10 (6)</td>
</tr>
<tr>
<td>Tendon</td>
<td>31 (18)</td>
</tr>
<tr>
<td>Fracture</td>
<td>5 (3)</td>
</tr>
<tr>
<td>Other</td>
<td>4 (2)</td>
</tr>
<tr>
<td>Injury severity</td>
<td></td>
</tr>
<tr>
<td>Minimal (1-3 days)</td>
<td>24 (14)</td>
</tr>
<tr>
<td>Mild (4-7 days)</td>
<td>32 (19)</td>
</tr>
<tr>
<td>Moderate (8-28 days)</td>
<td>64 (37)</td>
</tr>
<tr>
<td>Severe (&gt;28 days)</td>
<td>51 (30)</td>
</tr>
<tr>
<td>Injured leg</td>
<td></td>
</tr>
<tr>
<td>Dominant</td>
<td>96 (56)</td>
</tr>
<tr>
<td>Nondominant</td>
<td>75 (44)</td>
</tr>
</tbody>
</table>

TABLE 1 Characteristics of Injuries (N = 171)
Nearly one third of the injuries were severe, leading to an 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 the injury rate between the dominant and nondominant leg (P = .86).

### Risk Factors for Lower Extremity Injury

Players suffering a lower extremity injury during the season were heavier and had a greater BMI compared with players with no injuries (Table 2). Univariate ORs for a new lower extremity injury are presented in Appendix Table A1 (available in the online version of this article at http://ajsm.sagepub.com/supplemental). 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 previous lower extremity injuries were candidate risk factors for new injuries. Multivariate analyses identified a greater BMI as the only factor associated with an increased risk of a lower extremity injury (Table 3).

### Risk Factors for Thigh Injury

A total of 32 legs were affected by a thigh injury during the season, and 35 injuries were recorded (see Appendix Table A2, available online). The majority of injuries affected the hamstring muscles (80%; n = 28), whereas 7 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 anatomic factors was associated with a new injury. From the multivariate analyses (Table 3), BMI was found to increase the risk of a thigh injury by 51% per SD increase.

### Risk Factors for Knee Injury

We recorded a total of 53 injuries in 45 knees, of which 5 were noncontact ACL injuries. A previous ACL injury was the only factor associated with a new knee injury (see Appendix Table A3, available online). Nineteen previous ACL injuries were reported (18 noncontact), and a previous ACL injury in the right knee gave a 9-fold increased risk of sustaining a new knee injury in the same leg (OR, 9.08; 95% CI, 1.90-43.44; P = .006), whereas this relationship was not found for the left knee (OR, 1.87; 95% CI, 0.37-9.38; P = .45). Neither the demographic, neuromuscular, or anatomic factors nor a previous knee injury was associated with new knee injuries. In the multivariate model, none of the candidate factors included were found to increase the risk of a new knee injury (Table 3).

### Table 2

<table>
<thead>
<tr>
<th>Player-Related Factors</th>
<th>Injured Players (n = 107)</th>
<th>Noninjured Players (n = 66)</th>
<th>Odds Ratio (95% CI)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>22.1 ± 4.3</td>
<td>20.4 ± 3.7</td>
<td>1.21 (0.99-1.47)</td>
<td>.06</td>
</tr>
<tr>
<td>Height, cm</td>
<td>166.6 ± 5.0</td>
<td>167.2 ± 5.7</td>
<td>0.93 (0.75-1.15)</td>
<td>.51</td>
</tr>
<tr>
<td>Weight, kg</td>
<td>62.8 ± 5.9</td>
<td>61.2 ± 6.3</td>
<td>1.34 (1.07-1.68)</td>
<td>.01</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>22.6 ± 1.7</td>
<td>21.8 ± 1.7</td>
<td>1.55 (1.24-1.94)</td>
<td>≤.001</td>
</tr>
<tr>
<td>Seasons at elite level, y</td>
<td>3.6 ± 3.5</td>
<td>3.2 ± 3.3</td>
<td>1.00 (0.83-1.21)</td>
<td>.96</td>
</tr>
<tr>
<td>Match and training exposure, h</td>
<td>249.1 ± 69.9</td>
<td>275.4 ± 79.4</td>
<td>0.86 (0.64-1.15)</td>
<td>.21</td>
</tr>
</tbody>
</table>

*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

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

*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.
Risk Factors for Ankle Injury

Thirty-two ankles were affected by at least 1 injury, and younger players were more likely to sustain an ankle injury compared with older players (see Appendix Table A4, available online). 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 angle was the only candidate risk factor significantly associated with a new ankle injury (Table 3).

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 (see Appendix Table A5, available online). A history of a knee injury within the previous year increased the risk of an injury to the lower leg or foot by more than 3-fold, but when investigating the potential limb differences, the finding was only confirmed for the right leg (OR, 3.69; 95% CI, 1.04-13.12; \( P = .04 \)). A previous knee injury was also a significant predictor for new leg and foot injuries in the multivariate analyses (Table 3).

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 a greater BMI was identified as a risk factor for a new lower extremity injury, whereas no association was found for any of the neuromuscular or anatomic factors. Also, 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 none of the candidate risk factors in the multivariate model was associated with new knee injuries.

Demographic Variables and Injury Risk

Among the intrinsic factors associated with a new lower extremity injury, BMI was the strongest factor, increasing the injury risk by 51% per 1 SD increase. A higher body mass may stress joint and ligament structures of the lower extremities to a greater extent and thereby influence the injury risk. More than half of the body mass is located in the upper body,\(^\text{56}\) and a link has already been established between trunk and upper body kinematics and lower extremity loading during sport-specific tasks.\(^\text{15,33}\) However, although significant, the difference in BMI between injured and noninjured players was relatively small (22.6 vs 21.8 kg/m\(^2\), respectively, corresponding to 1.6 kg), and the clinical relevance may be limited. In contrast to our findings, neither studies among female senior players\(^\text{20,42}\) nor youth players\(^\text{14,50}\) found any influence of BMI on the injury risk. 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 with our findings.

Although a higher age has been suggested as a predictor for lower extremity injuries and has been shown to increase the injury risk in Swedish female elite players,\(^\text{42}\) we found no association between age and the risk of lower extremity injuries in general or with new injuries to any of the specific locations. This corresponds to the findings reported in 2 cohort studies on female senior players.\(^\text{20,47}\)

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 with noninjured 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.\(^\text{31}\) Moreover, rates of lower extremity injuries in female athletes have been reduced after neuromuscular training, aiming to increase frontal-plane knee control and thus reducing dynamic knee valgus.\(^\text{30,41,49}\) 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 who are 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° of valgus may be little,\(^\text{22}\) as well as the potential sources of error in different steps of the 3D analysis, including landmark palpation, skin movement artifacts, joint center estimation, and definition of joint axes, which may affect the results.\(^\text{7,12,36}\)

Functional Balance. Proper functional balance and control of the lower extremity are 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 an increased risk of lower extremity injuries.\(^\text{43}\) 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 3 of the original 8 reaching directions, which were different from those selected in other studies.\(^\text{29,41}\) Furthermore, in contrast to previous studies investigating each direction separately, we calculated a mean score for all 3 directions. Separate analyses could potentially reveal differences.

Controversially, in a Swedish investigation,\(^\text{47}\) female players with lower postural sway in a single-legged stance, that is, better balance, had a higher risk of injury. Similar
findings were demonstrated by Östenberg and Roos, who found that players performing better in a functional performance task had a 4-fold increased risk of 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 a single test. On the other hand, as shown in a study among youth female players, highly skilled players may be more exposed to potential injury situations, thus leaving them more vulnerable to injury compared with less skilled players.

Muscle Strength. Muscle strength deficits may represent a potential predictor for lower extremity injuries, and increased muscle strength will likely improve dynamic stability and hence reduce the 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 the maximal strength and thus have no information on muscle recruitment or timing, which is of interest with respect to how these factors could assist in avoiding injuries.

Anatomic Factors and Injury Risk

We could not identify any associations between anatomic 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 patients with a history of an ACL tear. 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.

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 a lower extremity injury in 2 of the previous studies among senior female players, in which greater generalized joint laxity increased the risk more than 3-fold. However, because of 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 9-fold increased risk for a knee injury in players with a 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. Furthermore, a previous knee injury resulted in a more than 3-fold increased risk of a lower leg or foot injury. On the contrary, previous injuries did not influence the risk of ankle injuries nor injuries to the lower extremity in general. This could be explained by 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, whereas an increased risk was found for youth female players with a previous injury. Corresponding findings have consistently been reported among male soccer players, both for injuries to the knees and ankles as well as for specific lower extremity muscle injuries. However, there were differences among the studies in their definition of previous injury and length of time before injuries were screened, which affect 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, eliminating the potential recall bias. In contrast, existing studies assessing risk factors among female soccer players based their injury reports on registration by medical staff, which has been found to underestimate the true burden of injuries by 50%. 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 demographic, neuromuscular, or anatomic 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 represents a strength of the study.

Despite 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 the risk of lower extremity injuries in general. For this reason, other tests to potentially better describe 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 anatomic 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, or exposure other than playing soccer. As injuries likely result from a complex interaction of multiple factors, our study cannot provide
a complete description of the injury risk in female soccer players. Thirdly, psychological factors and life stressors, as well as the lack of energy, illness, or motivational barriers, may have influenced the injury risk in these players, and these were factors not captured by 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 the statistical power for such subgroup analyses. This may have affected the conclusions drawn, and potential associations may have been masked.

CONCLUSION

In conclusion, a greater BMI was the only factor associated with new lower extremity injuries in elite female soccer players. A greater BMI was associated with thigh injuries, and players with lower peak knee valgus angles in a dropjump landing were more likely to sustain a new ankle injury. 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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