Risk Factors for Injuries in Football

Arni Arnason,*†‡ MSc, PT, Stefan B. Sigurdsson,† PhD, Arni Gudmundsson,‡ Ingar Holme,* PhD, Lars Engebretsen,* MD, PhD, and Roald Bahr,*§ MD, PhD
*From the *Oslo Sports Trauma Research Center, University of Sport & Physical Education, Oslo, Norway, the †Department of Physiology, University of Iceland, Reykjavik, Iceland, and the ‡Gaski Physiotherapy Clinic, Reykjavik, Iceland*

Background: The injury risk in football is high, but little is known about causes of injury.

Purpose: To identify risk factors for football injuries using a multivariate model.

Study Design: Prospective cohort study.

Methods: Participants were 306 male football players from the two highest divisions in Iceland. Before the 1999 football season started, the following factors were examined: height, weight, body composition, flexibility, leg extension power, jump height, peak O_2 uptake, joint stability, and history of previous injury. Injuries and player exposure were recorded throughout the competitive season.

Results: Older players were at higher risk of injury in general (odds ratio [OR] = 1.1 per year, $P = 0.05$). For hamstring strains, the significant risk factors were age (OR = 1.4 [1 year], $P < 0.001$) and previous hamstring strains (OR = 11.6, $P < 0.001$). For groin strains, the predictor risk factors were previous groin strains (OR = 7.3, $P = 0.001$) and decreased range of motion in hip abduction (OR = 0.9 [1°], $P = 0.05$). Previous injury was also identified as a risk factor for knee (OR = 4.6) and ankle sprains (OR = 5.3).

Conclusions: Age and previous injury were identified as the main risk factors for injury among elite football players from Iceland.

Keywords: football; injuries; injury types; risk factors

Injuries are more common in football compared to most other types of sport,[11] and numerous studies have been carried out to investigate the type, location, and severity of injuries in football.[1,4-6,8,10,13-15,19,27,28,31,39,43,47] Several studies have also examined selected potential intrinsic (person-related) or extrinsic (environment-related) risk factors,[1,4,5,10,12-17,19,27,28,31,43,47,50,51] whereas injury mechanisms rarely have been studied.[1,5,6,12,14,27,28,43,47] These studies have shown that intrinsic risk factors such as increased age,[47] career duration,[12,47] and previous injury[14,15] seem to increase the risk of injuries. Some studies also indicate that mechanical instability in ankles or knees, general joint laxity, or functional instability predispose players for new injuries in football,[1,47,52] whereas other studies have failed to find such results.[4] Extrinsic risk factors such as lack of training,[12] low training-to-match ratio,[17] and playing on a hard surface with high friction[1,45] seem to increase the injury risk.

Understanding the individual risk factors for injury in football is important as a basis to develop preventive measures. However, a multivariate model is needed to examine the contribution of the various factors in injury etiology and to explore their interrelationship.[42] Unfortunately, there are only three studies that have used a multivariate approach to analyze risk factors for injuries in football, and they include a limited number of athletes and risk factors.[47,50,55] Ostenberg and Roos[47] followed 123 female football players at various levels of play over one season and found that older players, players with general joint laxity, and players who performed well on a square hop test were at greater risk of injury using a multivariate model. Watson[55] followed 102 players from football, Gaelic football, and hurling for 2 years and found that player acceleration, posture, number of musculo-skeletal deficiencies, and previous injury were significant predictors of injury. Taimela et al.[50] studied 37 male football players at various levels of play and found that slow reaction time and some personality factors correlated with injuries. Thus, the aim of the present study was to investigate the incidence of injury, as well as the type, location, and severity of injuries in elite male football players and to examine whether different factors (age, body size, body composition, range of motion [ROM], power, jumping ability, peak O_2 uptake, ankle or knee instability, previous injury, or player exposure) could be identified as risk factors for injuries in a multivariate model.

§ Address correspondence and reprint requests to Roald Bahr, MD PhD, Oslo Sports Trauma Research Center, Norwegian University of Sport and Physical Education, P.O. Box 4014, Ullevål Stadion, 0806 Oslo, Norway.

The American Journal of Sports Medicine, Vol. 32, No. 1 Suppl.
DOI: 10.1177/0363546503258912

MATERIALS AND METHODS

Twenty male football teams participated in the Icelandic elite league and first division, lasting from mid-May until mid-September during the 1999 football season, and 17 of these accepted an invitation to participate in this study. Each coach selected the 18 best players from his team to participate. This approach was used because we wanted to test and follow a well-defined group of first-string players, that is, the players who were assumed to receive the most playing time in matches during the following season. A total of 306 players (mean age, 24; range, 16 to 38 years) were followed. The players performed a series of testing procedures and answered a questionnaire about previous and recurrent injuries (type, location, and severity) just before the start of the season to establish baseline information on potential risk factors for injury. The tests were conducted and the questionnaire was administered by two of the authors (AA and SBS). The testing procedures included the following: peak O_2 uptake (226 players completed this test), body composition (n = 228), power testing (n = 215), jump tests (n = 217), flexibility tests (n = 249), ankle and knee stability tests (n = 257), and a questionnaire (n = 257). A total of 153 players participated in all of the tests, and 301 players took part in at least one of the tests. Peak O_2 uptake and power/jump testing was done on separate days.

Injuries were recorded prospectively throughout the season by the team physical therapist on a special form, which was collected by one of the authors (AA) once a month. This form included information about the type and location of the injury, former similar injuries, the injury mechanism, duration of the injury, and the exact diagnosis. During the same time period, the coaches recorded individual training exposure, that is, player participation for every training session (including the duration of each session) on a special form. Player exposure in matches was also recorded. A player was defined as injured if he was unable to participate in a match or a training session because of an injury that occurred in a football match or during training. The player was defined as injured until he was able to play a match or comply fully with all instructions given by the coach, including sprinting, turning, shooting, and playing football at full tempo.[1,38] The injury severity was classified in three categories according to their duration: mild (1 to 7 days), moderate (8 to 21 days), and severe (more than 21 days). Acute injuries were defined as injuries with a clear onset as a result of trauma (for example, tackling, kicking, or sprinting). Overuse injuries were defined as injuries with an insidious onset with a gradually increasing intensity of discomfort without an obvious trauma.[57]

Peak O_2 Uptake

The exercise session started with a warm-up period of about 6 minutes running on a level treadmill (h/p Cosmos, Quasar med, H-P-Cosmos Sports & Medical GmbH, Nussdorf-Traunstein, Germany). The speed was gradually increased during the first 3 minutes until 70% to 80% of maximal heart rate was obtained and maintained for the final 3 minutes. After a 3-minute break when the participant was allowed to stretch, he was connected to a mouth/nose piece (Hans Rudolph, Kansas City, Missouri, model 7940), and O_2 uptake and CO_2 production were measured while he ran for about 2 minutes at the same speed as the final speed during the warm-up period. The speed was then increased by 0.5 meter per second every minute until 4 meters per second was reached, and after that the inclination of the treadmill was increased by 1.5° every minute until volitional exhaustion. O_2 uptake and CO_2 production were measured using test instruments from VacuMed (Ventura, California, model 17620 and 17630) connected to a Macintosh Quadra 650 computer using a Super Scope II 2.17 program. The meters were calibrated using gases with known O_2 uptake and CO_2 concentrations determined by Scholander technique.[48] Heart rate was measured using a Polar Sport Tester PE 4000 pulse meter (Polar Electro oy, Kemoele, Finland). The total exercise session took about 16 to 20 minutes: 10 to 12 minutes for warm-up and stretching and about 6 to 8 minutes for the test itself.

Body Composition

Skin-fold measurements were taken from six different areas by the same examiner (SBS): triceps brachii, subscapular, pectoralis major, iliac crest, abdomen, and anterior thigh (Lange Skinfold Caliper from Cambridge Scientific Industries Inc., Cambridge, Maryland). Because there is some variation between different formulas for body composition, the results were calculated using four commonly accepted formulas,[25,32,33,49] and the average was used as the final result for body composition (percent body fat). This was done to reduce the effect of variation between different formulas and increase the comparability between players. Body mass index (BMI, kg • m^{-2}) was calculated as the weight (kg) divided by the squared height (meters).

Power Testing

Maximal average power was measured in the extension phase of a squat. The player warmed up on a Monark cycle ergometer for 6 minutes (50 revolutions per minute) at 100 W. Then, a squat test was performed in a Smith machine (MultiPower, TechnoGim, Torreveccia Teatinge, Italy), which is a slide machine with a guided horizontal barbell. The MuscleLab unit (Ergotest Technology a.s., Langesund, Norway) was connected to the Smith machine with a linear encoder (ET-Enc-01, Ergotest Technology a.s., Langesund, Norway), which measures vertical movement of the bar as a function of time. The linear encoder is connected to the bar with a cord that rotates a measuring wheel that generates 512 pulses per each round, measuring distance with a resolution of <0.1 mm. The MuscleLab unit counts the pulses with 10 millisecond intervals. The calculation of velocity, force, and power has been described in detail by Bosco et al.[7]

After receiving instructions, the player put on a weightlifting belt and practiced the technique with light loads: hands on the bar, grip a little wider than shoulder width, hips and feet under the bar, and shoulder width between the feet. After a few practice runs, when his technique was acceptable, the player rested the bar on his trapezius and lifted it from the locked position. He took a deep breath and bent his hips and knees to 90° measured with a goniometer, stopped observably for 1 to 2 seconds, and then extended his hips and knees as fast as possible. Tests were performed with external weights of 20, 40, 60, and 80 kg. To avoid a fatigue effect on the results at the highest load, the players were given two attempts at each weight. The better outcome was used as the result. Pilot studies indicated that after the players had practiced the technique, there is minimal difference between test results with the same load. The players were accustomed to regular weight training as part of their training program. The intrarater reliability of this method in our lab ranges between 4% (light load) and 6% (heavy load) coefficient of variance (CV) (Gaasvaer JI, personal communication).

Jump Testing

Jump tests were performed right after the power test on a contact mat (PE, TapeSwitch Corp., New York) connected to the MuscleLab unit, which measures the height of rise of the center of gravity above the ground (h, cm) based on the flight time (t_f, seconds), with the formula $h = t_f^2 \bullet g \bullet 8^{-1}$.[7] The players were instructed to jump and land in exactly the same place with the body in an erect position during the jump until landing. The better of two outcomes was used as the result.

Three types of jumps were tested.[7] A standing jump (SJ) was performed when the player held his hands on the iliac crest, bent his knees to 90°, stopped there observably for 1 to 2 seconds, and then extended his knees and hips and jumped as high as he could. No countermovement of the trunk or knees was allowed. A countermovement jump (CMJ) was done in the same way but without stopping in the lowest position. A one-leg countermovement jump (CMJ one) was also done on each leg. No arm swing was allowed in any of the jumps. The intrarater reliability (CV%) of these methods in our lab is 4.3% for SJ, and 5.3% for CMJ (Gaasvaer JI, personal communication).

Flexibility Tests

Flexibility was measured as static ROM for the hamstrings, adductors, rectus femoris, and hip flexors. Before the flexibility tests, the players warmed up on a Monark cycle ergometer, as for the power tests. The tests were performed on an examination table with a wooden surface. For each test, the players were fixed on the bench with belts to avoid accessory movements. Three reflex points were marked on the player for each test, one nearest to the movement axis for the involved joint and two other proximally and distally to the joint in the center line of relevant bones. The predetermined movement was carried out with the same load for each player, measured with a tension meter (MIE Medical Research Ltd., Leeds, England) or a Myometer (Penny & Giles Transducers, Christchurch, England). ROM was measured based on photos taken with a JVC digital camera and analyzed using the KineView movement analysis system (Kine, Reykjavik, Iceland), except for hip abduction, which was measured with a double-armed goniometer. One of the authors (AA, an experienced physical therapist) conducted all of the measurements, and one assistant took all of the photos. For all of the flexibility tests, the intrarater reliability (CV%) ranged between 0.9% and 3.5% (Table 1).

TABLE 1
Intrarater Reliability of Flexibility Tests from 31 Athletes[a]

Flexibility test	Left	Right	Average
Hamstrings	3.2	2.8	2.4
Hip flexors	1.1	0.9	0.8
Rectus femoris	2.2	2.4	1.7
Hip adductors	3.5	3.2	2.2

[a] Results are reported as the coefficient of variance (%)

Passive Knee Extension (Test for Hamstring Muscles). The player was in the supine position with a firm lumbar support. The pelvis and one of the legs were stabilized on the table with a belt. The hip of the other leg was fixed at 120° flexion with a belt and the player supported against further hip flexion by pressing with both hands distally on his anterior thigh. The ankle and foot were relaxed and the hip was in neutral rotation, abduction and adduction. Three reflex points were placed on the leg: the lateral malleolus, the lateral femoral epicondyle, and the major trochanter. The player performed two hold-relax hamstring contractions before the knee was extended passively with an 8-kg load (Fig. 1A). The tension meter was placed just proximal to the lateral malleolus at a 90º angle to the calf, as controlled visually.[22]

Hip Extension (Test of Hip Flexors). The player was in the supine position with the hips at the edge of the examination table. Reflex marks were placed on the lateral femoral epicondyle and major trochanter. The player held around one knee with both hands and pressed it against his chest until the lumbar spine reached the bench (tested with a plastic ruler under the lumbar spine)[20] (Fig. 1B). The other leg was relaxed and the angle between the femur and a line parallel to the bench at the height of the major trochanter was measured.

Knee Flexion (Test of m. Rectus Femoris). The player was fixed prone on the examination table with an abdominal support and a belt over the pelvis. One leg was outside the bench with the knee kept in 120° flexion and the foot on the floor vertically below the hip. Reflex points were put on the contralateral leg lateral malleolus, lateral femoral epi-

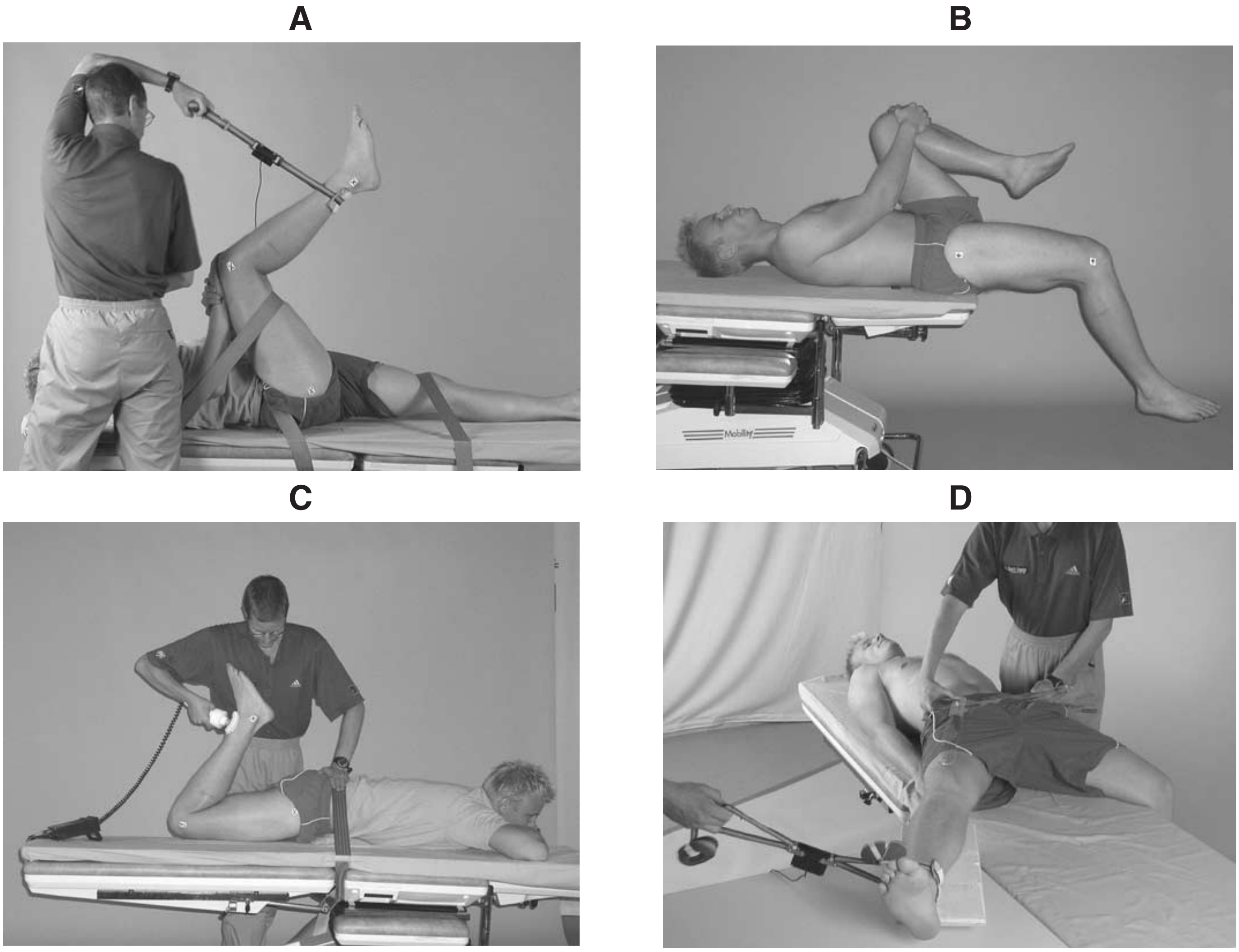

Figure 1. Flexibility measurements: (A) knee extension (test for hamstrings), (B) hip extension (test for hip flexors), (C) knee flexion (test for rectus femoris), and (D) hip abduction (test for adductors).

condyle, and major trochanter. The knee was passively flexed using a 7-kg load (Fig. 1C).

Hip Abduction (Test of Adductors). The player was supine with one leg fixed in slight abduction outside the examination table. The other leg was placed on a sliding board and passively abducted using a 4-kg load. The tension meter was placed proximal to the lateral malleolus at 90° angles to the lower leg, as visually controlled (Fig. 1D). The amount of abduction was measured using a double-armed goniometer, with the axis 5 cm below the anterior iliac spine, one arm pointing horizontally 5 cm below the other anterior iliac spine, and the other arm to the midpoint of the patella.

Ankle and Knee Stability

The mechanical stability of knees and ankles was tested manually by one experienced physical therapist, and for each test the players were classified stable or unstable.[2,40] For the ankle, the anterior drawer and talar tilt tests for lateral stability and a medial stability test were performed. For the knee, the Lachmann test, a valgus test for medial stability, a varus test for lateral stability, and a posterior drawer test were performed.

Statistical Methods

Test reliability has been reported as the group average CV percentage for paired measurements.[23] Exposure time in matches was calculated as the duration of all matches played by each team during the season multiplied by the number of players from the team on the field (n = 11). Exposure time in training was calculated as the time each team spent in training during the season multiplied by the number of players present. Injury incidence was calculated as the number of injuries per 1000 match or training hours. The standard error of the mean (SEM) for injury incidence was calculated as the SEM = ($\sqrt{}$number of injuries) / (exposure time) × 1000. The difference in injury rate between the elite league and the first division was cal-

TABLE 2
Number and Location of Acute and Overuse Injuries

	Acute							
	Match		Training		Overuse		Total	
Injury location	*n*	(%)	*n*	(%)	*n*	(%)	*n*	(%)
Head and neck	5	(3.4)	3	(5.1)	0	(0.0)	8	(3.3)
Upper extremity	13	(8.8)	2	(3.4)	0	(0.0)	15	(6.1)
Back	4	(2.7)	3	(5.1)	3	(7.9)	10	(4.1)
Abdomen	0	(0.0)	0	(0.0)	6	(15.8)	6	(2.5)
Groin	16	(10.9)	6	(10.2)	10	(26.3)	32	(13.1)
Thigh	39	(26.5)	19	(32.2)	1	(2.6)	59	(24.2)
Knee	22	(15.0)	9	(15.2)	7	(18.4)	38	(15.6)
Lower leg	17	(11.6)	7	(11.8)	7	(18.4)	31	(12.7)
Ankle	15	(10.2)	6	(10.2)	0	(0.0)	21	(8.6)
Foot	7	(4.8)	4	(6.8)	1	(2.6)	12	(4.9)
Other	9	(6.1)	0	(0.0)	3	(7.9)	12	(4.9)
Total	147	(100)	59	(100)	38	(100)	244	(100)

culated with the *Z*-test: $Z = ((d_1/t_1) - (d_2/t_2)) / (\sqrt{((d_1/t_1^2) + (d_2/t_2^2))})$, where d_1 and d_2 represent the number of injuries in the elite league and first division and t_1 and t_2 represent the exposure time in the two divisions. SPSS (version 10.0; SPSS Inc., Chicago, Illinois) was used to compare uninjured and injured groups of players, treating potential risk factors as continuous or categorical variables using univariate logistic regression analysis. For the categorical analyses, the players were grouped for each variable in three groups. The OR and 95% confidence interval (95% CI) were calculated for the groups of players with the lowest (>1 SD below the mean) and the highest (>1 SD above the mean) values for each variable, respectively, with the intermediate group of players as the reference group. In the continuous analyses, all variables with *P* value ≤0.20 were considered further in a backward stepwise multivariate logistic regression analysis to evaluate potential predictor variables. Exact *P* values are generally reported, and *P* values of ≤0.05 were considered statistically significant.

RESULTS

During the 4-month competition season, 170 of the 306 players (56%) incurred 244 injuries: 206 (84%) acute injuries and 38 (16%) overuse injuries (Table 2). The total exposure of all participating players was 5968 hours during matches and 27,871 hours during training. The incidence of acute injuries was 24.6 injuries per 1000 player hours during matches and 2.1 injuries per 1000 player hours during training. This corresponds to one injury per 1.2 matches and 19.3 training sessions. No significant difference was found in the incidence of injury between the elite and first division or between the first and second half of matches or training sessions. Ninety-six injuries (39%) were classified as minor (1 to 7 days), 92 (38%) as moderate (8 to 21 days), and 56 (23%) as severe (lasted more than 21 days) (Table 3).

TABLE 3
Injury Severity Shown as the Number of Minor (Lasting 1–7 days), Moderate (Lasting 8–21 days), and Severe Injuries (Lasting >21 days) for Different Types and Locations

Type and location	Minor *n*	Moderate *n*	Severe *n*	Total *n*
Muscle strains	23	32	20	75
Posterior thigh	7	13	11	31
Anterior thigh	0	3	4	7
Groin	8	11	3	22
Other	8	5	2	15
Ligament sprains	13	20	12	45
Knee	2	7	11	20
Ankle	7	12	1	20
Other	4	1	0	5
Contusions	38	9	3	50
Thigh	16	2	0	18
Lower leg	13	3	1	17
Other	9	4	2	15
Overuse injuries	11	19	8	38
Other injuries	11	12	13	36
Total	96 (39.3)	92 (37.7)	56 (23.0)	244 (100)

Injury Type and Location

Two hundred and one (82%) injuries were located on the lower extremities. The thigh was the most frequent injury location (24%), followed by the knee (16%), groin (13%), lower leg (13%), and ankle (9%) (Table 2).

The most frequent injury type was muscle strains, and they were typically located in the posterior thigh (n = 31) or groin (n = 22) (Table 3). The majority of the muscle strains occurred during matches (n = 55, or 73%). The total

TABLE 4
Incidence of the Most Common Acute Injury Types[a]

	Match	Training	Total
Muscle strains	8.4 ± 1.2	0.8 ± 0.2	2.2 ± 0.3
Posterior thigh	3.0 ± 0.7	0.5 ± 0.1	0.9 ± 0.2
Groin	2.7 ± 0.7	0.2 ± 0.1	0.6 ± 0.1
Ligament sprains	5.5 ± 1.0	0.4 ± 0.1	1.3 ± 0.2
Knee	2.3 ± 0.6	0.2 ± 0.1	0.6 ± 0.1
ACL	0.50 ± 0.29	0.07 ± 0.05	0.15 ± 0.07
Ankle	2.3 ± 0.6	0.2 ± 0.1	0.6 ± 0.1
Contusions	5.9 ± 1.0	0.5 ± 0.1	1.5 ± 0.2
Total acute injuries	24.6 ± 2.0	2.1 ± 0.3	6.1 ± 0.4

[a] The incidence is reported as the number of injuries per 1000 hours (± standard error of the mean).

incidence of muscle strains was 8.4 injuries per 1000 match hours and 0.8 injuries per 1000 training hours (Table 4).

There were 45 ligament sprains, mostly to the knee (n = 20) or ankle (n = 20) (Table 3). More than half of the knee sprains (n = 11) were severe, including five ACL ruptures (four total and one partial), one partial PCL rupture, four medial collateral ligament (MCL) injuries and one lateral collateral ligament injury. The majority of the moderate and minor knee sprains were MCL injuries. Fourteen of the knee sprains occurred during matches and six during training sessions. More than half of the ankle sprains (n = 12) were moderate. Of the ankle sprains, 14 occurred during matches and six during training sessions. The total incidence of ligament sprains was 5.5 injuries per 1000 match hours and 0.4 injuries per 1000 training hours (Table 4).

There were 50 contusions, mostly to the thigh (n = 18) or lower leg (n = 17) (Table 3). Most of them were minor (n = 38), and the total incidence of contusions was 5.9 injuries per 1000 match hours and 0.5 injuries per 1000 training hours (Table 4).

Risk Factors for Injury

The injured group was significantly older than the noninjured group, and match exposure was also higher among players in the injured group. There was a trend toward higher maximal average power and lower training/match ratio in the injured group compared with the noninjured group (Table 5). In keeping with this, players in the oldest age group (>1 SD above mean, 29 to 38 years) had a higher risk of injury than the intermediate age group. Players who had the lowest match exposure (>1 SD below mean, <2.1 hours) incurred significantly fewer injuries than the intermediate group. The players with the highest exposure during training (>1 SD above mean, >88.7 hours) showed a significantly lower injury rate than the intermediate group, and players with the lowest exposure during training (>1 SD below mean, <39.1 hours) and highest exposure during matches (>1 SD above mean, >26.0 hours) also showed such a trend (Table 5).

Increased age was found to be a significant predictor variable in a multivariate logistic regression analysis (P = 0.05) (where match exposures also were included) (Table 6), and for match exposure there was also a trend (P = 0.075). Since the results from the univariate analysis showed that the P values for height, weight, body fat, BMI, flexibility, CMJ, SJ, and peak O_2 uptake were >0.2, these variables were not included in the multivariate analysis.

Risk Factors for Hamstring Strains

The players who incurred hamstring strains in the study period were significantly older, and there was a trend toward higher body fat percentage than in the group without hamstring strains (Table 7). A history of a previous strain was a significant risk factor for a new strain on the same side during the study period (Fig. 2). Also, when risk factors were treated as categorical variables, the oldest group of players (>1 SD above mean, 29 to 38 years) had a significantly higher risk of a hamstring strain than the intermediate group (P = 0.02).

In the multivariate logistic regression analysis (where previous injury, age, weight, and body fat were included), age and previous hamstring strains were found to be significant predictor variables (Table 6). The regression coefficient for age changed from 0.20 ± 0.05 (univariate analysis) to 0.33 ± 0.09 (multivariate analysis), which indicates that previous injury is a confounding factor for age. The regression coefficient for previous injury changed from 2.48 ± 0.49 (univariate analysis) to 2.45 ± 0.62 (multivariate analysis), which indicates that age is not a confounder for previous injury. The other variables were not significant. Since the results from the univariate analysis showed that the P values for height, BMI, hamstring flexibility, maximal average power, CMJ, CMJ on one leg, SJ, peak O_2 uptake, and player exposure were >0.2, these variables were not included in the multivariate analysis.

Risk Factors for Groin Strains

Players in the groin strain group had significantly higher body fat than the group without groin strains (P = 0.02). There was also a trend toward less hip adductor flexibility and higher maximal average power in the groin strain group than the group without groin strains (Table 8). A history of a previous strain was a significant risk factor for a new strain on the same side during the study period (Fig. 2). The oldest group of players (>1 SD above mean, 29 to 38 years) had a significantly higher risk of groin strains than the intermediate group did (P = 0.02).

In the multivariate logistic regression analysis, a previous groin strain (P = 0.001) and lower ROM in hip abduction (P = 0.05) were found to be significant predictor variables for a new groin strain (previous groin strain, hip adductor flexibility, and hip flexor flexibility were included in the analysis) (Table 6). There were only small changes in the regression coefficients for previous groin strains and ROM in hip abduction from the univariate to the multi-

TABLE 5
Comparison Between the Uninjured and Injured Groups of Players With Potential Risk Factors Treated as Continuous or Categorical Variables Using Univariate Logistic Regression Analyses[a]

	Risk factor as continuous variable					Risk factor as categorical variable			
	Uninjured		Injured			>1 SD below mean		>1 SD above mean	
	n	Mean ± SEM	*N*	Mean ± SEM	*P* value	OR (95% CI)	*P* value	OR (95% CI)	*P* value
Age (years)	168	23.4 ± 0.3	130	24.8 ± 0.4	0.005	0.91 (0.46–1.80)	0.97	2.69 (1.37–5.25)	0.004
Height (cm)	135	180.4 ± 0.5	101	180.9 ± 0.5	0.51	0.63 (0.32–1.26)	0.19	0.87 (0.44–1.64)	0.62
Weight (kg)	134	76.3 ± 0.6	100	76.9 ± 0.6	0.52	0.68 (0.30–1.56)	0.36	1.09 (0.53–2.27)	0.81
Body composition (% fat)	127	10.4 ± 0.4	101	10.8 ± 0.4	0.53	0.61 (0.27–1.38)	0.23	1.22 (0.58–2.55)	0.60
BMI ($kg·m^{-2}$)	127	23.5 ± 0.2	101	23.6 ± 0.2	0.62	0.84 (0.37–1.92)	0.68	0.93 (0.43–2.04)	0.86
Flexibility (sum, in degrees)	141	939 ± 4	108	939 ± 5	0.98	1.00 (0.49–2.03)	0.99	1.37 (0.68–2.77)	0.38
Maximal average power (W)	119	1326 ± 18	96	1377 ± 20	0.06	0.75 (0.34–1.65)	0.48	1.42 (0.66–3.05)	0.37
Counter movement jump (cm)	121	39.2 ± 0.5	96	39.3 ± 0.5	0.99	1.35 (0.64–2.84)	0.43	1.17 (0.52–2.62)	0.70
Standing jump (cm)	121	37.6 ± 0.4	96	37.5 ± 0.5	0.79	1.28 (0.59–2.76)	0.53	0.51 (0.22–1.19)	0.12
Peak O_2 uptake ($mL·kg^{-1}·min^{-1}$)	126	62.7 ± 0.4	100	62.6 ± 0.5	0.53	1.09 (0.54–2.19)	0.81	0.66 (0.30–1.42)	0.28
Exposure matches (hours)[b]	171	12.4 ± 1.0	130	16.3 ± 0.9	0.004	0.18 (0.09–0.35)	<0.001	0.61 (0.34–1.08)	0.09
Exposure training (hours)[b]	103	65.3 ± 2.7	101	62.5 ± 2.2	0.40	0.51 (0.25–1.04)	0.07	0.34 (0.15–0.78)	0.01
Training/match ratio (hours)[b]	92	29.4 ± 8.3	99	11.9 ± 3.0	0.08	[c]			

[a] The number of players in the uninjured and injured groups reflects the number of players who completed each of the tests. The odds ratio (OR; 95% confidence interval [CI]) was calculated for the group of players with the lowest (>1 SD below the mean) and the highest (>1 SD above mean) values for each variable, respectively, with the intermediate group of players as reference group.
[b] Exposure during matches and training was calculated for each player.
[c] Because of a high exposure in training but low exposure during matches by some of the players, the standard deviation was very high and it was not feasible to analyze training/match ratio as a categorical risk factor.

TABLE 6
Significant Predictor Variables for Injuries in Soccer From the Multivariate Logistic Regression Analysis[a]

Variable	OR	95% CI	*P*
Injured—not injured			
Increasing age (1 year)	1.1[b]	1.0–1.1	0.05
Hamstring strains			
Increasing age (1 year)	1.4[c]	1.2–0.4	<0.001
Previous hamstring strains	11.6[c]	3.5–39.0	<0.001
Groin strains			
Previous groin strains	7.3[d]	2.3–23.2	0.001
Decreased ROM in hip abduction (one degree)	0.9[d]	0.8–1.0	0.05

[a] Odds ratio, 95% confidence interval for odds ratio, and *P* values are shown for each variable.
[b] Estimated per person for 1-year increase in age. The estimate was obtained when age and exposure hours in matches were included in the multivariate model.
[c] Estimated per leg, when previous hamstring strains, age, weight, and body composition (% fat) were included in the multivariate model.
[d] Estimated per leg, when previous groin strains, the amount of hip abduction, and hip extension were included in the multivariate model.

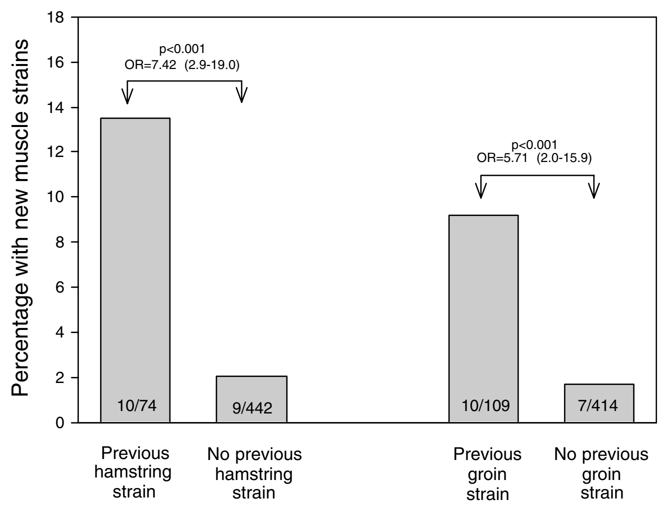

Figure 2. Comparison of the risk of new hamstring (left) and groin strains (right) among players who previously had sustained such an injury and players with no previous injury. Each leg has been treated as a separate case. *P* values were obtained using univariate logistic regression. Odds ratios (OR) are presented with 95% confidence intervals.

variate analysis (see Table 6 for multivariate results and Table 8 for univariate results). Candidate variables not entered into the multivariate regression were age, CMJ, CMJ on one leg, SJ, and exposure. No significant predictor variable was found in a multivariate logistic regression analysis for variables tested per person (height, weight, body fat, BMI, power, and peak O_2 uptake).

TABLE 7
Comparison Between the Group of Players Who Incurred Hamstring Strains and the Group of Players Who Did Not Incur Hamstring Strains With Potential Risk Factors Treated as Continuous Variables Using Univariate Logistic Regression Analyses[a]

	No hamstring strain		Hamstring strain		
	n	Mean ± SEM	*n*	Mean ± SEM	*P* value
Age (years)	280	23.8 ± 0.2	18	27.8 ± 0.9	<0.001
Height (cm)	220	180.6 ± 0.4	16	180.6 ± 1.3	0.97
Weight (kg)	218	76.3 ± 0.4	16	78.9 ± 1.7	0.13
Body composition (% fat)	215	10.4 ± 0.3	13	12.5 ± 1.4	0.08
BMI ($kg\cdot m^{-2}$)	215	23.6 ± 0.1	13	24.2 ± 0.5	0.22
Hamstrings flexibility (in degrees)	481	113.2 ± 0.6	17	116.6 ± 3.7	0.32
Maximal average power (W)	204	1341.0 ± 13.7	11	1398.0 ± 46.3	0.34
Counter movement jump (cm)	205	39.3 ± 0.4	12	39.1 ± 1.4	0.87
Counter movement jump one leg (cm)	405	22.0 ± 0.2	13	21.2 ± 1.1	0.41
Standing jump (cm)	205	37.7 ± 0.3	12	36.7 ± 1.4	0.49
Peak O_2 uptake ($mL\cdot kg^{-1}\cdot min^{-1}$)	213	62.6 ± 0.3	13	61.6 ± 1.0	0.46
Exposure matches (hours)	283	14.0 ± 0.7	18	16.0 ± 2.1	0.48
Exposure training (hours)	189	64.3 ± 1.9	15	59.5 ± 5.6	0.47
Training/match ratio (hours)	176	22.2 ± 4.8	15	3.9 ± 0.6	0.12

[a] The number of subjects in the uninjured and injured groups reflects the players (or, in the case of hamstring flexibility and countermovement jump on one leg, the number of legs) who completed each of the tests. SEM, standard error of the mean; BMI, body mass index.

TABLE 8
Comparison Between the Group of Players Who Incurred Groin Strains and the Group of Players Who Did Not Incur Groin Strains With Potential Risk Factors Treated as Continuous Variables Using Univariate Logistic Regression Analyses[a]

	No groin strain		Groin strain		
	n	Mean ± SEM	*n*	Mean ± SEM	*P* value
Age (years)	281	24.0 ± 0.2	17	25.1 ± 1.2	0.27
Height (cm)	226	180.5 ± 0.4	10	183.0 ± 1.4	0.15
Weight (kg)	223	76.4 ± 0.4	11	79.1 ± 1.2	0.17
Body composition (% fat)	214	10.3 ± 0.3	14	13.1 ± 1.4	0.02
BMI ($kg\cdot m^{-2}$)	214	23.5 ± 0.1	14	24.2 ± 0.6	0.13
Hip adductor flexibility (in degrees)	485	43.4 ± 0.2	13	40.9 ± 1.1	0.08
Hip flexor flexibility (in degrees)	485	179.0 ± 0.3	13	176.5 ± 1.4	0.14
Maximal average power (W)	203	1342.0 ± 13.8	12	1440.0 ± 51.0	0.09
Counter movement jump (cm)	205	39.3 ± 0.4	12	39.4 ± 1.4	0.93
Counter movement jump one leg (cm)	407	21.9 ± 0.2	11	23.0 ± 0.8	0.30
Standing jump (cm)	205	37.6 ± 0.3	12	37.3 ± 1.2	0.84
Peak O_2 uptake ($mL\cdot kg^{-1}\cdot min^{-1}$)	212	62.7 ± 0.3	14	60.7 ± 1.2	0.13
Exposure matches (hours)	284	14.0 ± 0.7	17	17.1 ± 2.4	0.30
Exposure training (hours)	191	64.1 ± 1.9	13	60.3 ± 4.5	0.59
Training/match ratio (hours)	178	21.7 ± 4.7	13	6.3 ± 2.0	0.41

[a] The number of subjects in the uninjured and injured groups reflects the players (or in the case of hip adductor flexibility, hip flexor flexibility, and countermovement jump on one leg, the number of legs) who completed each of the tests. SEM, standard error of the mean; BMI, body mass index.

Risk Factors for Ankle Sprains

None of the test variables were significantly different between those who incurred an ankle sprain during the season and those who did not. A history of a previous ankle sprain was a significant risk factor for a new sprain on the same side during the study period (Fig. 3). Since the number of injuries was small, no categorical analysis was performed, and since no other variables except previous ankle sprain showed a P value ≤0.2, a multivariate analysis was not performed. In previously sprained ankles, there was an increased frequency of lateral instability ($P < 0.001$) and positive anterior drawer tests ($P < 0.001$) compared with ankles without previous injury.

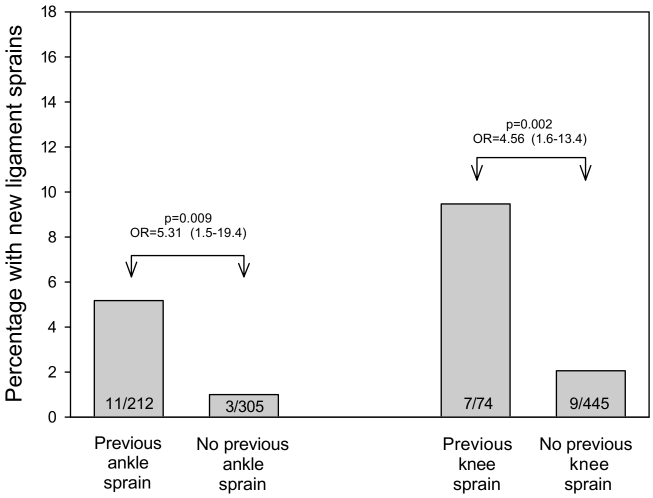

Figure 3. Comparison of the risk of new ankle (left) and knee sprains (right) among players who previously had sustained such an injury and players with no previous injury. Each leg has been treated as a separate case. *P* values were obtained using univariate logistic regression. Odds ratios (OR) are presented with 95% confidence intervals.

Risk Factors for Knee Ligament Injury

None of the test variables were significantly different between those who incurred a knee ligament injury during the season and those who did not. A history of a previous knee sprain was a significant risk factor for a new sprain on the same side during the study period (Fig. 3). Since the number of injuries was small, no categorical analysis was performed, and since no other variables except previous knee sprain had a P value of ≤0.2, neither was a multivariate analysis performed. In the group of players with previous knee sprains, the frequency of medial instability was significantly higher than among players who never had sprained their knees (P = 0.02).

DISCUSSION

The main finding of the present study was that previous injury was consistently identified as the most important risk factor for injury. Players with former injuries had a four- to sevenfold increased risk for the four most frequent injury types—knee sprains, ankle sprains, groin strains, and hamstring strains. The results also showed that older players were at increased risk of injury, whereas few of the fitness variables studied could predict injury (except decreased ROM in hip abduction for adductor strains).

Methodological Considerations

Before examining the results in more detail, there are some methodological factors that need to be considered. First, the precision of the reported general incidence rates, as well as the incidence for specific injury types, depend on the accuracy of the injury and exposure registration and correct diagnoses. Although the quality of Icelandic football is high, with a number of player transfers to professional leagues all over Europe, the clubs have limited resources. The injury registration was performed prospectively by the team physical therapists, but these were usually present only before, during, and after matches. They usually did not attend training sessions, and very few teams had a team physician present during matches or training sessions. Although players were instructed to contact their physical therapist if injured, their limited training attendance may have led to an underestimation of minor injuries causing players to miss only one or two training sessions. Also, the injury registration period was limited to the competitive season. This means that injuries that occurred before the start of season were not registered, even if the players could not participate during the beginning of the season. This means that the absence due to injury was somewhat higher than indicated by the incidence rates reported. Finally, injury duration was recorded to the end of the season, which may have caused an underestimation of injury severity in cases that occurred late in the season.

Second, although match participation is a matter of official record, the coaches or their assistants recorded training attendance. Because individual training attendance records from five of the teams were somewhat incomplete, training exposure was estimated based on the training schedule for each of the teams and personal communication with the coaches.

Third, although this is one of the largest studies of risk factors for football injuries to date, the main limitation of a cohort study of this kind is the number of cases and events. Between 215 and 257 players participated in each of the tests, and 43% to 46% of these suffered an injury during the season. However, only 50% of the cohort participated in all of the tests, and this limits the usefulness of the multivariate tests, especially when examining risk factors for specific injury types with fewer cases. The reason why players did not participate in testing is in most cases unknown: Some declined the invitation to be tested, and others simply did not show up for their appointment. Although a few could not perform certain tests because of off-season injuries, we do not know of any bias in recruitment for testing. The main impediment was probably that many of the players had to travel considerable distances to Reykjavik for testing on two separate occasions. No differences were found in age, height, weight, level of play, or injury rate between players who participated in different tests and those who did not. For most of the tests, the players who participated had a significantly higher exposure during matches than the players who we were unable to test. This indicates that the most exposed players have been tested, which increases the validity of the study.

Finally, our ability to measure potential intrinsic risk factors accurately is a critical aspect for the risk factor analyses. For the factor that consistently turned out to be the most important—previous injury—the main limitation is recall bias, which usually causes an underestimation of previous injuries or a misclassification because players cannot remember the exact injury site. For the physiological variables—endurance, muscular power, flexibility, and so forth—these were measured using established methods with acceptable reliability, and it is our impression that the players who were tested were well motivated. Nevertheless, in most cases we were unable to show any difference in injury risk between players with high versus low performance on the various tests. This could be related to a lack of statistical power, that is, few subjects or cases. However, it is important to note that with few exceptions, there seemed to be no trend toward a difference in performance between injured and noninjured players and no increase in injury risk for the subgroups of players with the highest (>1 SD above mean) or lowest (>1 SD below mean) performance on each of the tests. Thus, it appears unlikely that any of the factors measured are candidate risk factors.

Injury Patterns

A comparison between previous studies on football injuries is difficult because of differences in study design, such as injury definitions and severity categories, registration methods, level of play, and so forth. Nevertheless, the high incidence observed—about 25 injuries per 1000 match hours—is in accordance with previous studies on elite male football players.[1,19,21,27,31,39,43] In the present study, 56% of the players incurred an injury during the season. This is lower than in most other studies on male football players, which have reported that between 65% and 91% of the players were injured during one season.[1,14,28,38,39,43] The reason for this apparent difference is probably that the Icelandic football season (the registration period) is relatively short (4 months) compared to most other studies (6 to 12 months). However, the rate of severe injuries is higher than in most previous studies,[1,14,27,28,39,47] and taken together, the high incidence and severity result means that on the average, each team suffered from 250 injury days during the 4-month season. This result, which is a minimum estimate, shows that there is an urgent need for appropriate injury prevention measures.

Four specific injury types were identified as the most frequent: hamstring strains, groin strains, knee sprains, and ankle sprains. Notably, this pattern differs from most previous studies in that the incidence and percentage of hamstring strains is higher than reported previously,[8,14,38,43,47] with the exception of two studies.[1,27] Also, the incidence and percentage of clinically diagnosed groin strains were higher than reported before.[1,14,18,21,38,43] The percentage of knee sprains (8.2% of total number of injuries) was in accordance with other studies (5.9 to 17.0%).[1,13,14,27,28,38] We have limited data on the incidence of ACL injuries in male, elite football, but the incidence in the present study (0.5 injuries per 1000 match hours) was similar to a previous Norwegian study (0.41).[5] On the other hand, the incidence of ankle sprains (0.6 injuries per 1000 hours) was lower than in a previous study from Iceland (1.3)[1] or a study from Swedish first division football (1.7 to 2.0).[19] Other studies have also shown a higher percentage of ankle sprains (11.2% to 21.0%) than the present study (8.2%).[1,15,19,21,27,38] The apparent differences in injury patterns—higher rates of hamstring and groin strains—could reflect cultural differences in training habits or playing style specific to elite, Icelandic football. However, since it appears that the more recent studies also find more of these injury types, it could reflect the evolution of football into a faster and more demanding game.

Risk Factors for Injury

Most studies on risk factors for football injuries have used a univariate analysis to compare injured and noninjured groups of players.[1,4,10,12-17,28,31,51] Because of the complexity of risk factor analysis and possible interaction between different risk factors, a multivariate model has been recommended.[42,47] The main risk factors identified in the present study were previous injury and age, and the multivariate tests showed that although there was some confounding, both factors influence injury risk. Previous injury is associated with increased age but is also an independent risk factor for injury. Previous studies have reported conflicting results on age as a risk factor, some finding that older players are more prone to injury[41,47] and others not.[10,12]

Previous studies on football players have reported a high rate of recurrent hamstring strains[1,27,43] and groin strains,[1,18,39] as well as knee[1,14] and ankle sprains.[1,14,19,29,43] In the present study, a previous strain or sprain on the same side was found to be a strong predictor for a new injury. In the case of adductor or hamstring strains, this may be due to changes in the structural or scar tissue formation in the muscle or tendon after injury[34,44] or inadequate rehabilitation as well as too early a return to competitive physical activity after the previous strain.[1,15,16,55] For ligament sprains, it has been shown that neuromuscular control of the ankle joint is reduced in athletes with persistent instability complaints after injury,[35,37,53] and even in the immediate recovery period after an acute injury,[36] but that this function can be restored with a balance board training program.[24,29,56] Other studies have shown that mechanical instability in ankles is common after previous sprains,[8,13,14] and ankle sprains have shown to be more frequent in players with mechanical instability.[15] Since functional instability can be rectified with proper training, and this type of training has been shown to be effective even in preventing ACL injuries in previously healthy athletes,[9] it seems reasonable to suggest that the increased injury risk is at least partly due to inadequate rehabilitation and early return to sport.

Interestingly, reduced ROM was a significant risk factor for groin strains but not for the hamstrings. Unfortunately, we were unable to measure adductor strength or the strength ratio between the hamstrings and quadriceps, which are believed to be risk factors for groin and hamstrings strains, respectively.[46,54] Ekstrand and Gillquist also found that players with less ROM in hip abduction were at higher risk of adductor muscle ruptures or tendinopathy.[15] Other studies have not found significant differences in ROM between players who incurred muscle strains and those who did not.[1,55] Ekstrand and Gillquist showed that football players were less flexible in hip abduction, hip extension, and knee flexion than a control group.[13] The reason for this can be the characteristics of the sport—high intensity, short sprints, with sudden turning and increasing or decreasing of speed. This places a high demand on the muscles and can result in muscle tightness.[1,13] Moreover, insufficient attention is often paid to flexibility training in football.[1,17,26,30]

Player exposure has been discussed as a possible risk factor for injuries in football,[12,17,30] but few studies are available. Ekstrand et al. found that teams with an average training incurred the highest injury rate and lower rates for those who trained less or more.[17] This is in accordance with the present study in which players in the highest and lowest exposure categories had a lower injury rate than players in the intermediate group. That players who trained and played football for fewer hours were less exposed, and therefore incurred fewer injuries, is not surprising. Why players with the highest exposure suffer fewer injuries is less clear. While it has been suggested that they are in better physical condition,[12,17] our test results do not seem to support this hypothesis. This group presumably receives more playing time because they are thought to be better players by the coach. Perhaps they have qualities—technique, anticipation, awareness of their surroundings—that not only make them better players but also protect them from injury. There was also a trend that uninjured players had a higher training-to-match ratio than the injured group did, which is in accordance with previous studies.[12,15] This underlines the importance of an adequate amount of training in relation to matches.

Practical Implications

The consistent observation that previous injury is an important risk factor for the four most common injury types indicates that more focus needs to be put on rehabilitation of injuries, at least in Icelandic football. Although these are teams that perform on a very high level, and their principal resource is the players, the financial standing of the clubs currently limits their ability to establish an optimal medical support team. The team physicians mainly serve their teams by being available for referral of injured players, and the team physical therapists are rarely able to be present during training sessions. Although this has not been studied explicitly in the present study, the results seem to indicate that the present level of follow-up of injury rehabilitation is inadequate to protect athletes from future reinjury. Too early return to training at high intensity after injuries can also be part of the explanation for the high risk of recurrent injuries observed. To take one example, recurrent ankle sprains can be prevented through a program of balance-training exercise and taping.[3] Tape or an appropriate orthosis should be worn at least until completion of rehabilitation, preferably 6 to 10 weeks. The present results, showing that the risk of knee and ankle sprains was about five times higher among athletes with former injury, indicate that a more intensive program of medical care may be a sound investment for the clubs.

CONCLUSION

The injury rate in Icelandic male football is high, with hamstring strains as the most frequent injury type, followed by groin strains, ankle sprains, and knee sprains. Older players and players with previous injury are at increased risk of new injuries of the same type and location. Players with less ROM for hip abduction also are at increased risk of groin strains. This calls attention to the need for adequate rehabilitation of previous injury and closer medical follow-up of teams at this level to prevent reinjuries.

ACKNOWLEDGMENT

The Oslo Sports Trauma Research Center has been established at the Norwegian University of Sport & Physical Education through generous grants from the Royal Norwegian Ministry of Culture, the Norwegian Olympic Committee & Confederation of Sport, Norsk Tipping AS, and Pfizer AS. In addition, financial support came from the Ministry of Education, Science, and Culture in Iceland and the Association of Icelandic Physiotherapists. We would like to thank the coaches and physical therapists who participated in this study.

REFERENCES

1. Arnason A, Gudmundsson A, Dahl HA, et al: Soccer injuries in Iceland. *Scand J Med Sci Sports 6:* 40–45, 1996
2. Arnheim DD: The foot, ankle, and lower leg: Acute injuries, in Arnheim DD (ed): *Modern Principles of Athletic Training*. St. Louis, Times Mirror/Mosby College, 1989, pp 490–537
3. Bahr R: Recent advances: Sports medicine. *BMJ 323:* 328–331, 2001
4. Baumhauer JF, Alosa DM, Renstrom AF, et al: A prospective study of ankle injury risk factors. *Am J Sports Med 23:* 564–570, 1995
5. Bjordal JM, Arnly F, Hannestad B, et al: Epidemiology of anterior cruciate ligament injuries in soccer. *Am J Sports Med 25:* 341–345, 1997
6. Boden BP, Kirkendall DT, Garrett WE Jr: Concussion incidence in elite college soccer players. *Am J Sports Med 26:* 238–241, 1998
7. Bosco C, Belli A, Astrua M, et al: A dynamometer for evaluation of dynamic muscle work. *Eur J Appl Physiol Occup Physiol 70:* 379–386, 1995
8. Brynhildsen J, Ekstrand J, Jeppsson A, et al: Previous injuries and persisting symptoms in female soccer players. *Int J Sports Med 11:* 489–492, 1990
9. Caraffa A, Cerulli G, Projetti M, et al: Prevention of anterior cruciate ligament injuries in soccer: A prospective controlled study of proprioceptive training. *Knee Surg Sports Traumatol Arthrosc 4:* 19–21, 1996
10. Chomiak J, Junge A, Peterson L, et al: Severe injuries in football players: Influencing factors. *Am J Sports Med 28:* S58–S68, 2000
11. de Loes M: Epidemiology of sports injuries in the Swiss organization “Youth and Sports” 1987–1989: Injuries, exposure and risks of main diagnoses. *Int J Sports Med 16:* 134–138, 1995
12. Dvorak J, Junge A, Chomiak J, et al: Risk factor analysis for injuries in football players: Possibilities for a prevention program. *Am J Sports Med 28:* S69–S74, 2000

13. Ekstrand J, Gillquist J: The frequency of muscle tightness and injuries in soccer players. *Am J Sports Med 10:* 75–78, 1982
14. Ekstrand J, Gillquist J: Soccer injuries and their mechanisms: A prospective study. *Med Sci Sports Exerc 15:* 267–270, 1983
15. Ekstrand J, Gillquist J: The avoidability of soccer injuries. *Int J Sports Med 4:* 124–128, 1983
16. Ekstrand J, Gillquist J, Liljedahl SO: Prevention of soccer injuries: Supervision by doctor and physiotherapist. *Am J Sports Med 11:* 116–120, 1983
17. Ekstrand J, Gillquist J, Moller M, et al: Incidence of soccer injuries and their relation to training and team success. *Am J Sports Med 11:* 63–67, 1983
18. Ekstrand J, Hilding J: The incidence and differential diagnosis of acute groin injuries in male soccer players. *Scand J Med Sci Sports 9:* 98–103, 1999
19. Ekstrand J, Tropp H: The incidence of ankle sprains in soccer. *Foot Ankle 11:* 41–44, 1990
20. Ekstrand J, Wiktorsson M, Oberg B, et al: Lower extremity goniometric measurements: A study to determine their reliability. *Arch Phys Med Rehabil 63:* 171–175, 1982
21. Engstrom B, Forssblad M, Johansson C, et al: Does a major knee injury definitely sideline an elite soccer player? *Am J Sports Med 18:* 101–105, 1990
22. Fredriksen H, Dagfinrud H, Jacobsen V, et al: Passive knee extension test to measure hamstring muscle tightness. *Scand J Med Sci Sports 7:* 279–282, 1997
23. Friedlander AL, Block JE, Byl NN, et al: Isokinetic limb and trunk muscle performance testing: Short-term reliability. *JOSPT 14:* 220–224, 1991
24. Gauffin H, Tropp H, Odenrick P: Effect of ankle disk training on postural control in patients with functional instability of the ankle joint. *Int J Sports Med 9:* 141–144, 1988
25. Golding LA, Myers CR, Sinning WE: The YMCA physical fitness test battery, in Golding LA, Myers CR, Sinning WE (eds): *Y's Way to Physical Fitness: The Complete Guide to Fitness Testing and Instruction*. Leeds, Human Kinetics, 1989, pp 61–138
26. Hawkins RD, Fuller CW: A preliminary assessment of professional footballers' awareness of injury prevention strategies. *Br J Sports Med 32:* 140–143, 1998
27. Hawkins RD, Fuller CW: A prospective epidemiological study of injuries in four English professional football clubs. *Br J Sports Med 33:* 196–203, 1999
28. Hawkins RD, Hulse MA, Wilkinson C, et al: The association football medical research programme: An audit of injuries in professional football. *Br J Sports Med 35:* 43–47, 2001
29. Holme E, Magnusson SP, Becher K, et al: The effect of supervised rehabilitation on strength, postural sway, position sense and re-injury risk after acute ankle ligament sprain. *Scand J Med Sci Sports 9:* 104–109, 1999
30. Inklaar H: Soccer injuries. II: Aetiology and prevention. *Sports Med 18:* 81–93, 1994
31. Inklaar H, Bol E, Schmikli SL, et al: Injuries in male soccer players: team risk analysis. *Int J Sports Med 17:* 229–234, 1996
32. Jackson AS, Pollock ML: Generalized equations for predicting body density of men. *Br J Nutr 40:* 497–504, 1978
33. Jackson AS, Pollock ML: Practical assessment of body composition. *Physician Sports Med 13:* 76–80, 1985
34. Jarvinen TA, Kaariainen M, Jarvinen M, et al: Muscle strain injuries. *Curr Opin Rheumatol 12:* 155–161, 2000
35. Karlsson J, Peterson L, Andreasson G, et al: The unstable ankle: A combined EMG and biomechanical modeling study. *Int J Sport Biomech 8:* 129–144, 1992
36. Konradsen L, Olesen S, Hansen HM: Ankle sensorimotor control and eversion strength after acute ankle inversion injuries. *Am J Sports Med 26:* 72–77, 1998
37. Konradsen L, Ravn JB: Prolonged peroneal reaction time in ankle instability. *Int J Sports Med 12:* 290–292, 1991
38. Lewin G: The incidence of injury in an English professional soccer club during one competitive season. *Physiotherapy 75:* 601–605, 1989
39. Luthje P, Nurmi I, Kataja M, et al: Epidemiology and traumatology of injuries in elite soccer: A prospective study in Finland. *Scand J Med Sci Sports 6:* 180–185, 1996
40. Magee DJ: Knee, in Magee DJ (ed): *Orthopedic Physical Assessment*. Philadelphia, WB Saunders, 1992, pp 372–477
41. McGregor JC, Rae A: A review of injuries to professional footballers in a premier football team (1990–93). *Scott Med J 40:* 16–18, 1995
42. Meeuwisse WH: Assessing causation in sport injury: A multifactorial model. *Clin J Sport Med 4:* 166–170, 1994
43. Nielsen AB, Yde J: Epidemiology and traumatology of injuries in soccer. *Am J Sports Med 17:* 803–807, 1989
44. Noonan TJ, Garrett WE Jr: Injuries at the myotendinous junction. *Clin Sports Med 11:* 783–806, 1992
45. Orchard J: Is there a relationship between ground and climatic conditions and injuries in football? *Sports Med 32:* 419–432, 2002
46. Orchard J, Marsden J, Lord S, et al: Preseason hamstring muscle weakness associated with hamstring muscle injury in Australian footballers. *Am J Sports Med 25:* 81–85, 1997
47. Ostenberg A, Roos H: Injury risk factors in female European football: A prospective study of 123 players during one season. *Scand J Med Sci Sports 10:* 279–285, 2000
48. Scholander PF: Analyzer for accurate estimation of respiratory gases in one-half cubic centimeter samples. *J Biol Chem 167:* 1–15, 1947
49. Siri WE: The gross composition of the body, in Lawrence JH, Tobias CA (eds): *Advances in Biological and Medical Physics IV*. New York, Academic Press, 1956, pp 239–280
50. Taimela S, Osterman L, Kujala U, et al: Motor ability and personality with reference to soccer injuries. *J Sports Med Phys Fitness 30:* 194–201, 1990
51. Tropp H, Ekstrand J, Gillquist J: Stabilometry in functional instability of the ankle and its value in predicting injury. *Med Sci Sports Exerc 16:* 64–66, 1984
52. Tropp H, Ekstrand J, Gillquist J: Stabilometry in functional instability of the ankle and its value in predicting injury. *Med Sci Sports Exerc 16:* 64–66, 1984
53. Tropp H, Odenrick P, Gillquist J: Stabilometry recordings in functional and mechanical instability of the ankle joint. *Int J Sports Med 6:* 180–182, 1985
54. Tyler TF, Nicholas SJ, Campbell RJ, et al: The association of hip strength and flexibility with the incidence of adductor muscle strains in professional ice hockey players. *Am J Sports Med 29:* 124–128, 2001
55. Watson AW: Sports injuries related to flexibility, posture, acceleration, clinical defects, and previous injury, in high-level players of body contact sports. *Int J Sports Med 22:* 222–225, 2001
56. Wester JU, Jespersen SM, Nielsen KD, et al: Wobble board training after partial sprains of the lateral ligaments of the ankle: A prospective randomized study. *J Orthop Sports Phys Ther 23:* 332–336, 1996
57. Wikstrom J, Andersson C: A prospective study of injuries in licensed floorball players. *Scand J Med Sci Sports 7:* 38–42, 1997