Muscle Strength Is a Poor Screening Test for Predicting Lower Extremity Injuries in Professional Male Soccer Players

A 2-Year Prospective Cohort Study

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Background: Lower extremity muscle strength tests are commonly used to screen for injury risk in professional soccer. However, there is limited evidence on the ability of such tests in predicting future injuries.

Purpose: To examine the association between hip and thigh muscle strength and the risk of lower extremity injuries in professional male soccer players.

Study Design: Case-control study; Level of evidence, 3.

Methods: Professional male soccer players from 14 teams in Qatar underwent a comprehensive strength assessment at the beginning of the 2013/2014 and 2014/2015 seasons. Testing consisted of concentric and eccentric quadriceps and hamstring isokinetic peak torques, eccentric hip adduction and abduction forces, and bilateral isometric adductor force (squeeze test at 45°). Time-loss injuries and exposure in training and matches were registered prospectively by club medical staff throughout each season. Univariate and multivariate Cox regression analyses were used to calculate hazard ratios (HRs) with 95% CIs.

Results: In total, 369 players completed all strength tests and had registered injury and exposure data. Of these, 206 players (55.8%) suffered 538 lower extremity injuries during the 2 seasons; acute muscle injuries were the most frequent. Of the 20 strength measures examined, greater quadriceps concentric peak torque at 300 deg/s (HR, 1.005 [95% CI, 1.00-1.01]; *P* = .037) was the only strength measure identified as significantly associated with a risk of lower extremity injuries in multivariate analysis. Greater quadriceps concentric peak torque at 60 deg/s (HR, 1.004 [95% CI, 1.00-1.01]; *P* = .026) was associated with the risk of overuse injuries, and greater bilateral adductor strength adjusted for body weight (HR, 0.75 [95% CI, 0.57-0.97; *P* = .032) was associated with a lower risk for any knee injury. Receiver operating characteristic curve analyses indicated poor predictive ability of the significant strength variables (area under the curve, 0.45-0.56).

Conclusion: There was a weak association with the risk of lower extremity injuries for 2 strength variables: greater quadriceps concentric muscle strength at (1) high and (2) low speeds. These associations were too small to identify an ''at-risk'' player. Therefore, strength testing, as performed in the present study, cannot be recommended as a screening test to predict injuries in professional male soccer.

Keywords: lower extremity injury; muscle strength; football (soccer); injury prevention; screening; injury risk

Lower extremity injuries represent a disconcerting cause of time lost from male professional soccer,[10,14,24] decreased player performance,[11,22] financial cost,[13] and possibly long-term player health.[9,27] Screening to identify players at an increased risk for injuries with a view to prescribing individualized prevention measures is commonly seen as an integral component of a periodic health evaluation (PHE) of athletes.[1,29] Muscle strength is considered an important factor predisposing a player to lower extremity injuries,[6,7,15,18,42] and muscle strength testing is one of the most utilized screening tests in professional soccer to detect injury risk.[32]

The role of muscle strength as a risk factor for lower extremity injuries has been widely discussed.[7,19,31,42] Isokinetic quadriceps and hamstring muscle strength have been associated with the risk of lower extremity injuries, in particular for acute muscle injuries and knee ligament

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injuries, in team and nonteam sports in some studies,[6,19,37,38] whereas other prospective studies do not support such a relationship.[15,17] In field-based sports, low hip adduction strength increases the risk of lower extremity muscle injuries.[42,51] Moreover, low hip abduction strength was associated with an increased risk of lower extremity knee ligament injuries[25]; however, the results are inconsistent.[7] Muscle strength imbalances, typically expressed as a ratio between an agonist and antagonist muscle, have also been associated with an increased risk of lower extremity injuries[6,42,46,51]; however, the evidence is inconclusive.[7,19,31]

Despite the widespread use of muscle strength testing within professional soccer clubs,[32] there are few prospective studies investigating the association between muscle strength and injury risk in professional soccer, and even fewer studies have investigated the predictive ability of such tests.[31] The utility of muscle strength testing as a screening tool not only depends on the strength of its association with injury risk but also on its ability to predict who is at risk of injuries and who is not.[1]

Therefore, the aim of this study was to assess whether hip and thigh muscle strength were associated with an increased risk for lower extremity injuries in professional male soccer players. Second, we assessed whether muscle strength represented a risk factor for acute lower extremity injuries, overuse lower extremity injuries, or knee injuries. We hypothesized that lower hip and thigh muscle strength would be associated with an increased risk for lower extremity injuries and that strength testing could be used to separate high-risk players from low-risk players.

METHODS

Study Design and Participants

In the present study, we prospectively collected data from a PHE of male professional soccer players in Qatar.[4] All players eligible to compete in the Qatar Stars League (QSL), the professional first division of soccer in Qatar, were invited to participate as they presented for their annual PHE at Aspetar Orthopaedic and Sports Medicine Hospital in Doha, Qatar, during the 2013/2014 and 2014/2015 seasons. The PHE was mainly performed during the preseason period (66.6%) (July-September), with a small group completing the tests during the early/mid-competition phase (23.8%) (October-December) each year and a minor group during the postseason (9.7%) (end of April–June) in 2014 (ie, used as the baseline for the 2014/2015 season).

As part of the musculoskeletal component of the PHE, all players underwent a comprehensive musculoskeletal test battery aimed at identifying potential biomechanical and anatomic risk factors for lower extremity injuries at the rehabilitation department of Aspetar.[4] Data from 3 strength tests were included in the current study. Players who competed for QSL clubs during the 2013/2014 and 2014/2015 seasons did not report a current time-loss injury at the time of testing, and reported injury and exposure surveillance data for the entire season were eligible for analysis. Ethics approval was obtained from the institutional review board of Anti-Doping Lab Qatar (F2013000003 and E2013000003). All players signed a written informed consent form at inclusion, permitting their data to be utilized for research.

Study Procedure

All test procedures were performed by sports physical therapists who had received a minimum of 5 hours of training in the methods. A total of 6 testers performed the strength tests during the study period. Before the strength tests, the players performed a self-selected 5- to 10-minute warm-up routine, consisting of either light running or cycling on a stationary exercise bicycle (Forma Exercise Bike; Technogym), with most players preferring cycling. We randomized the test order for each strength test and leg (left, right). Data on player characteristics (ie, age, date of birth, player position) and previous injuries (lower extremity injuries and groin, hamstring, quadriceps femoris, knee, and ankle injuries) were collected from the Fédération Internationale de Football Association (FIFA) precompetition medical assessment form, which was completed during the medical part of the PHE on the same day as the strength tests.[4] A previous injury refers to any time-loss injury occurring within 12 months before the PHE. We obtained information on height, weight, and leg dominance before testing and defined the dominant leg as the limb preferred for a penalty kick.

Quadriceps and Hamstring Strength

Maximal isokinetic knee flexion and extension were tested using an isokinetic dynamometer (Multi-Joint System 3; Biodex Medical Systems). We used a standardized protocol composed of 3 different modes and speeds, as previously described.[45,50] The axis of rotation of the dynamometer was individually aligned with the knee joint and the hip

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angle at 90°. We used straps around the thigh, waist, and trunk to minimize secondary joint movement. After an explanation of the testing methodology, players were first tested over 5 repetitions of concentric knee flexion and extension at 60 deg/s. This was followed by 10 repetitions of concentric knee flexion and extension at 300 deg/s. Finally, players performed 5 repetitions of eccentric knee extension at 60 deg/s. Accordingly, we calculated a hamstring-to-quadriceps (HQ) ratio for the same mode and speed of the concentric contraction and a mixed ratio from hamstring eccentric at 60 deg/s to quadriceps at 300 deg/s. The highest peak torque (N·m) observed from all repetitions performed for each of the 3 different tests was recorded. Between each mode of testing, a minimum of 60 seconds of rest was provided. The isokinetic muscle strength testing protocol has been established as a highly reliable tool for assessing muscle force (intraclass correlation coefficient [ICC], 0.83-0.96).[39,41]

Hip Strength

Hip Eccentric Adduction and Abduction Test. We measured maximal eccentric hip adduction and abduction strength with a break test, using a handheld dynamometer (Commander PowerTrack II; JTECH Medical) and with the player in a side-lying position as previously described.[36,43] The leg being tested was placed in a straight position, in line with the body, and the contralateral leg in 90° of hip and knee flexion. The players held their hands on the side of the examination table to stabilize themselves during testing. We applied resistance in a fixed position 8 cm proximal to the most prominent point of the lateral malleolus, and the player exerted a 3-second maximal isometric contraction against the dynamometer, followed by a 2-second break performed by the examiner. The player was given 1 practice trial followed by 3 tests, with a minimum of a 30-second rest between each test. We recorded the maximum score (N) and also calculated an adduction-to-abduction (ADD:ABD) ratio for analysis.[36]

Adductor Squeeze Test (Bilateral Adductor Test). Maximal isometric adductor squeeze strength was measured using the handheld dynamometer and the player in a supine position. We placed the dynamometer between the player's knees with the hip flexed at 45° and feet flat on the table, and the player pressed his knees together against the handheld dynamometer with maximal force without lifting the legs or pelvis. The player was allowed 1 test trial followed by 1 maximum trial, which was recorded for analysis (N). A detailed description of the test is given by Mosler et al.[36] These strength procedures have been established as highly reliable for assessing hip strength (ICC, 0.83-0.94).[8,30,43] Also, Mosler et al[36] demonstrated moderate to good interrater reliability (ICC, 0.66-0.84) of the hip strength measurement, when conducted with the same cohort and testers as in the present study.

Injury Registration

Injury and exposure data were obtained from the Aspetar Injury and Illness Surveillance Program (AIISP). The AIISP includes prospective injury and exposure (minutes of training and match play) recording from all 14 QSL teams.[10] An injury was recorded if the player was unable to fully participate in future soccer training or match play because of an injury to the lower extremity (time-loss injury).[10,21] The player was considered injured until declared fit for full participation in training and available for match selection by medical staff.

The team physician for each team recorded all injuries and individual training and match exposure daily throughout the 2013/2014 and 2014/2015 soccer seasons (July-May; 44 weeks). For each injury recorded, the team physician completed a standardized injury card containing information on the body part injured, injury type, and cause of injury (overuse or acute). Overuse and acute injuries were defined according to the consensus statement on injury definitions and data collection procedures in studies of soccer injuries.[21] In addition, the injury card included questions related to reinjuries and the injury mechanism (contact or collision) as well as information on whether the injury occurred during training or a match. Injury severity was determined by the number of days absent from matches or training sessions due to an injury and was classified as mild (1-3 days), minor (4-7 days), moderate (8-28 days), or severe (>28 days).[10] Injury and exposure data were passed on to the study group each month; data were checked and cleaned and any questions clarified with the team doctor as needed.

Statistical Analysis

Data were analyzed with SPSS Statistics version 24.0 (IBM). Descriptive data are presented as mean ± SD unless otherwise stated. Muscle strength measures are presented as absolute (peak torque for the quadriceps and hamstring strength tests and peak force for the hip strength tests) and weight-normalized values. The eccentric hip abduction and adduction strength measures were normalized to weight and lever arm (N·m/kg).[36,43] Legs with missing data for all 3 strength tests were excluded from the final analyses.

Individual exposure data were calculated as the sum of the total number of hours of training and match play from the date of screening until the end of each season or until the date of the first injury. On the basis of a previous epidemiological study[10] on the injury incidence of the QSL, we expected between 200 and 300 lower extremity injuries per season as well as about 250 to 300 soccer players to present for the PHE at our study center each year. Therefore, a priori, we estimated the statistical power to be sufficient to detect small to moderate associations (n = 200 injuries), as outlined by Bahr and Holme.[2]

To examine the relationship between any lower extremity injury (yes/no) with muscle strength scores and other potential risk factors (anthropometric data, player position, previous injury, season, dominant leg), we used Cox regression analyses (STATA version 11.0; StataCorp) with each leg as the unit of analysis. For players sustaining more than 1 injury after baseline testing, we only included their first lower extremity injury. In the case of

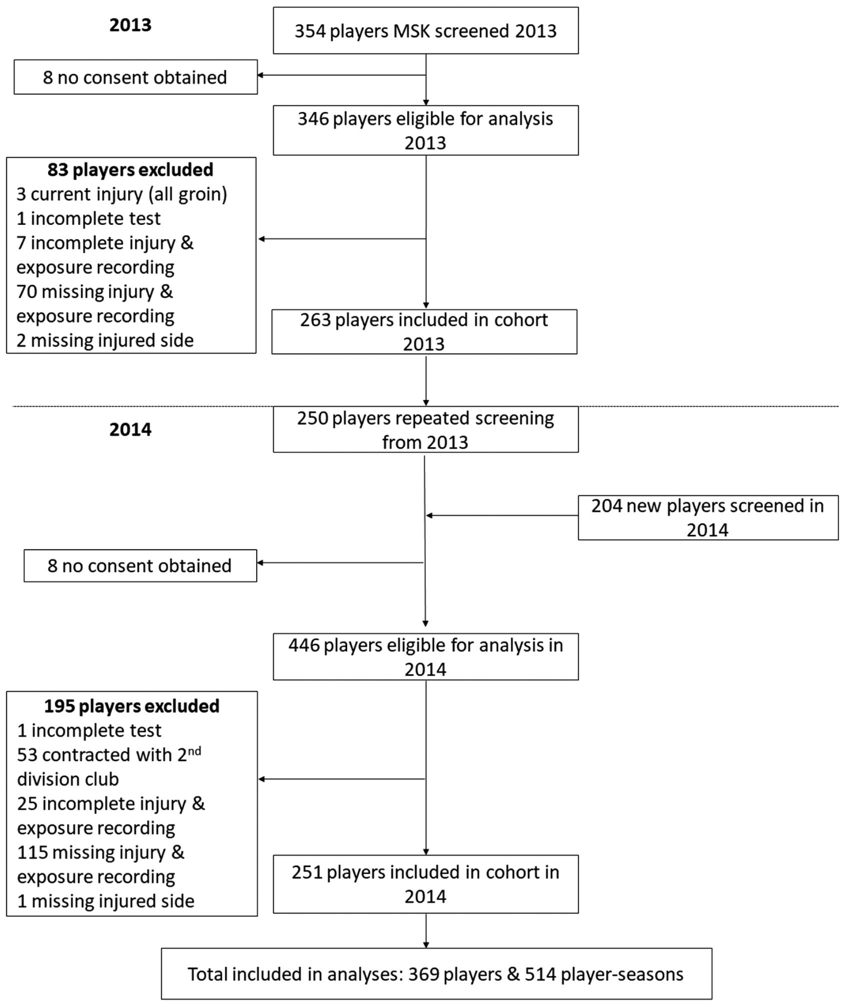

Figure 1. Flowchart demonstrating the movement of players and repeated strength tests between the 2 seasons. MSK, musculoskeletal.

a bilateral injury, these were included in the analyses as an injury sustained to both legs. To account for the repeated measures performed over the 2 seasons, as well as the fact that not every participant had the same number of measurements (ie, some participants had test results for both seasons and some for only 1 season), we used player identity to cluster the related observations when estimating the Cox model. Similar and separate analyses were performed for assessing the relationship between muscle strength scores and acute lower extremity, overuse lower extremity, and knee injuries (including knee ligament, meniscus, or cartilage injuries). The hazard ratios (HRs) presented with 95% CIs are per 1 unit of change in the independent continuous risk factor (muscle strength, anthropometric data). For categorical variables (season, position, previous injuries, dominant leg), the HR represents the change in risk when compared with the reference category. After univariate analysis, all factors with a P value of <.20 were investigated further in a backward stepwise multivariate model to evaluate potential predictor variables. The significance level was set at $P < .05$.

In case there were significant associations between a strength variable and outcome measure, we performed receiver operating characteristic (ROC) curve analyses to investigate the sensitivity and specificity characteristics of the particular variable. The area under the curve (AUC) indicates how well the strength variable discriminates between the injured and uninjured players and was interpreted as excellent (1.00-0.90), good (0.90-0.80), fair (0.80-0.70), poor (0.70-0.60), or fail (<0.60).[35]

RESULTS

Participants

A total of 369 players were included in the final analyses, participating in 514 player-seasons (1028 legs) and representing 42 nationalities, with the majority from the Middle East (64.5%) (Figure 1 and Table 1). The mean player exposure was 213 ± 92 hours per season, with 188 ± 87 hours of training and 25 ± 17 hours of match play.

TABLE 1
Characteristics of All Players (N = 369)[a]

	Value
Age, y	26.0 ± 4.7
Height, cm	176.8 ± 6.9
Weight, kg	72.2 ± 9.1
Body mass index, kg/m^2	23.0 ± 1.9
Ethnicity	
Arab	201 (54.5)
Black	112 (30.4)
White	20 (5.4)
East Asian	7 (1.9)
Persian	21 (5.7)
Other	8 (2.2)
Player position	
Goalkeeper	39 (10.6)
Defender	130 (35.2)
Midfielder	133 (36.0)
Forward	67 (18.2)
Previous lower extremity injury	
Yes	127 (34.4)
No	233 (63.1)
Missing	9 (2.4)
Player-seasons	
Season 1 only	118 (32.0)
Season 2 only	106 (28.7)
Seasons 1 and 2	145 (39.3)

[a]Data are presented as mean ± SD or n (%).

We recorded a total of 543 (n = 13 bilateral) lower extremity injuries during the 2 seasons. For 3 of the players, data on the injured side were missing for their index injury, and these injuries were excluded from the final analyses. Of the 369 players included, 206 (55.8%) sustained at least 1 lower extremity injury during the 2 seasons, and a total of 538 lower extremity injuries were reported in 294 legs, of which 24 (4.5%) in 12 players were bilateral (mainly groin injuries). An acute muscle injury was the most frequent injury type (Table 2). During the 2013/2014 season, 145 of the 263 (55.1%) players (1 player with bilateral injuries) suffered at least 1 lower extremity injury, while during the 2014/2015 season, 139 of the 251 players (55.4%) (9 players with bilateral injuries) experienced at least 1 lower extremity injury. Slightly more than half of the injuries occurred during training (n = 288, 53.5%), and more than one-third of the injuries were moderate (n = 210, 39.0%), leading to an absence from soccer training and match play for 8 to 28 days. Most players were right-leg dominant (80.5%, n = 297/369 players), and almost two-thirds (61.2%, n = 329/538 injuries) of the injuries occurred on the player's dominant side.

Association Between Muscle Strength and Lower Extremity Injuries

The results of the univariate analysis are shown in Table 3. Analysis of the strength variables identified greater concentric quadriceps peak torque at 300 deg/s and hamstring eccentric peak torque at 60 deg/s as potential risk factors for a lower extremity injury, whereas players with a greater eccentric ADD:ABD ratio were at less risk of lower extremity injuries. However, only greater concentric quadriceps peak torque at 300 deg/s remained significant in the multivariate analysis (Table 4). Of the other candidate risk factors, age, player position, injury to the dominant leg, and playing in season 2 were factors associated with an increased risk of lower extremity injuries; these remained significant in the multivariate model (Table 4). We also performed similar and separate subanalyses in which we excluded contact injuries (n = 67). Because there were many cases with missing information (n = 105), only the category of any noncontact lower extremity injury (n = 122) was analyzed. In addition to the strength variables identified as significantly associated with the risk of lower extremity injuries in Table 3, greater hip eccentric abduction peak force (N) (HR, 1.01 [95% CI, 1.00-1.01]; P = .001) and weight and lever arm adjusted (N·m/kg) (HR, 1.49 [95% CI, 1.01-2.19]; P = .044) were significantly associated with the risk of lower extremity injuries. However, the outcome remained the same; greater concentric quadriceps peak torque at 300 deg/s was the only factor significantly associated with an increased risk of lower extremity injuries when adjusted for other candidate risk factors in the multivariate model (HR, 1.01 [95% CI, 1.00-1.02]; P = .009).

TABLE 2
Injury Characteristics (n = 538)

	n (%)
Injury classification	
Acute	302 (56.1)
Overuse	236 (43.9)
Any knee	85 (15.8)
Acute knee[a]	39 (7.2)
Injury type	
Muscle strain	193 (35.9)
Muscle cramp/spasm	69 (12.8)
Sprain/ligament	89 (16.5)
Contusion	71 (13.2)
Meniscus/cartilage	15 (2.8)
Tendon	56 (10.4)
Fracture	10 (1.9)
Other	35 (6.5)
Severity	
Mild (1-3 days)	124 (23.0)
Minor (4-7 days)	117 (21.7)
Moderate (8-28 days)	210 (39.0)
Severe (>28 days)	86 (16.0)
Missing[b]	1 (0.2)
Injured side	
Right	296 (55.0)
Left	216 (40.1)
Bilateral	24 (4.5)
Missing[b]	2 (0.4)

[a]Acute knee injury refers to acute ligament, meniscus, or cartilage injuries.
[b]Nonindex injury.

Risk Factors for Acute Injuries

A total of 203 legs were affected by acute injuries during the 2 seasons, and 302 injuries were recorded. In the univariate

TABLE 3
Univariate Comparison From Cox Regression Analysis
Between Legs With and Without a Lower Extremity Injury (n = 1028 Legs)[a]

	n	Injured (n = 294)	Uninjured (n = 734)	HR (95% CI)	*P* Value
Age, y	1028	26.9 ± 4.7	26.2 ± 4.7	1.04 (1.01-1.06)	**.006**
Height, cm	1028	176.9 ± 6.9	176.6 ± 6.6	1.01 (0.99-1.02)	.515
Weight, kg	1028	72.7 ± 9.0	72.0 ± 9.0	1.01 (0.99-1.02)	.171
Body mass index, kg/m^2	1028	23.2 ± 2.0	23.0 ± 1.9	1.05 (0.99-1.11)	.131
Player position, n (%)	1028				
Goalkeeper[b]		22 (7.5)	88 (12.0)	1.00	
Defender		105 (35.7)	253 (34.5)	1.76 (1.15-2.69)	**.009**
Midfielder		109 (37.1)	281 (38.3)	1.71 (1.13-2.59)	**.011**
Forward		58 (19.7)	112 (15.3)	2.20 (1.40-3.46)	**.001**
Previous lower extremity injury (yes),[c] n (%)	996	99 (34.4)	249 (35.2)	1.05 (0.80-1.36)	.740
Dominant leg (yes), n (%)	1028	182 (61.9)	332 (45.2)	1.63 (1.29-2.06)	**<.001**
Season (season 2),[d] n (%)	1028	148 (50.3)	354 (48.2)	1.36 (1.07-1.72)	**.012**
Isokinetic quadriceps and hamstring strength					
Quadriceps concentric at 60 deg/s	864	237.8 ± 46.3	232.4 ± 46.4	1.00 (0.99-1.01)	.121
BW adjusted, N·m/kg	864	3.28 ± 0.55	3.25 ± 0.58	1.06 (0.85-1.32)	.623
Quadriceps concentric at 300 deg/s	862	136.6 ± 26.2	133.2 ± 25.3	1.005 (1.00-1.01)	**.044**
BW adjusted, N·m/kg	862	1.88 ± 0.30	1.86 ± 0.29	1.23 (0.80-1.89)	.347
Hamstring concentric at 60 deg/s	863	128.2 ± 26.6	125.3 ± 27.4	1.00 (0.99-1.01)	.113
BW adjusted, N·m/kg	863	1.77 ± 0.31	1.75 ± 0.34	1.11 (0.76-1.62)	.584
Hamstring concentric at 300 deg/s	862	97.4 ± 20.2	95.5 ± 19.3	1.01 (0.99-1.01)	.138
BW adjusted, N·m/kg	862	1.34 ± 0.25	1.33 ± 0.24	1.09 (0.65-1.82)	.740
Hamstring eccentric at 60 deg/s	857	206.5 ± 46.6	201.2 ± 40.9	1.003 (1.00-1.01)	**.031**
BW adjusted, N·m/kg	857	2.84 ± 0.54	2.81 ± 0.51	1.12 (0.88-1.43)	.367
HQ concentric ratio at 60 deg/s	863	0.54 ± 0.08	0.54 ± 0.10	0.92 (0.30-2.80)	.889
HQ concentric ratio 300 deg/s	862	0.72 ± 0.11	0.72 ± 0.12	0.67 (0.24-1.86)	.446
HQ eccentric to concentric ratio at 60/300 deg/s	855	1.53 ± 0.31	1.53 ± 0.29	1.02 (0.67-1.54)	.921
Hip strength					
Adductor squeeze at 45°	1016	238.8 ± 63.6	238.1 ± 60.9	1.00 (0.99-1.00)	.567
BW adjusted, N/kg	1016	3.30 ± 0.83	3.33 ± 0.84	0.99 (0.85-1.14)	.860
Hip eccentric adduction	1006	254.8 ± 56.5	256.3 ± 52.3	0.99 (0.99-1.00)	.561
BW and lever arm adjusted, N·m/kg	1004	3.03 ± 0.63	3.08 ± 0.61	0.84 (0.68-1.04)	.118
Hip eccentric abduction	1019	209.7 ± 36.9	208.6 ± 40.7	1.00 (0.99-1.00)	.305
BW and lever arm adjusted, N·m/kg	1017	2.49 ± 0.40	2.50 ± 0.44	1.02 (0.78-1.33)	.882
ADD:ABD ratio	1004	1.23 ± 0.27	1.25 ± 0.27	0.63 (0.41-0.98)	**.039**

[a]Data are presented as mean ± SD for injured and uninjured legs unless otherwise indicated. Hazard ratios (HRs), per 1 unit of change for continuous variables and change in the risk when compared with the reference category for categorical variables, are presented with 95% CIs and *P* values from Cox regression analyses accounting for clustering factors (player identity) and using leg as the unit of analysis. Bolded *P* values indicate statistical significance. ADD:ABD, adduction-to-abduction; BW, body weight; HQ, hamstring-to-quadriceps.
[b]Reference group.
[c]Previous injury refers to any injury occurring within 12 months before testing.
[d]Reference group: season 1 (2013/2014).

analysis, players with a greater eccentric hip ADD:ABD ratio were less likely to sustain an acute injury (Table 5). None of the other strength variables were significantly associated with an acute injury. Age, injury to the dominant leg, and playing in season 2 were other factors associated with acute injuries. In the multivariate model, these factors remained significant. Neither the ADD:ABD ratio nor any of the other strength variables were significantly associated with an acute injury in the multivariate model (Table 4).

Risk Factors for Overuse Injuries

Of the 236 overuse injuries recorded in 169 legs, greater concentric quadriceps peak torque at 60 deg/s and greater concentric hamstring peak torque at 60 deg/s were associated with an increased risk of overuse injuries. Being a defender or forward was also associated with an increased risk of overuse injuries (Table 5). Quadriceps concentric peak torque at 60 deg/s and player position (compared with goalkeeper) remained significant predictors of an injury in the multivariate analysis (Table 4).

Risk Factors for Knee Injuries

Seventy legs were affected by a knee injury, and 85 injuries were recorded, of which 39 injuries represented an acute knee ligament, meniscus, or cartilage injury. According to the univariate analysis (Table 5), greater bilateral

TABLE 4
Significant Risk Factors for a Lower Extremity Injury From Multivariate Cox Regression Analysis[a]

	HR (95% CI)	*P* Value
Lower extremity injury		
Quadriceps concentric at 300 deg/s, N·m	1.005 (1.00-1.01)	.037
Age	1.04 (1.01-1.07)	.014
Player position[b]		
Defender	1.73 (1.06-2.80)	.027
Midfielder	1.66 (1.02-2.70)	.041
Forward	2.26 (1.34-3.80)	.002
Dominant leg (yes)	1.57 (1.21-2.05)	.001
Season (season 2)	1.65 (1.26-2.15)	<.001
Acute injury		
Age	1.04 (1.01-1.07)	.018
Dominant leg (yes)	2.08 (1.54-2.80)	<.001
Season (season 2)	1.66 (1.25-2.21)	<.001
Overuse injury		
Quadriceps concentric at 60 deg/s, N·m	1.004 (1.00-1.01)	.026
Player position[b]		
Defender	2.47 (1.16-5.26)	.020
Midfielder	2.18 (1.02-4.67)	.044
Forward	3.25 (1.47-7.19)	.004
Any knee injury		
Adductor squeeze at 45°, N/kg	0.75 (0.57-0.97)	.032
Previous knee injury[c]	2.43 (1.28-4.61)	.007
Acute knee injury[d]		
Body mass index	1.19 (1.02-1.39)	.032

[a]Hazard ratios (HRs), per 1 unit of change for continuous variables and change in the risk when compared with the reference category for categorical variables, are presented with 95% CIs and *P* values from Cox regression analyses accounting for clustering factors (player identity) and using leg as the unit of analysis.

[b]Reference group: goalkeeper.

[c]Previous injury refers to any injury occurring within 12 months before testing.

[d]Acute knee injury refers to acute ligament, meniscus, or cartilage injuries.

isometric adductor strength adjusted for weight was associated with a lower risk for any knee injury. None of the other strength variables were associated with an increased risk of knee injuries, whereas players with a previous knee injury were more prone to knee injuries. Bilateral adductor strength adjusted for weight and previous knee injury remained significant in the multivariate model (Table 4).

We performed a subanalysis on the 39 acute knee ligament, meniscus, or cartilage injuries, of which the majority were collateral ligament injuries (n = 19, 48.7%) and 9 (23.1%) were anterior cruciate ligament (ACL) injuries. Of the strength variables, only greater bilateral isometric adductor strength adjusted for weight was associated with an acute knee ligament, meniscus, or cartilage injury (Table 5). Of the other candidate factors, only a greater body mass index was associated with an increased risk of injuries. Only body mass index remained significant in the multivariate model (Table 4).

Muscle Strength Test Characteristics

ROC curve analyses revealed an AUC of 0.46 and 0.45 for quadriceps concentric strength at 300 deg/s (any lower extremity injury) and 60 deg/s (overuse injury), respectively, and 0.56 for the adductor squeeze test, indicating a failed combined sensitivity and specificity of the strength variables identified as significantly associated with injury risk.

DISCUSSION

The main finding of this large 2-year prospective cohort study on male professional soccer players was that only 2 strength variables (of 20 examined), greater quadriceps concentric muscle strength at (1) high and (2) low speeds, were associated with an increased risk of lower extremity injuries. In addition, greater bilateral adductor strength adjusted for weight was associated with a lower risk for knee injuries, which is a finding not previously reported in soccer.

Association Between Muscle Strength and Lower Extremity Injuries

Thigh Strength. Our finding of an association between greater quadriceps concentric peak torque strength at high (300 deg/s) and low (60 deg/s) speeds and the risk of injury (lower extremity injury and overuse injury) (Table 4) extends those of 2 other reports to suggest that greater quadriceps strength increases the risk of lower extremity injuries (particularly for a thigh muscle injury).[19,49] Despite the statistically significant association, the HR demonstrated merely a 0.4% to 0.5% increase in injury risk per 1-unit increase in concentric quadriceps strength (mean difference, 3.4 N·m [136.6 vs 133.2 N·m] and 8.0 N·m [240.6 vs 232.6 N·m], respectively). This finding, in addition to the small group difference in strength between the injured and uninjured players (2.5% and 3.4% strength difference, respectively), means that it is essentially impossible to distinguish the injured and uninjured groups clinically. Furthermore, the smallest detectable difference for concentric quadriceps peak torque is about 20%,[39] so the difference in strength between the injured and uninjured groups is equivalent to test-retest variability. It may be argued that intrinsic risk factors, such as muscle strength, are more relevant for noncontact than contact injuries. Interestingly, the association between greater quadriceps concentric peak torque strength at high speed (300 deg/s) remained the same (weak) when contact injuries were excluded, suggesting that the clinical value of this finding remains limited.

We found no association between any of the 13 isokinetic strength variables evaluated and the risk of acute lower extremity injuries or knee injuries, which argues against using isokinetic quadriceps and hamstring strength as an injury prediction tool. Our study extends the results of a prospective study on the risk of acute ACL injuries in male military academy cadets.[47]

TABLE 5
Univariate HRs for Relationship Between All Strength Variables and Other Candidate Risk Factors and Binary Outcome–Dependent Injury Variables (n = 1028 Legs)[a]

	Acute (n = 203)	Overuse (n = 169)	Any Knee (n = 70)	Acute Knee[b] (n = 39)
Age, y	**1.04 (1.01-1.07)**	1.02 (0.99-1.05)	1.01 (0.97-1.06)	1.02 (0.96-1.08)
Height, cm	1.01 (0.99-1.03)	1.00 (0.98-1.03)	1.00 (0.97-1.04)	0.98 (0.94-1.03)
Weight, kg	1.01 (0.99-1.02)	1.01 (0.99-1.02)	1.02 (0.99-1.05)	1.02 (0.99-1.06)
Body mass index, kg/m^2	1.03 (0.96-1.10)	1.03 (0.96-1.11)	1.13 (0.99-1.29)	**1.23 (1.06-1.42)**
Player position				
Goalkeeper[c]	1.00	1.00	1.00	1.00
Defender	1.29 (0.82-2.06)	**2.59 (1.29-5.20)**	0.81 (0.37-1.78)	1.07 (0.30-3.82)
Midfielder	1.50 (0.94-2.39)	1.93 (0.97-3.83)	0.89 (0.40-1.96)	1.74 (0.51-5.91)
Forward	1.42 (0.85-2.37)	**3.26 (1.58-6.72)**	1.49 (0.65-3.42)	2.10 (0.58-7.57)
Previous injury[d]				
Lower extremity injury (yes)	1.10 (0.82-1.47)	1.06 (0.76-1.48)	1.01 (0.60-1.69)	0.89 (0.45-1.77)
Knee injury (yes)	1.49 (0.95-2.34)	1.09 (0.65-1.85)	**2.18 (1.15-4.12)**	2.04 (0.85-4.86)
Dominant leg (yes)	**2.08 (1.54-2.80)**	1.14 (0.85-1.53)	1.33 (0.84-2.11)	1.79 (0.94-3.38)
Season (season 2)[e]	**1.67 (1.26-2.22)**	1.05 (0.77-1.44)	1.49 (0.92-2.39)	1.03 (0.54-1.94)
Quadriceps and hamstring strength				
Quadriceps concentric at 60 deg/s	0.99 (0.99-1.00)	**1.004 (1.00-1.01)**	0.99 (0.99-1.01)	1.00 (0.99-1.01)
BW adjusted, N·m/kg	0.88 (0.68-1.15)	1.30 (0.97-1.74)	0.75 (0.49-1.15)	0.94 (0.56-1.58)
Quadriceps concentric at 300 deg/s	1.00 (0.99-1.01)	1.01 (0.99-1.01)	1.00 (0.99-1.01)	1.01 (0.99-1.02)
BW adjusted, N·m/kg	1.01 (0.60-1.70)	1.49 (0.86-2.58)	0.86 (0.34-2.15)	1.08 (0.32-3.61)
Hamstring concentric at 60 deg/s	1.00 (0.99-1.01)	**1.01 (1.00-1.01)**	0.99 (0.99-1.01)	1.00 (0.99-1.01)
BW adjusted, N·m/kg	1.07 (0.65-1.74)	1.57 (0.99-2.46)	0.61 (0.30-1.23)	0.62 (0.27-1.45)
Hamstring concentric at 300 deg/s	1.00 (0.99-1.01)	1.01 (0.99-1.01)	1.00 (0.99-1.01)	1.01 (0.99-1.02)
BW adjusted, N·m/kg	1.03 (0.54-1.94)	1.33 (0.68-2.57)	0.53 (0.16-1.74)	0.68 (0.14-3.29)
Hamstring eccentric at 60 deg/s	1.00 (0.99-1.01)	1.00 (0.99-1.01)	1.00 (0.99-1.01)	1.00 (0.99-1.01)
BW adjusted, N·m/kg	1.16 (0.86-1.58)	1.12 (0.83-1.51)	0.85 (0.51-1.42)	0.82 (0.39-1.69)
HQ concentric ratio at 60 deg/s	2.33 (0.65-8.39)	0.99 (0.24-4.13)	1.25 (0.09-16.48)	0.25 (0.00-13.58)
HQ concentric ratio at 300 deg/s	0.85 (0.28-2.64)	0.75 (0.19-3.03)	0.24 (0.03-1.81)	0.20 (0.01-3.25)
HQ eccentric to concentric ratio at 60/300 deg/s	1.23 (0.78-1.93)	0.88 (0.51-1.54)	0.86 (0.34-2.19)	0.67 (0.14-3.13)
Hip strength				
Adductor squeeze at 45°	1.00 (0.99-1.00)	1.00 (0.99-1.00)	0.99 (0.99-1.00)	0.99 (0.99-1.00)
BW adjusted, N/kg	1.02 (0.87-1.20)	1.04 (0.86-1.26)	**0.77 (0.60-0.99)**	**0.66 (0.46-0.97)**
Hip eccentric adduction	0.99 (0.99-1.00)	0.99 (0.99-1.00)	1.00 (0.99-1.01)	1.00 (0.99-1.01)
BW and lever arm adjusted, N·m/kg	0.86 (0.68-1.10)	0.94 (0.72-1.24)	0.95 (0.67-1.35)	0.95 (0.60-1.51)
Hip eccentric abduction	1.00 (0.99-1.01)	0.99 (0.99-1.00)	1.00 (0.99-1.01)	1.00 (0.99-1.01)
BW and lever arm adjusted, N·m/kg	1.24 (0.92-1.66)	0.90 (0.62-1.30)	1.03 (0.62-1.71)	0.89 (0.42-1.92)
ADD:ABD ratio	**0.53 (0.31-0.91)**	0.99 (0.54-1.82)	0.85 (0.37-1.95)	1.15 (0.35-3.79)

[a]Data are presented as HR (95% CI). Hazard ratios (HRs), per 1 unit of change for continuous variables and change in the risk when compared with the reference category for categorical variables, are presented with 95% CIs and P values from Cox regression analyses accounting for clustering factors (player identity) and using leg as the unit of analysis. Bolded values indicate statistical significance. ADD:ABD, adduction-to-abduction; BW, body weight; HQ, hamstring-to-quadriceps.
[b]Acute knee injury refers to any acute ligament, meniscus, or cartilage injuries.
[c]Reference group.
[d]Previous injury refers to any injury occurring within 12 months before testing.
[e]Reference group: season 1 (2013/2014).

Hip Strength. We found no association between any of the hip strength variables examined (eccentric adductor and abductor strength as well as bilateral isometric adductor strength) and the risk of all lower extremity injuries nor acute or overuse injuries. In contrast, low adductor strength proved a risk factor for groin injuries in 2 recent meta-analyses on athletes in field-based sports.[42,51] A plausible explanation for the apparent discrepancy may be that while low hip adductor strength may be associated with a greater risk of groin injuries specifically, this effect may be diluted when looking at lower extremity injuries in general, even if muscle injuries comprised almost 50% of the injuries included in the current study (of which 28% were adductor-related injuries). Our results lend no support using these hip strength variables to identify the player at risk of lower extremity injuries.

Interestingly, we identified greater bilateral adductor strength, adjusted for weight, as a protective factor for any knee injury, decreasing injury risk by 23% per 1-N/kg increase in strength (which represents a 6% increase in strength relative to the group mean). This has previously not been described as an independent risk factor for knee injuries and contrasts with previous reports of the association between hip abductor weakness and an increased risk of ACL injuries and patellofemoral pain.[16,25] However, although statistically significant, the group difference in bilateral adductor strength between injured and uninjured players was small (3.14 vs 3.34 N/kg, respectively, corresponding to a mean difference of –0.2 N/kg). In addition, the smallest detectable difference for the adductor squeeze test is between 11% and 13%,[28] which most likely renders these findings clinically invaluable.

Muscle Imbalance. There was no association between any of the ratios examined in the current study (HQ ratio and ADD:ABD ratio) and the risk of lower extremity injuries, regardless of injury type (lower extremity injury and acute, overuse, or knee injury). Although univariate analysis revealed that players with a lower ADD:ABD ratio were at an increased risk of lower extremity injuries, these findings were not confirmed in the multivariate model. Our findings suggest that muscle imbalance as expressed in an HQ ratio or ADD:ABD ratio does not identify players at risk of a lower extremity injury. Similar findings have been reported for the HQ ratio in a meta-analysis on risk factors for hamstring injuries.[19] In contrast to our result, 2 recent systematic reviews on risk factors for groin injuries reported the ADD:ABD ratio as a significant risk factor.[42,51]

Predictive Ability of Muscle Strength Testing

In addition to demonstrating an association with injuries, a valid screening tool to predict a sports injury should distinguish athletes at high risk of injuries from those who are not.[1] The ROC curve analyses revealed an AUC of <0.50 (0.46 for quadriceps concentric strength at 300 deg/s and 0.45 for quadriceps concentric strength at 60 deg/s) for strength variables identified as potential risk factors for lower extremity injuries, confirming that these variables are no better than chance (or flipping a coin) in predicting the player at risk of lower extremity injuries.[35] This inability to predict injuries is substantiated by the small association and group difference in strength between the injured and uninjured players for these 2 strength variables; there was no cutoff point on the horizontal (bilateral adductor strength score) axis that would allow us to distinguish between injured and uninjured players. Similarly, the ROC curve analysis for bilateral adductor strength revealed an AUC of 0.56, confirming that the ability of the strength variable to predict the player at risk of a knee injury was also poor.

Should Muscle Strength Tests Be Used to Screen for Injury Risk in Professional Soccer?

While our results suggest that muscle strength testing is not useful as a screening tool to identify the individual players at risk, it does not necessarily mean that clinicians should not use muscle strength testing in preseason screening. Such testing may identify current conditions that require further assessment or treatment.[4] It is possible to intervene with strength training to reduce lower extremity injuries in soccer.[3,44] For example, the implementation of the Nordic hamstring exercise for eccentric hamstring strength reduces the risk of acute hamstring injuries by at least 50%.[3,40,48] Specific adductor strength training can prevent groin injuries in subelite soccer players.[23] On the basis of our results, such prevention programs should be implemented at a group level (ie, team) rather than on the individual level based on screening tests.

In addition, strength testing may also be a useful baseline measure as a reference point for a future return-to-play decision and perhaps also as a measure of the effect of strength training programs to prevent injuries. Injuries generally result from a complex interaction of multifactorial factors[33]; a player's injury risk is probably dynamic and subject to frequent changes in external factors (heavy training load, congested playing schedule, or psychological factors).[33,34] Multiple assessments (or monitoring) of the player throughout the sports season may represent a more suitable strategy to prevent injuries.[20] Wollin et al[52] recently reported clinically meaningful isometric adductor strength reduction during periods of match congestion in elite youth soccer players compared with baseline, when players were monitored daily for adductor strength.

Methodological Considerations

To detect strong to moderate associations in a prospective cohort study, 30 to 40 injury cases are required,[2] whereas 200 injury cases are required to detect small to moderate associations.[2] The large number of participants and injured players represents a strength in the current study (n = 294 injured legs). The organization of sports medicine care in Qatar, with all club medical doctors being part of the centrally regulated National Sports Medicine Program, allowed for standardization of injury and exposure recording.

Limitations to the present study include the fact that the team medical staff responsible for injury and exposure reporting was not blinded to the muscle strength scores. Also, we did not control for preventive measures that may have been implemented based on the player's strength test score during the study period. Given the high number of injuries recorded during the 2 seasons (n = 538), we believe that these factors represent a low risk of bias.

We acknowledge that the strength tests examined in the current study are commonly used to identify the risk of muscle injuries to the thigh, particularly to hamstring strain and groin injuries, and not to identify the risk of lower extremity injuries in general. However, these tests are frequently used in the assessment of other injury types (ie, knee injury) than hamstring strain and groin injuries. For this reason, we performed subanalyses for acute, overuse, and knee injuries.[5,7,16] Given that muscle strength is considered an important factor in injury causation,[7,34] we believe that examining the injury prediction value of these tests for any injury type is valuable.

We measured strength with standard measurement procedures widely used in clinical practice.[32,51] Other testing protocols may yield different results, particularly for isokinetic strength testing. Measuring knee extension and flexion strength at different angular velocities provides additional information on quadriceps strength deficits after an ACL injury.[12]

Although our sample size was large and allowed for small to moderate associations to be detected for lower extremity, overuse, and acute injuries,[2] the limited number of knee injuries reduced the statistical power for such subgroup analyses. This may have affected the conclusions drawn, and potential associations may have been masked.

Another limitation is related to the fact that injuries were from different mechanisms (contact or noncontact). We relied on the team doctor to classify the injury as contact or noncontact, but this was often not reported perhaps because it may be difficult to interpret what happens in an injury situation.[26] As a result, the statistical power to perform subgroup analyses other than for any lower extremity injury was limited.[2] Finally, our study included male professional soccer players, which limits the generalizability of the findings to other sports, age groups, athletes at lower performance levels, and female athletes.

CONCLUSION

This study identified only a weak association with the risk of lower extremity injuries for 2 strength variables: quadriceps concentric muscle strength at (1) high and (2) low speeds. These associations were too small to identify the individual player at risk of injuries. Therefore, strength testing, as performed in the present study, cannot be recommended as a screening tool to predict injuries in professional male soccer.

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