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Musculoskeletal screening tests and bony hip morphology cannot identify male professional soccer players at risk of groin injury: a 2 year prospective cohort study

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ABSTRACT

Background

Musculoskeletal hip/groin screening tests are commonly performed to detect at-risk individuals. Bony hip morphology is considered a potential intrinsic risk factor, but has not been examined prospectively.

Hypothesis/Purpose

This exploratory study aimed to evaluate the association between intrinsic risk factors identified from musculoskeletal and X-ray screening, and hip/groin injuries leading to time loss from training and/or match play in professional male soccer players.

Study Design

Prospective cohort study

Methods

Male professional soccer players, aged ≥ 18 years, underwent screening specific for hip/groin pain during two consecutive seasons of the Qatar Stars League. The screening battery included: pain provocation, range of motion, and strength tests, and hip X-ray examination. X-ray screening included an AP pelvic and 45° Dunn view, with bony hip morphology determined using quantitative methods. Time-loss (>1 day) hip/groin injuries and individual player exposure (training and match play) were recorded prospectively, and injuries were categorized as: adductor-related, inguinal-related, iliopsoas-related, pubic-related, hip-related groin pain, or "other", as recommended in the Doha agreement. We calculated hazard ratios from univariate and multivariate Cox regression models to assess the relationship between potential risk factors and hip/groin injury.

Results

There were 438 players, completing 609 player seasons, and 113 hip/groin injuries that met the criteria for inclusion, with 85 injuries categorized as adductor-related. The proportion of players with bony morphological variants was: cam 71%, pincer 5%, acetabular dysplasia 13%. Previous hip/groin injury (hazard ratio= 1.8; 95% confidence intervals, 1.2-2.7) and eccentric adduction strength were associated with hip/groin injury risk. Higher (>1SD above the mean) than normal eccentric adduction strength was associated with increased risk for all hip/groin injuries (hazard ratio=1.6; 95% confidence intervals, 1.0-2.5). Lower (<1SD below the mean) than normal eccentric adduction strength was associated with increased risk for adductor-related injuries (hazard ratios=1.7; 95% confidence intervals, 1.0-3.0). No other musculoskeletal screening test, or bony hip morphology, variables were associated with injury risk.

Conclusion

Previous groin injury and eccentric adduction strength were associated with groin injury risk. However, these associations were not strong enough to identify an 'at-risk' individual and therefore, not useful screening tests to dictate individualized prevention strategies. Bony hip morphology was not associated with groin injury risk.

Key Terms: adductor, sport, strain, femoroacetabular impingement, pubic

What is known about the subject?

Hip/groin pain is common in soccer and results in considerable burden for a player and their team. To date, groin injury prevention has had limited success, and there is conflicting evidence regarding the risk factors for hip/groin injury. Bony hip morphology (cam, pincer, dysplasia) have recently been suggested as a potential intrinsic risk factor, but these bony hip morphologies have never been investigated prospectively in an athletic population.

What this study adds to existing knowledge:

1. Bony hip morphology (cam, pincer or dysplasia) is not associated with groin injury risk in male professional soccer players in Qatar.
2. Previous groin injury and eccentric adduction strength (both high and low) were weakly associated with increased risk of groin injury.
3. Baseline musculoskeletal screening specific for hip and groin pain is ineffective at predicting at-risk individuals.
4. Hip/groin injury prevention programs are likely to be less effective if implemented at the individual level, based on screening test response, than at the group level.

INTRODUCTION

Hip and groin injury is common in professional soccer and causes considerable time lost from training and match play.[14,21,33,45] In the Qatar Stars League (QSL), the premier professional league in Qatar, 21% of players experienced a hip/groin injury per season over two seasons, with an overall injury burden of 24.3 days/1000 h exposure.[33] Despite knowledge of the high burden of groin injury, prevention programs have limited success.[15] The identification of risk factors for injury was highlighted as an important component of a successful injury prevention model.[16,29]

Musculoskeletal screening tests are commonly performed in soccer to detect individuals with these risk factors, aiming to prescribe individualised, targeted injury risk reduction programs based on the test findings.[5] Intrinsic, or player-related, risk factors for hip/ groin injury in soccer have been reported from prospective studies.[4,14,21,25,45,47] Most studies were conducted over a single season,[4,14,25,47] with analyses potentially hampered by low injury numbers. In addition, only 3 studies used a multivariate models of analysis,[4,14,21] and only two studies accounted for individual exposure time.[14,21] Two recent systematic reviews synthesised the findings of the studies investigating risk factors for hip/groin injury.[35,46] Both reviews concluded that previous injury and low adduction strength (both absolute and relative to abduction strength) were significant risk factors. The reviews described conflicting results for hip range of motion as a risk factor for hip/groin injury, with a positive finding in field-based sports,[35] but no association in all sports.[46] Furthermore, heterogeneity between the included studies in both risk factor methodology and injury definition precluded meta-analyses. Consequently, the clinical significance of these associations with groin injury risk is difficult to assess. Therefore, prospective research with large sample sizes, using optimal injury and exposure surveillance methodology, is required. [6,17,41]

Cam morphology is associated with the presence of femoroacetabular impingement syndrome (FAIS)[18] and therefore considered a potential intrinsic risk factor for hip/groin injury.[9,27] Athletes presenting with longstanding groin pain have a high prevalence of bony hip morphology associated with FAIS.[24,43] However, there is growing evidence that cam morphology is also present in many asymptomatic hips,[19,26] and has a high prevalence in soccer players, independent of symptoms.[2,32,37] Therefore, the relationship between bony hip morphology and clinical signs and symptoms of hip/groin pain in athletes is unclear. Furthermore, the potential association between bony hip morphology and the risk of developing hip/groin injury in soccer players has never been examined prospectively.

Our aim was to examine the association between musculoskeletal hip/groin screening tests and bony hip morphology, to time-loss hip/groin injury in male professional soccer players.

MATERIALS AND METHODS

Study Design and Participants

This prospective cohort study was conducted during the 2013-14 and 2014-15 soccer seasons of the QSL. The QSL is the highest level of professional soccer in Qatar and during the study observation period comprised of 14 clubs in the first division and 18 clubs in the second division. The regular soccer season ran from the end of August to the end of April. The QSL finals and post-competition cups were played in May each year. Soccer teams in the QSL generally train 5 days per week and on average play one game each week.

All study participants were male soccer players aged > 18 years who played professionally in Qatar during one or both of these football seasons. Players who left the QSL during the season (due to club transfer or personal reasons) were included in the cohort until their departure.

Soccer players underwent pre-competition, Fédération Internationale de Football Association (FIFA)-compliant screening in one or both soccer seasons as previously described in detail.[7,8,31,32] This screening was deemed mandatory by the QSL for all soccer players playing in the league and all screening was performed at Aspetar Orthopaedic and Sports Medicine Hospital, Qatar. During the musculoskeletal component of the screening, players were informed of the study, and invited to participate. The study participants therefore represent a sample of convenience of all soccer players in the QSL. A flow diagram of the inclusion of participants for the study analysis is presented in Figure 1. Players with an injury other than to the hip/groin, but who completed the full groin screening, were included with reduced exposure reflecting their time-loss injury. Players who presented to screening with a current time-loss hip/groin injury were excluded from the analysis for that season. Players were also excluded if injury and exposure surveillance data were missing for that season.

All soccer players were given the option of not allowing their data to be used for research purposes, and all study participants provided written informed consent for the study. Ethical approval was obtained from the Institutional Review Board, Anti-doping Lab Qatar (Approval number: F2013000003). The reporting of this study follows the STROBE statement.[40]

Hip/groin musculoskeletal screening protocol

A comprehensive screening test battery, specifically designed to examine potential demographic, musculoskeletal and bony morphological risk factors for hip/groin injury, was conducted.

Demographics

Demographic information was acquired from each participant as part of the screening process including: date of birth, height, weight, player position (goalkeeper, defender, midfielder, forward), leg dominance (preferred leg for a penalty kick), previous hip/groin injury history and current hip/groin symptoms. To reduce the risk of recall bias, previous hip/groin injury was defined as a time-loss hip/groin injury from the preceding 12 months, confirmed by prospectively recorded injury surveillance data.[21] The player's medical notes were consulted to resolve any discrepancies and ensure accuracy of this variable. The new QSL signings included in the study did not have prospectively recorded injury surveillance data from the previous year, and did not have case notes available to consult. Therefore, in order to ensure best achievable accuracy of injury recall for these players, all media sources were reviewed for reports on previous injury.

Pain Provocation tests

Each player was screened using the following four pain provocation tests (Appendix 1):

- Flexion, adduction, internal rotation test (FADIR).
- Flexion, abduction, external rotation test (FABER).
- Squeeze test at both 0° and 45° of hip flexion.

Pain severity was recorded for each test using an 11-point numeric rating scale (0-10), with location of pain also recorded. A test was considered positive only if pain was reported in the expected location for each test: FADIR - anterior and/or deep hip/groin pain, FABER - deep hip/groin pain, squeeze test - adductor or pubic pain.

Range of motion

Hip joint range of motion was assessed using five different tests which were described in detail, including pictorial and inter-rater reliability findings, in a prior publication (Appendix 1).[31] Methods are described briefly below:

- Hip internal rotation (IR) range of motion was examined with the player in supine and 90° of hip flexion, measured with a goniometer.
- Hip external rotation (ER) range of motion was examined with the player in supine and 90° of hip flexion, measured with a goniometer. This test was added in the second season of screening.
- Hip internal rotation (IR) range was also measured in prone using two digital inclinometers.

- Bent knee fall out (BKFO) was measured bilaterally using a rigid tape measure with the player in supine, 45° of hip flexion and 90° knee flexion.
- Hip abduction range was measured in side-lying using a digital inclinometer.

Strength

Hip strength was measured with three tests which were also described in detail, including pictorial and inter-rater reliability findings, in a prior publication (Appendix 1).[31] Methods are described briefly below:

- Hip adduction and abduction strength were measured in side-lying with a hand held dynamometer using an eccentric break test.[31] These eccentric strength measures were normalized to body weight and lever arm for each participant.
- Bilateral isometric hip adduction strength was measured using the squeeze test with the legs in 45° hip flexion, and 90° knee flexion. A hand held dynamometer was placed between the knees and bilateral isometric adduction strength was normalised to body weight.

Radiographic Examination

The methodology for the X-ray screening has been described in detail, including inter-rater reliability in a prior publication.[32] Two standardized views were obtained; a standing anteroposterior (AP) pelvic view with both hips in 15° of internal rotation, and a 45° Dunn view of both hips.[32] The 45° Dunn view was performed with the participant in supine, and hips placed in 45° flexion, neutral rotation and 20° abduction. A film-focus distance of 115cm was used, with the beam centred at 2.5cm superior to the pubic symphysis for the AP view, and centralized over the pubic symphysis for the Dunn view. Bony hip morphology was quantified using previously described quantitative measures of the alpha angle and lateral centre edge angle (LCEA).[1,3,32] These quantitative measures were automatically calculated using MATLAB v7.1.0 software (mathWorks Inc, Natick, Massachusetts, USA) from a point set that was manually positioned along the contour of the bone on the radiograph.[32] The bony hip morphology variables were then dichotomised according to the following definitions; cam morphology = alpha angle >60° on either the AP or Dunn view, large cam morphology= alpha angle >78° on either the AP or Dunn view, pincer deformity = LCEA >40° and acetabular dysplasia= LCEA< 20°.[32] All X-rays were performed at the Department of Radiology, Aspetar Orthopaedic and Sports Medicine Hospital, Doha, Qatar.

Injury definition and surveillance

Hip/groin injury was defined as previously described by Werner et al 2009:[45] "Injury located to the hip joint or surrounding soft tissues or at the junction between the anteromedial part of the thigh, including the proximal part of the adductor muscle bellies, pubic symphysis, and the lower abdomen, that resulted from playing soccer and led to a player being unable to fully participate in future training or match play (i.e. time-loss injury)." Hip/groin injuries were subsequently categorized as the four defined clinical entities of: adductor-related, iliopsoas-related, inguinal-related, pubic-related groin pain, and the two additional categories of hip-related groin pain, and 'other". This categorization followed the recommendations outlined in the consensus statement that resulted from the Doha agreement meeting held between leading clinicians and researchers in the field of hip/groin injury in November, 2014.[42] The process of this categorization is described in detail in a previous publication.[33]

Only index hip/groin injuries were included in the analysis, with injury and exposure data for the injured player censored for the remainder of the season until they attended screening again. Injuries were included in the analysis only if they occurred within 12 months following musculoskeletal screening. Contusion injuries that resulted from direct contact and medical causes of hip/groin injury were excluded from the analysis. A secondary risk factor analysis was conducted with the dependent variable being injuries categorized as adductor-related groin pain. The comparative group was injury free players, so in this secondary analysis, players were excluded for that season if they sustained a hip/groin injury of a category other than adductor-related groin pain.

Injury and exposure surveillance

Prospective injury and exposure surveillance of the QSL was conducted through the Aspetar Injury and Illness Surveillance Program (AIISP) between July 2013-May 2014 (season 1) and July 2014-May 2015 (season 2).[8] All time-loss injuries, and individual player participation (training and match play exposure in minutes), were recorded by the club medical staff using previously described standardised methods.[8,13,20,45] These methods are in accordance with the “Consensus statement on injury definitions and data collection procedures in studies of football (soccer) injuries”.[17] Club doctors completed a standardised injury card for each injury sustained during the observation period. The injury cards contained information on the injury type, recurrence, mechanism, location, diagnosis, severity in days lost, plus activity being undertaken when injured (training or match). The clinical diagnosis for hip/groin injury was determined by the club doctors who were familiar and trained in both the terminology and clinical entity approach.[23] Injury surveillance and exposure data was requested monthly by the research team, and the accuracy was regularly checked against the exposure data, and clarified with club medical staff as required.

Statistical Analyses

To examine the association between the potential intrinsic risk factors and the development of a time-loss hip/groin injury, univariate Cox regression survival analyses were performed with each leg as the unit of analysis and clustered for player identity. The clustering of player identity in the statistical model took into account the correlation between the two legs of each player for the independent variables, and the repeated measures performed for players that attended screening both seasons. All analyses were performed in Stata, version 11 (Stata Corporation, College Station, Texas). The statistical model included exposure time to index injury, or exposure time to end of the season if the player did not sustain a time-loss hip/groin injury. Hazard ratios (HR) with 95% CIs are presented for all independent variables. The player-related demographic variables examined were: age, height, weight, body mass index, playing position, leg dominance and previous groin injury. In addition to these demographic variables all musculoskeletal screening test results as well as femoral and acetabular morphology, were included in the univariate analysis. Since we expected a non-linear relationship between the continuous independent variables and the dependent variable, stratification of all range of motion and strength variables were also included in the univariate analysis. These variables were categorized as: low group (less than 1 standard deviation (SD) below the mean), normal reference group (between 1SD below and 1SD above the mean), high group (greater than 1SD above the mean). A significantly associated independent variable was defined as one with a p value <0.05, while a candidate variable was defined as one with a p value ≤ 0.1 in the univariate analyses. Independent variables that demonstrated an association with hip/groin injury in the univariate analyses with a p value ≤ 0.1 were included in a backward stepwise multivariate Cox regression analysis. For the multivariate analysis, the significance level was set at $p<0.05$. The same procedure was then repeated with adductor-related groin injuries as the dependent variable.

RESULTS

Participants

A total of 438 individual male soccer players, representing 609 player seasons, were included in the final cohort (Figure 1). The number of excluded players from the study analysis are also summarized in Figure 1. There were 105 players who were screened only in season 1, 171 players screened in both seasons, and 162 players screened only in season 2.

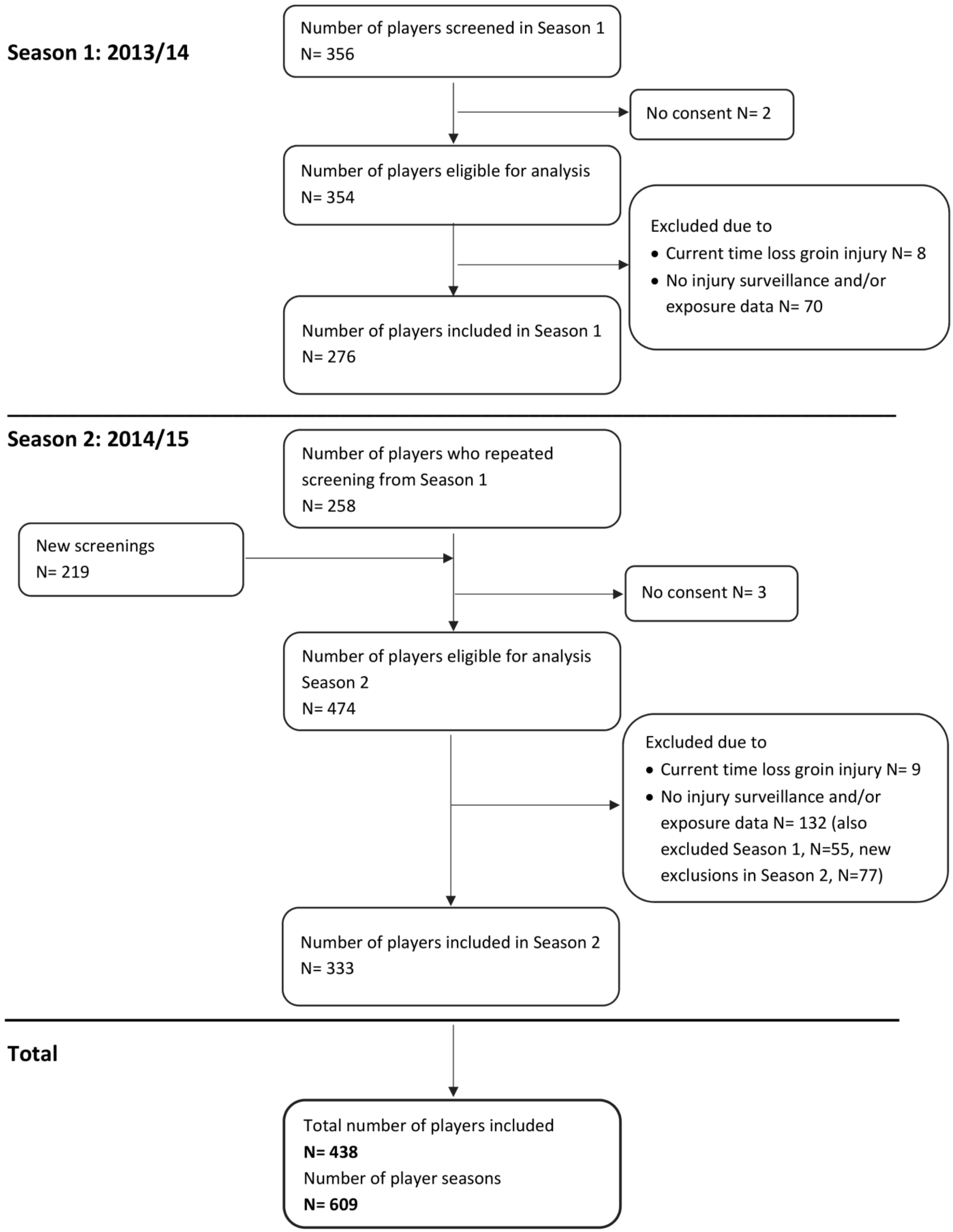

Figure 1 Flow diagram for study cohort inclusion. The movement of players, and repeated measurements between the two seasons, is shown.

At baseline, the participants were 26 ± 5 years old (18-38), height= 1.77 ± 0.67 m (1.56-2.04), weight= 72 ± 9 kg (47-105), BMI= 23.2 ± 2.0 kg/m^2 (17.8-29.1). There were 46 (11%) goalkeepers, 151 (35%) defenders, 159 (36%) midfielders and 82 (19%) forwards and 350 (80%) of the players were right-leg dominant. Of the 438 players included, 97 (22%) sustained an index hip/groin injury in one or both of the two QSL seasons. Players experienced a mean of 234 ± 109 hours of total exposure per season, of which 209 ± 102 hours were training and 25 ± 18 hours were match play.

Injury epidemiology

The epidemiology for time-loss hip/ groin injury for the 2013/14 and 2014/15 seasons of the QSL has previously been described in detail.[33] In summary, there were 206 hip/groin injuries (18% of all time-loss injuries) sustained by 150 individual players. Overall incidence of hip/groin injury was 1.0/1000 hours (95% CI 0.9 to 1.1). A higher incidence of hip/groin injury occurred during match play 3.5/1000h (95% CI 2.7-4.3) than training 0.7/1000h (95% CI 0.6-0.8, $p < 0.001$). The median proportion of players injured per club per season was 21% (IQR 10–28%). There were 6.6 (IQR 2.9–9.1) time loss hip/groin injuries sustained per season per average club roster of 30 players.[33]

Of the 206 hip/groin injuries that were sustained in the QSL during the observation period, 113 index hip/groin injuries met the inclusion criteria. Injuries were excluded for the following reasons: injury did not occur within 12 months following screening (58 injuries), second injury in the same season (24), contusion injury (5), no exposure data recorded for the player (5), player not screened (1).

Of the 113 injuries included in the analysis, 85 (75%) were categorized as adductor-related, 15 (13%) iliopsoas-related, 8 (9%) inguinal-related, 14 (12%) pubic-related, and 1 (1%) hip-related groin pain. There were 101 (89%) cases with a single category of groin pain, 10 (9%) cases with two categories and 2 (2%) cases with three categories. The median time-loss for the 113 hip/groin injuries included in the analysis was 11 days (IQR 6-25, range 1-209 days).

Prevalence of bony morphological variants

The prevalence of bony morphological variants in our cohort was as follows: cam morphology 59% per hip and 71% per player; large cam morphology 22% per hip, 33% per player; pincer morphology 3% per hip, 5% per player; acetabular dysplasia 9% per hip, 13% per player.

Risk Factors for hip/ groin injury identified from the screening battery

Table 1 presents the results of the univariate Cox regression analysis for all independent variables, with leg as the unit of analysis and all hip/groin injuries as the dependent variable. The univariate analysis found the following independent variables significantly associated with hip/groin injury: previous injury, eccentric adduction strength (high group) and external rotation range of motion (high group). The candidate variables (p-values between 0.05 and 0.1) identified in the univariate analysis were: dominant limb, player position, squeeze strength (continuous), eccentric adduction strength (low group). Due to missing data on ER range of motion (Table 1), this variable was not included in the multivariate analysis. All other significantly associated and candidate variables were included in the multivariate analysis with the final results shown in Table 2. Previous injury (HR= 1.8, 95% CI 1.2-2.7) and having higher than normal eccentric adduction strength (HR= 1.6, 95% CI 1.0-2.5) were identified as significant risk factors for hip/groin injury. Figure 2 graphically demonstrates the lower survival rate (time to first injury) of soccer players with previous hip/groin injury. Figure 3 exhibits the mean difference in eccentric adduction strength between the injured and uninjured legs of the soccer players.

Table 1 Univariate risk factor analysis of all hip/groin injuries. Results are presented as number of legs or means with standard deviations, as appropriate.

	Total Legs (n=1218)	Uninjured (n=1105)	Injured (n=113)	Absolute risk (%) or MD[¥]	HR[*]	95% CI	p value
Demographics				MD			
Age (yrs)	1218	26 ± 4.7	26 ± 4.3	-0.03	1.00	0.96-1.04	0.862
Height (cm)	1218	177 ± 6.7	176 ± 6.5	-0.52	0.99	0.96-1.02	0.389
Weight (kg)	1218	72 ± 9.1	72 ± 9.1	-0.19	1.00	0.98-1.02	0.806
BMI (kg/m2)	1218	23 ± 2.0	23 ± 2.1	0.08	1.02	0.93-1.12	0.629
Limb dominance				%			
Non-dominant limb	609	562	47	8	1.00		
Dominant limb	609	543	66	11	1.40	0.99-2.00	0.060
Player position[#]							
Goal keeper	134	126	8	6	1.00		
Defender	422	385	37	9	1.58	0.67-3.68	0.293
Midfield	448	403	45	10	1.83	0.80-4.21	0.154
Forward	214	191	23	11	2.14	0.86-5.32	0.100
Previous groin injury^							
No	1029	945	86	8	1.00		
Yes	189	160	27	14	**1.76**	**1.14-2.69**	**0.010**
Season							
Season 1 (2013/14)	552	498	54	10	1.00		
Season 2 (2014/15)	666	607	59	9	1.15	0.80-1.66	0.458
MUSCULOSKELETAL SCREENING							
Pain Provocation tests				%			
FADIR (pain NO)	1144	1041	103	9	1.00		
FADIR (pain YES)	72	63	9	13	1.52	0.77-3.00	0.227
FABER (pain NO)	1190	1082	108	9	1.00		
FABER (pain YES)	26	22	4	15	1.61	0.57-4.55	0.367
SQUEEZE 0° (pain NO)	1135	1028	107	9	1.00		
SQUEEZE 0° (pain YES)	81	76	5	6	0.56	0.23-1.39	0.210
SQUEEZE 45° (pain NO)	1104	998	106	10	1.00		
SQUEEZE 45° (pain YES)	108	102	6	6	0.58	0.23-1.50	0.265

					Continuous variables			Categorical variables					
								low (1SD below mean)			high (1SD above mean)		
Range of Motion tests	Total Legs	Uninjured	Injured	MD	HR	95% CI	p value	HR	95% CI	p value	HR	95% CI	p value
IR 90° flexion (°)	1216	35 ± 8.1	34 ± 7.5	-0.45	0.99	0.97-1.01	0.493	0.67	0.37-1.23	0.200	0.65	0.37-1.15	0.140
ER 90° flexion (°)	666	38 ± 8.7	39 ± 9.2	1.25	1.02	0.98-1.05	0.328	1.17	0.50-2.74	0.712	**1.96**	**1.06-3.60**	**0.031**
Total rotation (°)	666	70 ± 10.5	71 ± 11.4	0.89	1.01	0.98-1.04	0.487	1.62	0.78-3.38	0.193	1.48	0.76-2.85	0.246
BKFO (cm)	1212	13.4 ± 4.3	13.2 ± 4.1	-0.17	0.98	0.94-1.03	0.468	0.86	0.49-1.50	0.595	0.82	0.46-1.45	0.491
Abduction (°)	1216	48 ± 7.8	48 ± 7.9	-0.03	1.00	0.98-1.03	0.721	0.73	0.40-1.33	0.303	1.06	0.63-1.78	0.840
IR prone (°)	1214	37 ± 7.9	38 ± 7.4	0.75	1.01	0.99-1.04	0.237	0.85	0.50-1.45	0.552	1.13	0.66-1.93	0.649
Strength tests													
SQUEEZE 45° (N)	1210	242 ± 63	250 ± 60	8.01	1.00	1.00-1.01	0.100	0.74	0.42-1.31	0.307	0.98	0.55-1.74	0.937
SQUEEZE 45° (N/kg)	1210	3.4 ± 0.8	3.5 ± 0.8	0.12	1.22	1.00-1.49	0.051	0.62	0.32-1.20	0.159	1.18	0.70-1.99	0.541
Eccentric Add (Nm/kg)	1202	3.0 ± 0.6	3.1 ± 0.7	0.02	1.06	0.75-1.50	0.736	1.56	0.94-2.56	0.082	**1.65**	**1.06-2.57**	**0.026**
Eccentric Abd (Nm/kg)	1208	2.5 ± 0.4	2.5 ± 0.4	0.00	1.08	0.68-1.70	0.742	0.69	0.37-1.28	0.240	0.96	0.57-1.61	0.867
Ratio Add/Abd	1199	1.2 ± 0.3	1.3 ± 0.3	0.01	1.05	0.50-2.20	0.899	0.97	0.57-1.65	0.911	0.82	0.47-1.45	0.504
X-RAY SCREENING				%									
No Cam (α<60°)	372	339	33	9	1.00								
Cam (α>60°)	590	532	58	10	1.12	0.73-1.71	0.619						
Small Cam (α=60-78°)	377	337	40	11	1.19	0.75-1.88	0.465						
Big Cam (α>78°)	213	195	18	8	0.98	0.55-1.75	0.950						
Normal acetabulum (LCEA= 20-40°)	842	765	77	9	1.00								
Acetabular dysplasia (LCEA<20°)	94	83	11	12	1.20	0.64-2.28	0.571						
Pincer (LCEA>40°)	26	23	3	12	1.32	0.44-3.97	0.625						

[¥]MD= mean difference between the injured and uninjured legs

*Hazard ratio (HR) per 1-unit of change for continuous variables and relative risk when compared to the reference category for categorical variables. Significant associations (HR) and p values are bolded

[#]Reference group: goalkeeper

^Previous groin injury refers to any hip/groin injury occurring within 12 months prior to screening

BMI= body mass index, FADIR= flexion, adduction, internal rotation test, FABER= flexion, abduction, external rotation test, IR= internal rotation, ER= external rotation, Add= Adduction, Abd= abduction, N=newton, Cam= cam morphology, α= alpha angle, LCEA= lateral centre edge angle

Table 2: Results of the multivariate cox regression analysis of potential risk factors for all hip/groin injuries with p≤ 0.1 identified from the univariate analysis

Risk Factors	HR*	95% CI	p value
Previous hip/groin injury	**1.78**	**1.16 - 2.73**	**0.008**
Dominant leg	1.39	0.99 - 1.97	0.061
Eccentric adduction strength (low group)	1.51	0.93 - 2.47	0.099
Eccentric adduction strength (high group)	**1.62**	**1.04 - 2.51**	**0.032**

*Hazard ratio (HR) defines the relative risk compared to the reference category. Significant associations (HR) and p values are bolded

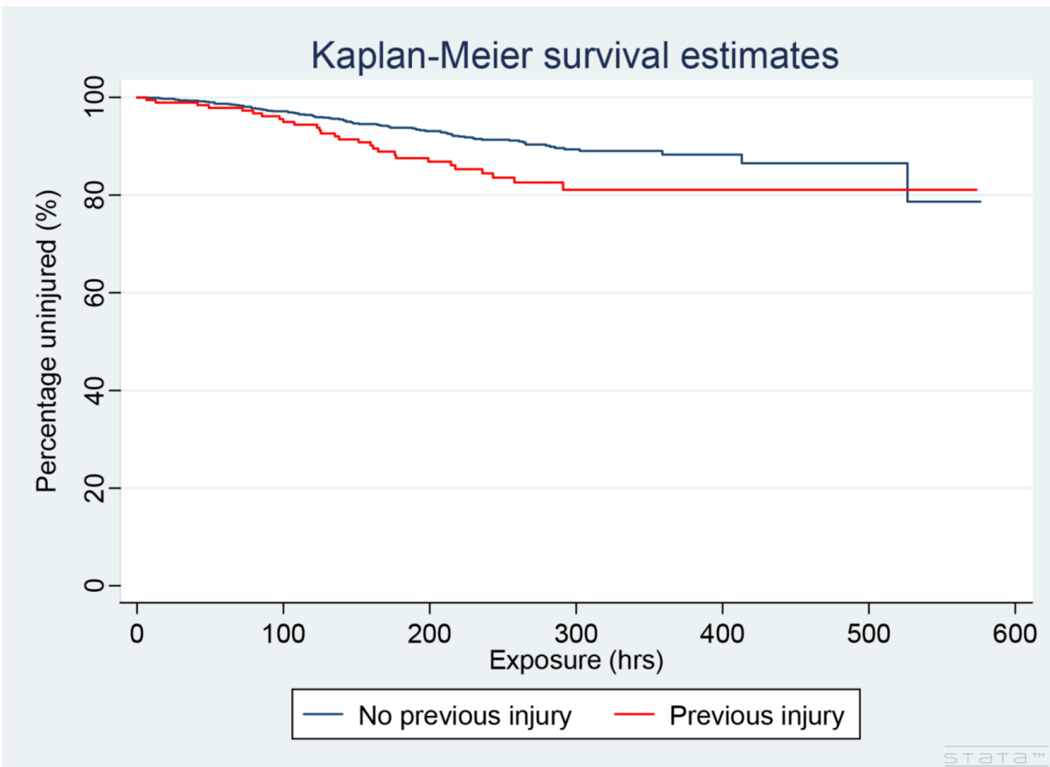

Figure 2: Survival curve demonstrating the lower survival rate of the soccer players with previous hip/groin injury compared to those without a previous hip/groin injury.

Table 3 presents the results for the secondary univariate cox regression analysis with the dependent variable being adductor-related groin injuries only. The following independent variables were significantly associated with adductor-related groin injury: previous injury, and eccentric adduction strength (low group). Candidate variables included: hip internal rotation (continuous and high group), and external rotation (high group). The secondary multivariate analysis (Table 4) revealed that previous injury (HR= 2.1, 95% CI 1.3-3.4) and having lower than normal eccentric adduction strength (HR =1.7; 95% CI 1.0-3.0) increased the risk of sustaining an adductor-related groin injury. Figure 3 exhibits the mean difference in eccentric adduction strength between the legs of the soccer players who sustained an adductor-related groin injury and those that did not.

Table 3 Univariate risk factor analysis of adductor-related groin injuries. Results are presented as number of legs or means with standard deviations, as appropriate

	Total Legs (n=1170)	Uninjured (n=1085)	Injured (n=85)	Absolute risk (%) or MD[¥]	HR*	95% CI	p value
Demographics							
Age (yrs)	1170	26 ± 4.7	27 ± 3.9	0.68	1.03	0.99-1.07	0.160
Height (cm)	1170	177 ± 6.7	176 ± 6.7	-0.62	0.98	0.95-1.02	0.377
Weight (kg)	1170	73 ± 9.1	72 ± 9.4	-0.06	1.00	0.98-1.02	0.942
BMI (kg/m^2)	1170	23 ± 2.0	23 ± 2.1	0.14	1.04	0.94-1.16	0.454
Limb Dominance				%			
Non-dominant limb	585	550	35	6	1.00		
Dominant limb	585	535	50	9	1.43	0.93-2.20	0.104
Player position[#]							
Goal keeper	132	125	7	5	1.00		
Defender	400	376	24	6	1.20	0.51-2.79	0.679
Midfield	436	397	39	9	1.82	0.81-4.08	0.148
Forward	202	187	15	7	1.63	0.66-3.99	0.288
Previous groin injury^							
No	990	928	62	6	1.00		
Yes	180	157	23	13	**2.05**	**1.28-3.29**	**0.003**
Season							
Season 1 (2013/14)	524	486	38	7	1.00		
Season 2 (2014/15)	646	599	47	7	1.25	0.82-1.89	0.297
MUSCULOSKELETAL SCREENING							
Pain Provocation tests				%			
FADIR (pain NO)	1101	1024	77	7	1.00		
FADIR (pain YES)	67	60	7	10	1.58	0.73-3.44	0.246
FABER (pain NO)	1144	1062	82	7	1.00		
FABER (pain YES)	24	22	2	8	1.14	0.28-4.64	0.858
SQUEEZE 0° (pain NO)	1088	1008	80	7	1.00		
SQUEEZE 0° (pain YES)	80	76	4	5	0.58	0.21-1.37	0.290
SQUEEZE 45° (pain NO)	1058	978	80	8	1.00		
SQUEEZE 45° (pain YES)	106	102	4	4	0.50	0.19-1.37	0.175

						Continuous variables			Categorical variables					
								1SD below mean			1SD above mean		
Range of Motion tests	Total Legs	Uninjured	Injured	MD	HR	95% CI	p value	HR	95% CI	p value	HR	95% CI	p value
IR 90° flexion (°)	1168	35 ± 8.1	33 ± 6.9	-1.32	0.98	0.96-1.01	0.070	0.72	0.37-1.38	0.318	0.52	0.25-1.09	0.083
ER 90° flexion (°)	646	37 ± 8.7	39 ± 9.2	1.44	1.02	0.98-1.06	0.291	1.14	0.46-2.84	0.777	1.97	1.00-3.90	0.051
Total rotation (°)	646	70 ± 10.5	71 ± 12	0.52	1.01	0.97-1.04	0.695	1.70	0.78-3.68	0.183	1.35	0.62-2.94	0.447
BKFO (cm)	1164	13.4 ± 4.3	13.1 ± 4.1	-0.31	0.98	0.93-1.03	0.345	1.03	0.57-1.87	0.926	0.84	0.44-1.60	0.599
Abduction (°)	1168	48 ± 7.8	49 ± 7.8	0.26	1.01	0.98-1.03	0.505	0.56	0.27-1.13	0.104	0.89	0.48-1.67	0.719
IR prone (°)	1166	37 ± 8.0	38 ± 7.7	0.73	1.01	0.99-1.04	0.329	0.86	0.46-1.63	0.651	1.11	0.59-2.08	0.756
Strength tests													
SQUEEZE 45° (Raw)	1162	241 ± 63	244 ± 60	2.53	1.00	0.99-1.00	0.536	0.89	0.48-1.65	0.714	1.01	0.50-2.03	0.988
SQUEEZE 45° (N/kg)	1162	3.34 ± 0.8	3.47 ± 0.7	0.03	1.09	0.85-1.39	0.516	0.73	0.36-1.47	0.381	0.99	0.50-1.97	0.974
Eccentric Add (Nm/kg)	1154	3.04 ± 0.6	2.95 ± 0.6	-0.09	0.76	0.52-1.11	0.159	**1.77**	**1.03-3.04**	**0.038**	1.29	0.73-2.28	0.377
Eccentric Abd (Nm/kg)	1162	2.50 ± 0.4	2.50 ± 0.4	0.00	1.08	0.66-1.78	0.750	0.79	0.42-1.48	0.457	0.92	0.52-1.64	0.788
Ratio Add/Abd	1151	1.24 ± 0.3	1.21 ± 0.3	-0.03	0.56	0.24-1.32	0.186	1.20	0.68-2.11	0.524	0.58	0.28-1.21	0.147
X-RAY SCREENING				%									
No Cam (α<60°)	359	334	25	7	1.00								
Cam (α>60°)	557	518	39	7	0.99	0.61-1.62	0.979						
Small Cam (α=60-78°)	357	332	25	7	0.99	0.57-1.72	0.969						
Big Cam (α>78°)	200	186	14	7	0.98	0.54-1.86	0.997						
Normal acetabulum (LCEA= 20-40°)	801	748	53	7	1.00								
Acetabular dysplasia (LCEA<20°)	90	81	9	10	1.42	0.71-2.86	0.325						
Pincer (LCEA>40°)	25	23	2	8	1.27	0.33-4.83	0.725						

[¥]MD= mean difference between the injured and uninjured legs

*Hazard ratio (HR) per 1-unit of change for continuous variables and relative risk when compared to the reference category for categorical variables. Significant associations (HR) and p values are bolded

[#]Reference group: goalkeeper

^Previous groin injury refers to any hip/groin injury occurring within 12 months prior to screening

BMI= body mass index, FADIR= flexion, adduction, internal rotation test, FABER= flexion, abduction, external rotation test, IR= internal rotation, ER= external rotation, Add= Adduction, Abd= abduction, N=newton, Cam= cam morphology, α= alpha angle, LCEA= lateral centre edge angle

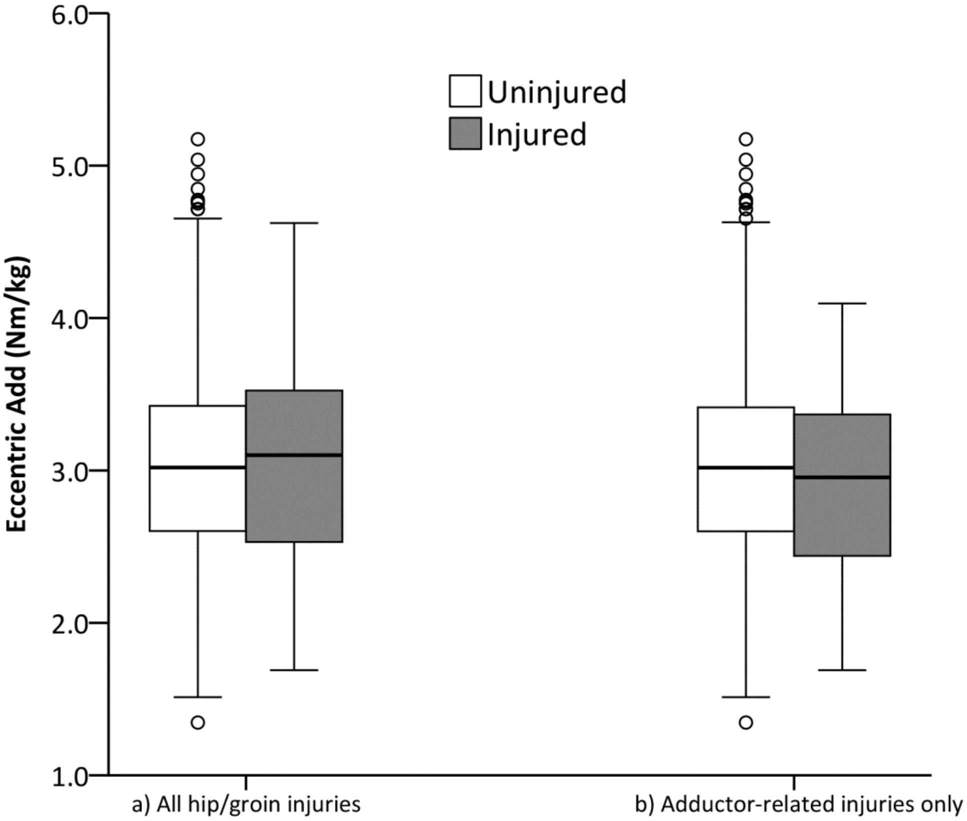

Figure 3: Box plots representing eccentric adduction strength, uninjured vs injured for a) all hip/groin injuries and b) adductor-related groin injuries only. Eccentric adduction strength was measured in Newtons and normalised to body weight and lever arm (Nm/kg). The small absolute differences between the injured and uninjured groups demonstrated in this figure exemplify the weak association between eccentric adduction strength and hip/groin injury.

Table 4: Results of the multivariate cox regression analysis of potential risk factors for adductor-related groin injuries with p≤ 0.1 identified from the univariate analysis

Risk Factors	HR*	95% CI	p value
Previous hip/groin injury	**2.09**	**1.30 - 3.36**	**0.002**
Internal rotation range of motion (low group)	0.76	0.39 - 1.48	0.414
Internal rotation range of motion (high group)	0.51	0.24 - 1.06	0.073
Eccentric adduction strength (low group)	**1.74**	**1.02 - 2.97**	**0.041**
Eccentric adduction strength (high group)	1.27	0.72 - 2.25	0.415

*Hazard ratio (HR) defines the relative risk compared to the reference category. Significant associations (HR) and p values are bolded

DISCUSSION

We examined the intrinsic risk factors for time-loss hip/groin injuries sustained over two consecutive football seasons in a large cohort of male professional soccer players. Previous groin injury and having higher than normal eccentric adduction strength were associated with increased risk of hip/groin injury. Previous hip/groin injury was also a risk factor for adductor-related groin injury, while having lower than normal eccentric adduction strength increased the risk of sustaining an adductor-related groin injury. All other demographic and musculoskeletal screening test variables were either not associated at a univariate level, or found to be insignificant in the stepwise multivariate analysis. Bony hip morphology was not found to be a risk factor for groin injury in this cohort.

Previous groin injury as a risk factor

Previous groin injury has consistently been identified as an intrinsic risk factor for groin injury in multiple cohorts and across different sports.[28,35,46] We also found previous hip/groin injury to be a risk factor for all hip/groin injuries (HR= 1.8, 95% CI 1.2-2.7) and for adductor-related groin injuries (HR= 2.1, 95% CI 1.3-3.4). However, the absolute risk findings indicate that this variable provides little value when identifying athletes at risk of hip/groin injury (Table 1). We found that 14% of previously injured legs sustained a future hip/groin injury compared to 8% of those without a previous injury (Table 1, Figure 2). Consequently, identification of an at-risk individual based solely on this variable could miss around half of the injuries that may occur in a soccer team. Thus it would be prudent to employ injury risk reduction strategies to the whole team when trying to reduce hip/groin injuries, not only those with a history of previous injury.

Association between strength and hip/groin injury

When all hip/groin injuries were examined, having higher than normal eccentric adduction strength was a significant risk factor (HR= 1.6, 95% CI 1.0-2.5). In contrast, having lower than normal eccentric adductor strength was a significant risk factor for adductor-related groin injury (HR =1.7; 95% CI 1.0-3.0), which is in agreement with the findings of previous risk factor studies.[14,28,35,39,46] Combined, these findings suggest that the mechanisms of injury may vary for adductor-related groin injuries in comparison to the other categories of hip/groin injury. This emphasizes the need to categorize hip/groin injuries in any research related to the mechanism, management, and epidemiology of hip/groin injuries as suggested in the recent Doha agreement meeting.[23,42] Despite the significant association of eccentric adduction strength, the mean difference between the injured and uninjured legs was equivalent to 8 N in a player of average height and weight (Figure 3). The error expected for this measure is 32 N.[31] Therefore this measure is not sensitive enough, nor the association strong enough, to distinguish the individual soccer player at risk of either hip/groin injury or adductor-related groin injury.

Since 75% of the hip/groin injuries in our cohort were categorized as adductor-related, eccentric adductor strength exercises could add benefit to an injury risk reduction program aimed specifically at reducing adductor-related groin injury in soccer players. However, such programs should be implemented to the whole group of players, rather than only to the individual based on their screening test result. Furthermore, the regular examination of soccer players using tests sensitive to detect early signs of hip/groin pain may be more effective in minimizing groin injury burden than baseline musculoskeletal screening.[12,30]

Range of motion screening

Having higher than normal external rotation range in flexion was identified as a risk factor for hip/groin injuries in the univariate analysis (Tables 1 and 3). This measure was added in the second year of screening and therefore could not be included in the multivariate model. The interaction of ER with the other independent variables is therefore unknown. The mean difference between the injured and uninjured legs was only 2° (Tables 1 and 3), within the measurement error of 4° for this test.[31] None of the other range of motion variables was significantly associated with hip/groin injury risk. These results extend the findings of two recent systematic reviews which found strong evidence that the ipsilateral leg's range of motion is not associated with groin injury risk in athletic populations.[36,46] There is therefore little indication to include range of motion measures in screening for the purpose of identifying athletes at risk of hip/groin injury.

Bony hip morphology was not associated with groin injury risk

Bony hip morphology was not associated with risk of hip/groin injury, or adductor-related groin injuries only, in our cohort of professional football players (Tables 1 and 3). However, we recorded only one hip injury; therefore we cannot assess the relationship between bony hip morphology and the risk of hip injuries. Our study is the first to examine bony hip morphology prospectively as an intrinsic risk factor for hip/groin injury in soccer. This negative risk factor finding is interesting considering the high prevalence of cam morphology found in this cohort (59% hips and 71% players). It has previously been suggested that cam and pincer morphology are associated with groin injury in athletes.[9,44] Our findings propose that this association is perhaps co-incidental. Our study findings also suggest that there is no indication for conducting x-rays to examine bony hip morphology in screening to predict groin injury in soccer players.

LIMITATIONS

The club medical staff who conducted the injury and exposure surveillance were not blinded to the screening results, which could be a source of bias in the data. We did not control for any injury risk reduction strategies that may have been implemented based on the screening results during the study period. However, considering the high number of hip/groin injuries recorded during these two seasons, and the fact that there was no association found between season and hip/groin injury risk, this is likely to represent a low risk of bias. Our study was initiated prior to the Doha agreement meeting,[42] and therefore the categorization of the hip/groin injury data represent post-hoc rather than *a-priori* categorization. However, the categorization of groin injury according to the entity approach[23] has been in use for several years in Qatar. In cases where there was doubt about the classification, the medical records were assessed by two members of the study team (AM and AW) to optimize accuracy.

The present study, using a screening model, is the largest intrinsic risk factor study for hip/groin injuries. The observation period was extended to two soccer seasons, to ensure a greater number of hip/groin injuries were sustained in the observation period than the customary single season previously observed.[4,14,25,47] With the large cohort observed prospectively (609 player seasons), and number of hip/groin injuries recorded (113 injuries), we attempted to optimize statistical power for this exploratory study. However, given the number of independent variables examined, it is possible that we were underpowered to identify weak relationships other than those described in this manuscript. With an exploratory analysis such as the present study, it is also possible that the identified associations may present by chance. However, surprisingly few associations were identified in the study analysis and the associations found concur with those of previous research. The multivariate model of analysis used in this study assessed the interaction between multiple intrinsic risk factors while accounting for exposure. However, the complex nature of sports injuries means that we could not account for all potential confounding variables and a causative link cannot therefore be assumed. Further research specifically designed to assess causation of hip/groin injury is required.

Since bony hip morphology is a three dimensional phenomenon, the use of two dimensional imaging techniques to quantify bony hip morphology is a study limitation. Furthermore, there is currently no consensus on the best alpha angle threshold to be used to quantify femoral head asphericity. The threshold levels used in this study to define cam and large cam morphology were derived from the findings of a large population-based validation study,[3] but these definitions may have affected the overall study findings. The use of only the lateral centre edge angle (LCEA) to quantify acetabular morphology may have underestimated the prevalence of pincer morphology and acetabular dysplasia. Previous studies have suggested using more subjective variables to define these morphologies, such as the cross-over sign to assess for acetabular version. Due to the reported poor reliability of these radiological signs, and potential for overestimation of these morphologies,[34,48] we chose not to use such variables in our study.

Finally, the time loss injury definition used in our study is likely to underestimate the true burden of hip/groin pain in soccer.[22,38] Regular use of questionnaires about the presence and impact of hip/groin pain on the soccer player would provide better insight into the overall burden of this injury, and may better highlight potential intrinsic risk factors.[10,11,22,38] The translation, cross-cultural adaptation and validation of such questionnaires for the commonly spoken languages and nationalities of the QSL soccer players may be beneficial to the monitoring and prevention of hip/groin pain in this cohort.

CONCLUSIONS

Significant associations were found in our cohort between hip/groin injury risk and both previous hip/groin injury, and eccentric adduction strength. However, these associations were not strong enough to identify an 'at-risk' individual. The baseline musculoskeletal hip/groin screening tests used in our screening battery are therefore not useful for the purpose of predicting groin injury. Bony hip morphology (cam, pincer or dysplasia) was not associated with groin injury risk in our cohort of soccer players.

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