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Preseason Hip/Groin Strength and HAGOS Scores Are Associated With Subsequent Injury in Professional Male Soccer Players

Hip and groin injuries account for a considerable amount of time lost from training and competition in elite soccer (football). Conservative estimates suggest that 1 in 5 players[12] will suffer a hip/groin injury in any given season, with a recurrence rate of approximately 30%.[8] However, these data likely underestimate the true prevalence of the problem, because many players continue to participate despite symptoms.[5,23] Clearly, there is a need to improve hip/groin injury prevention programs, but this first requires a better understanding of risk factors that may contribute to these injuries.

DESIGN: Prospective cohort.

OBJECTIVE: To explore the association between preseason assessments of (1) isometric hip adductor and abductor strength using a novel field test and (2) the Copenhagen Hip and Groin Outcome Score (HAGOS) and subsequent hip/groin injury in male professional soccer players.

METHODS: In total, 204 male elite soccer players from 10 professional A-League and English Football League Championship clubs underwent assessments of hip adductor and abductor strength and completed the HAGOS in the 2017-2018 preseason. All subsequent hip/groin injuries were reported by team medical staff. Data reduction was conducted using principal-component analysis. The principal component for the HAGOS and 3 principal components for strength and imbalance measures were entered, with age and prior hip/groin injury, into a multivariable logistic regression model to determine their association with prospectively occurring hip/groin injury.

RESULTS: Twenty-four players suffered at least 1 hip/groin injury throughout the 2017-2018 season. The principal component for between-limb abduction imbalance (peak strength in the preferred kicking limb – nonpreferred limb) (odds ratio [OR] = 0.58; 95% confidence interval [CI]: 0.38, 0.90; $P = .011$), the principal component for peak adduction and abduction strength (OR = 0.71; 95% CI: 0.51, 1.00; $P = .045$), and the principal component for the HAGOS (OR = 0.77; 95% CI: 0.62, 0.96; $P = .022$) were independently associated with a reduced risk of future hip/groin injury. Receiver operating characteristic curve analysis of the whole model revealed an area under the curve of 0.76, which indicates a fair combined sensitivity and specificity of the included variables but an inability to correctly identify all subsequently injured players.

CONCLUSION: Hip abduction imbalance favoring the preferred kicking limb, higher levels of hip adductor and abductor strength, and superior HAGOS values were associated with a reduced likelihood of future hip/groin injury in male professional soccer players. *J Orthop Sports Phys Ther 2020;50(5):234-242. Epub 17 Sep 2019. doi:10.2519/jospt.2020.9022*

KEY WORDS: *football, groin pain, hip/pelvis/thigh, muscle injuries, physical therapy/rehabilitation*

Lower isometric[5] and eccentric[12] hip adduction strength has been associated with an increased risk of hip/groin injuries in male soccer players. Athletes with groin pain also have lower adductor strength on an isometric squeeze test than asymptomatic athletes.[11] However, handheld dynamometer or sphygmomanometer measures of strength[5,11,12] are susceptible to error without external fixation and may be confounded by poor intertester reliability.[20] As a consequence, the strength differences observed between currently or subsequently injured athletes and uninjured athletes are often smaller than measurement error.

Given that groin injury may be at least partly related to a reduced ability to stabilize the pelvis during running and change-of-direction movements, it is possible that deficits or between-limb imbalances in hip abductor strength may

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also be associated with injury.[6] However, no study has explored the association between isometric hip abductor strength and prospectively occurring hip/groin injury, and studies employing concentric[14] and eccentric[12] measures have reported conflicting results.

A novel field-testing device (ForceFrame; Vald Performance Pty Ltd, Newstead, Australia) for the assessment of hip adductor and abductor strength has been developed to overcome some of the limitations of traditional methods. The device allows for a rapid (less than 1 minute), reliable,[18] and valid[13] assessment of isometric hip/groin strength and between-limb imbalance, without the need for extensive operator expertise. We have previously reported normative strength data for elite soccer players using this device,[13] but it remains to be seen whether these measures are associated with the development of hip/groin injury in this population.

Patient-reported outcome measures are another important factor that may differentiate athletes with and those without hip/groin pain.[11] Of these outcomes, the Copenhagen Hip and Groin Outcome Score (HAGOS) is the only valid and reliable tool[22] specifically designed for young to middle-aged adults, and is commonly employed to assess and monitor hip/groin health in soccer players. Whether HAGOS scores are associated with the development of hip/groin injury in soccer players has not been studied.

An improved understanding of the factors that predispose elite soccer players to, or protect them against, hip/groin injury may help to inform the design of effective injury prevention and rehabilitation strategies. The aim of this study was to assess whether preseason measures of (1) hip adductor and abductor strength and between-limb imbalance measures using a novel field-testing device and (2) HAGOS scores were associated with clinically diagnosed hip/groin injury in the subsequent season in male professional soccer players. A secondary aim was to explore the impact of advancing age and prior injury on future injury risk.[4,15]

METHODS

Participants and Study Design

This prospective cohort study was conducted during the 2017-2018 Australian A-League and English Football League Championship competitions. In total, 204 male elite soccer players (mean ± SD age, 24.5 ± 5.1 years; height, 181.3 ± 6.7 cm; body mass index, 23.5 ± 1.6 kg/m^2) from 9 A-League clubs and 1 English Football League Championship club provided written informed consent to participate in this study. Players were excluded at the discretion of team medical staff when, due to an injury or illness at the time of testing, they could not perform maximal resistance exercise.

On a single day during the preseason period (June-July 2017), players were asked to complete the HAGOS questionnaire and a standardized questionnaire to report their age, height, weight, limb dominance (preferred kicking limb), playing position, and history of lower-limb injury. It was not possible to confirm reports of prior injury, due to the absence of a centralized injury reporting system in the A-League. Subsequently, isometric hip adduction and abduction strength were assessed using the GroinBar (Vald Performance) strength testing device. Ethical approval for this study was granted by La Trobe University's Human Ethics Committee (HEC16-118).

Prospective Hip/Groin Injury Reporting

A hip/groin injury was defined as "an 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 adductor muscle bellies, pubic symphysis and the lower abdomen, that resulted from playing football and led to a player being unable to fully participate in future training or match play."[27]

All injuries that satisfied the inclusion criteria were reported by team medical staff using a standardized injury report form that detailed the date of injury, time of injury (if during a match), date of return to training and competition, number of training sessions and matches missed due to injury, number of modified sessions due to injury, side of body and/or limb injured (preferred [kicking] or nonpreferred), injury location (adductor related, iliopsoas related, inguinal related, pubic related, hip related, other), injury type (muscle strain, myotendinous strain, myofascial strain, nerve injury, tendon injury), injury severity (grade 1-3), injury recurrence (yes/no), and use of imaging to confirm the diagnosis (yes/no).

Team medical staff recorded the onset of injury (sudden or gradual), type of injury (contact or noncontact), and activity at the time of injury (running, kicking, stretching, change of direction, tackling or being tackled, other). The head physical therapist for each club was given detailed instructions on how and when to complete the form before the start of the competitive season. A single investigator (M.N.B.) followed up with the team physical therapist via e-mail once a month to collect the reports.

The HAGOS

Players completed the HAGOS after receiving written and verbal instructions from investigators. The HAGOS comprises 6 subscales: pain (10 items), symptoms (7 items), function in activities of daily living (5 items), function in sport and recreation (8 items), participation in physical activities (2 items), and hip and/or groin-related quality of life (5 items).[22] Each item is answered on a 5-point Likert scale scored from 0 to 4, with 0 indicating no hip/groin problem and 4 indicating extreme hip/groin problem. The 6 scores were calculated as the sum of the items included. Reliability (intraclass correlation coefficient = 0.82-0.91) of the HAGOS has been previously established in individuals with hip/groin pain.[22]

Hip Adductor and Abductor Strength Testing

All strength assessments were conducted using a novel hip and groin strength testing device (ForceFrame; Vald Performance). This device comprises an adjustable rig fitted with 4 independent and adjustable, custom-made, uniaxial load cells, which standardizes testing positions and may increase reproducibility.[13] With participants lying supine, hip adduction and abduction strength was measured in 2 different positions: (1) from the ankle with the hip in neutral and the knee fully extended (supine) (**FIGURE 1A**) and (2) from the knee with the hip at approximately 60° of flexion and the knee at approximately 90° of flexion (60°/90°) (**FIGURE 1B**). In the first position, the medial and lateral malleoli of each ankle were in contact with the load cells, and in the second position, the medial and lateral aspects of each knee were in contact with the load cells. Reliability (intraclass correlation coefficient = 0.94)[18] and validity[13] of hip adductor and abductor strength assessments using the ForceFrame device have been reported previously.

In each position, participants performed 1 set of 3 bilateral maximal voluntary isometric hip adductor contractions, followed by 1 set of 3 maximal voluntary isometric hip abductor contractions. Participants were provided with 5 to 10 seconds of rest between repetitions, 20 to 30 seconds of rest between sets, and at least 1 minute of rest between positions. Throughout all testing, investigators provided strong verbal encouragement to elicit maximal effort. A trial was acceptable if the force trace plateaued after reaching a distinct peak, indicating the development of maximal volitional force.

Data Analysis

Subscale values for the HAGOS were calculated according to the HAGOS user's guide.[26] Peak hip adductor and abductor force for each position was calculated as the maximal force value (Newtons) recorded from the 3 repetitions. Between-limb imbalance for hip adduction and abduction in each position was determined as the peak force of the preferred limb minus that of the nonpreferred limb.

Statistical Analysis

All statistical analyses were performed using JMP 10.02 (SAS Institute Inc, Cary, NC). Descriptive statistics are presented as means and standard deviations. To compare injured and uninjured groups, independent *t* tests assuming unequal variance were used. Pearson product-moment correlations were calculated for pairwise correlations between (1) hip adductor and abductor strength variables and (2) HAGOS subscale scores. Given the magnitude of these correlations, data reduction was conducted on hip strength variables (peak abduction, peak adduction, abduction imbalance, and adduction imbalance at both supine and 60°/90° testing positions) and on the HAGOS subscale scores using principal-component analysis (PCA).

When several related variables are measured, some may be highly correlated and violate collinearity, leading to redundancy in the variables. Principal-component analysis uses orthogonal transformation to reduce the number of related variables into fewer independent principal components.[7] These principal components represent optimally weighted linear combinations of the original variables that account for the most variance in the original values. Each principal component has a corresponding eigenvalue that reflects the amount of variance accounted for by that component. Because the sum of the eigenvalues is equivalent to the number of variables in the PCA, an eigenvalue greater than 1 accounts for more variance than any single original variable.

To determine the association between (1) principal components for hip adductor and abductor strength and imbalance, (2) the principal component for the HAGOS, (3) prior injury, and (4) age and subsequent hip/groin injury in either limb, a multivariable logistic regression model was constructed. Principal components with eigenvalues greater than 1 were included in the model, in addition to age and prior hip/groin injury. Parameter estimates were expressed as odds ratios (ORs) and 95% confidence intervals (CIs) per 1-unit change in the principal component. For all analyses, alpha was set at $P<.05$.

To evaluate the predictive validity of the multivariable model, a receiver operating characteristic curve was calculated to determine its sensitivity and specificity. The area under the curve describes the ability of the model to discriminate between subsequently injured players and uninjured players, and is reported as excellent (0.90-1.00), good (0.80-0.90), fair (0.70-0.80), poor (0.60-0.70), or fail (0.50-0.60).[1]

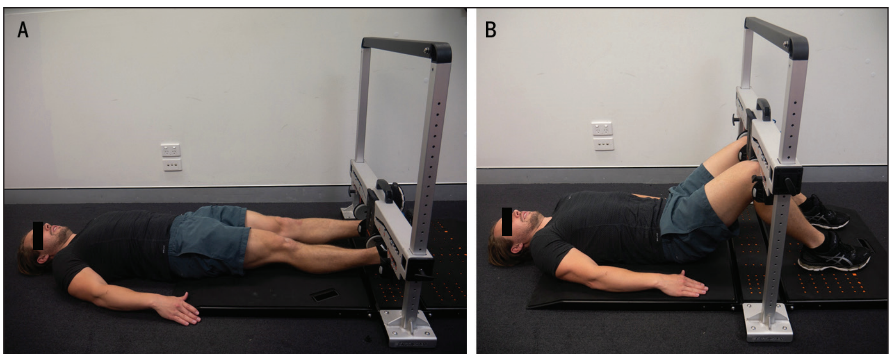

FIGURE 1. (A) Supine testing position and (B) 60°/90° testing position. In each position, players completed 3 maximal voluntary isometric hip adductor contractions, followed by 3 maximal voluntary isometric hip abductor contractions.

RESULTS

Complete prospective follow-up was obtained for 152 players (**TABLE 1**). One Australian team (n = 22) was lost to follow-up due to a change in medical staff at the club. Thirty players were excluded due to missing or incomplete preseason data. There were no significant differences between players lost to follow-up and those in the study cohort in age, height, weight, score on the principal components of the HAGOS, peak adductor and abductor strength, and abductor and adductor between-limb imbalance (all, $P>.05$).

Twenty-four players with complete preseason screening data sustained at least 1 hip/groin injury throughout the 2017-2018 season (mean ± SD age, 25.3 ± 5.6 years; height, 179.7 ± 5.3 cm; body mass, 77.2 ± 8.2 kg). Two (n = 2) players suffered more than 1 injury; however, these secondary injuries were not included in the analysis. On average, injuries resulted in 1.7 (median, 2; range, 0-8) missed games, 6.5 (median, 6; range, 2-25) missed training sessions, and 2.2 (median, 2; range, 0-7) modified training sessions. Two thirds of injuries affected the nonpreferred limb. The majority (67%) of injuries were adductor related, 17% were iliopsoas related, and 8% were inguinal related. Eighty percent were sudden onset, and half occurred during match play.

TABLE 1 DESCRIPTIVE STATISTICS FOR PARTICIPANTS' PHYSICAL CHARACTERISTICS[a]

	Injured (n = 24)	Uninjured (n = 128)	Total (n = 152)	Injured Versus Uninjured: Mean Difference[b]	Injured Versus Uninjured: P Value
Age, y	25.3 ± 5.6	23.7 ± 4.8	24.0 ± 4.9	1.6 (0.9, 4.1)	.199
Height, cm	179.7 ± 5.3	181.8 ± 7.0	181.4 ± 6.8	2.1 (0.4, 4.6)	.099
Weight, kg	77.2 ± 8.2	77.8 ± 7.2	77.7 ± 7.3	0.6 (−3.0, 4.3)	.726
BMI, kg/m²	23.8 ± 2.0	23.5 ± 1.5	23.6 ± 1.6	0.4 (−0.5, 1.3)	.413

Abbreviation: BMI, body mass index.
[a]*Values are mean ± SD unless otherwise indicated.*
[b]*Values in parentheses are 95% confidence interval.*

TABLE 2 DESCRIPTIVE STATISTICS FOR PREFERRED-LIMB STRENGTH, NONPREFERRED-LIMB STRENGTH, AND BETWEEN-LIMB IMBALANCE[a]

Test Position, Component/Measure	Injured (n = 24)	Uninjured (n = 129)	Total (n = 153)
60°/90°, N[b]			
Adduction			
Peak	418.0 ± 105.0	425.5 ± 92.8	424.3 ± 94.5
Preferred limb	421.2 ± 107.4	423.8 ± 95.0	423.4 ± 96.7
Nonpreferred limb	414.8 ± 103.4	427.2 ± 92.8	425.2 ± 94.3
Between-limb imbalance	6.4 ± 18.4	−3.4 ± 28.6	−1.8 ± 27.4
Abduction			
Peak	411.6 ± 91.8	421.7 ± 72.9	420.1 ± 75.9
Preferred limb	408.0 ± 88.1	425.3 ± 79.1	422.5 ± 80.5
Nonpreferred limb	415.3 ± 99.6	418.1 ± 69.4	417.6 ± 74.7
Between-limb imbalance	−7.3 ± 40.8	7.2 ± 30.3	4.9 ± 32.5
Supine[c]			
Adduction			
Peak	195.0 ± 37.8	207.7 ± 52.7	205.7 ± 50.7
Preferred limb	196.3 ± 38.4	206.0 ± 53.4	204.5 ± 51.4
Nonpreferred limb	193.6 ± 39.2	209.4 ± 54.1	207.0 ± 52.2
Between-limb imbalance	2.6 ± 17.6	−3.4 ± 21.6	−2.5 ± 21.1
Abduction			
Peak	172.8 ± 42.0	181.1 ± 37.3	179.8 ± 38.1
Preferred limb	169.8 ± 40.5	180.4 ± 39.4	178.7 ± 39.7
Nonpreferred limb	175.7 ± 45.1	181.8 ± 37.0	180.8 ± 38.3
Between-limb imbalance	−5.9 ± 16.8	−1.4 ± 16.8	−2.1 ± 16.8
Principal component			
1: peak adduction and abduction strength	−0.413 ± 1.591	0.111 ± 1.731	0.028 ± 1.715
2: abduction imbalance	−0.457 ± 1.493	0.082 ± 1.184	−0.004 ± 1.248
3: adduction imbalance	0.189 ± 1.057	−0.041 ± 1.057	−0.004 ± 1.057

[a]*Values are mean ± SD.*
[b]*Defined as 60° of hip flexion and 90° of knee flexion.*
[c]*Defined as 0° of hip and knee flexion.*

Hip Adductor and Abductor Strength

Descriptive statistics for peak hip adductor and abductor strength and between-limb imbalance (preferred – nonpreferred limb) for the supine and 60°/90° testing positions are reported in **TABLE 2**. Adductor and abductor strength and between-limb imbalance variables for both positions were correlated (**APPENDIX A**, available at www.jospt.org). All strength variables were included in the PCA (see loading matrix in **APPENDIX B**, available at www.jospt.org), and the corresponding eigenvalues are reported in **TABLE 3**. Principal component 1 (peak adduction and abduction strength), principal component 2 (abduction between-limb imbalance), and principal component 3 (adduction between-limb imbalance) were retained for subsequent analysis.

The HAGOS

Descriptive statistics for HAGOS subscale scores can be found in **TABLE 4**. A correlation matrix of the 6 HAGOS subscales (symptoms, pain, function in activities of daily living, function in sport and recreation, participation in physical activities, hip and/or groin-related quality of life) revealed pairwise correlations of greater than 0.47 among all of the variables (**APPENDIX C**, available at www.jospt.org). The PCA was performed using all 6 HAGOS subscales, and the eigenvalues are reported in **TABLE 5.** Only the first principal component displayed an eigenvalue greater than 1, representing 71% of the total variance in the data (**APPENDIX D**), and this was retained for subsequent analysis.

TABLE 3 EIGENVALUES FOR HIP ADDUCTOR AND ABDUCTOR STRENGTH

Principal Component[a]	Eigenvalue	Percent Variance	Cumulative Percent Variance
1	2.9815	.37268	.37268
2	1.5757	.19696	.56965
3	1.1202	.14002	.70967
4	0.8718	.10898	.81865
5	0.5820	.07275	.89140
6	0.4001	.05001	.94141
7	0.2896	.03620	.97761
8	0.1791	.02239	1.00000

[a]*Principal component 1 captured the peak adduction and abduction strength, principal component 2 captured the between-limb abduction imbalance, and principal component 3 captured the between-limb adduction imbalance.*

TABLE 4 DESCRIPTIVE STATISTICS FOR THE HAGOS SUBSCALE SCORES[a]

HAGOS Subscale, Component	Injured (n = 26)	Uninjured (n = 133)	Total (n = 159)
Symptoms	80 ± 14	83 ± 13	82 ± 14
Pain	91 ± 9	94 ± 8	93 ± 9
Function in activities of daily living	93 ± 10	97 ± 9	96 ± 9
Function in sport and recreation	86 ± 18	91 ± 12	90 ± 14
Participation in physical activities	90 ± 13	93 ± 13	93 ± 13
Hip and/or groin-related quality of life	84 ± 20	88 ± 15	87 ± 16
Principal component	−0.63 ± 2.40	0.12 ± 1.99	0.00 ± 2.07

Abbreviation: HAGOS, Copenhagen Hip and Groin Outcome Score.
[a]*Values are mean ± SD.*

TABLE 5 EIGENVALUES FOR THE COPENHAGEN HIP AND GROIN OUTCOME SCORE

Principal Component	Eigenvalue	Percent	Cumulative Percent
1	4.2878	.71463	.71463
2	0.5819	.09698	.81161
3	0.4443	.07406	.88567
4	0.2944	.04907	.93475
5	0.2487	.04144	.97619
6	0.1429	.02381	1.00000

Multivariable Logistic Regression Analysis

Details of the multivariable logistic regression model can be found in **TABLE 6** and **FIGURE 2.** The receiver operating characteristic analysis of the model revealed an area under the curve of 0.76, which we interpreted as fair.[1] The full model was significant, and the most prominent features to be independently associated with risk of future hip/groin injury were the principal component that captured between-limb abduction imbalance (OR = 0.58; 95% CI: 0.38, 0.90; P = .011), the principal component that described peak adduction and abduction strength (OR = 0.71; 95% CI: 0.51, 1.00; P = .045), and the principal component for the HAGOS (OR = 0.77; 95% CI: 0.62, 0.96; P = .022). **FIGURE 2** shows the distribution of principal component scores for between-limb abduction imbalance and the HAGOS by prospective injury. Age (OR = 1.09; 95% CI: 0.98, 1.22; P = .112), prior hip/groin injury (OR = 0.43; 95% CI: 0.09, 1.98; P = .255), and the principal component that captured between-limb adduction imbalance (OR = 1.32; 95% CI: 0.77, 2.29; P = .304) were not associated with future hip/groin injury. To interpret the relationship between principal component scores and raw strength and HAGOS values, please refer to **APPENDIX E** (available at www.jospt.org).

DISCUSSION

THIS STUDY DEMONSTRATED THAT (1) an abduction-strength between-limb imbalance favoring the preferred kicking limb, (2) increased hip adductor and abductor strength, and (3) better HAGOS values in the preseason all reduce the likelihood of subsequent hip/groin injury in male professional soccer players.

Between-Limb Hip Abduction Imbalance and Subsequent Injury

In our cohort, stronger hip abductors in the preferred kicking limb were associated with a reduced likelihood of sustaining a future hip/groin injury in either limb.

Given that this study is the first to assess the association between hip abduction imbalance and subsequent injury, comparison to previous work is difficult, and the mechanisms underpinning the observed effect remain unclear. The majority of acute groin injuries in male soccer players occur following change-of-direction movements,[19] characterized by hip extension, abduction, and external rotation during push-off, and performance in these tasks is highly correlated with hip abductor strength.[17]

Isometric hip abduction strength is 17% to 31% greater[21] in soccer players than in healthy controls, and elite soccer players are stronger in the kicking limb than in the nonpreferred limb.[24] It is plausible that stronger abductors in the preferred kicking limb improve the ability to stabilize the contralateral pelvis during change-of-direction maneuvers,[16] which may prevent the development of potentially injurious kinematic changes.[6] Indeed, soccer players with groin pain have been reported to exhibit significantly less gluteus medius activation than adductor activation during stance and standing hip flexion.[10] Although it is not known whether players in the current study performed cutting and change-of-direction maneuvers more frequently with their preferred limb, young male soccer players may have superior change-of-direction performance and greater hip abductor strength on this side.[17] Clearly, further work is needed to understand how greater hip abductor strength in the preferred limb protects against hip/groin injuries. However, our results suggest that hip abductor imbalance should be considered in injury prevention programs for elite soccer players.

Hip Adduction and Abduction Strength and Subsequent Injury

In a recent large-scale randomized controlled trial, isolated strength training for the hip adductors (using the Copenhagen Adductor Strengthening Programme) reduced the rate of groin injuries by 41% among 652 semi-professional Norwegian soccer players.[9] In our study, players with greater hip adduction and abduction strength had significantly reduced odds of suffering a future hip/groin injury. These findings support most earlier high-quality prospective studies exploring the association between hip adductor[2,5,12,14,25] and abductor[14] strength and the development of sports-related groin pain; however, only 2 of these studies specifically examined soccer players.[5,12] In the first, involving 61 groin injuries in 508 amateur soccer players, Engebretsen and colleagues[5] reported that athletes with weak adductors were 4-fold more likely to suffer a future injury than stronger athletes. More recently, Mosler and colleagues[12] reported no significant association between isometric hip adduction strength and 133 subsequent hip/groin injuries in 438 male elite soccer players. As far as the authors are aware, the current study is the first to explore the association between isometric hip abductor strength and prospectively occurring hip/groin injury in any sport. Our results suggest that professional soccer players should prioritize the development of both adductor and abductor strength to minimize the risk of future hip/groin injury.

Association Between the HAGOS and Subsequent Injury

The HAGOS is the most frequently used tool for subjectively monitoring hip/groin health in elite soccer.[22] Players with high HAGOS values in the preseason were 23% less likely to suffer a subsequent hip/groin injury in the subsequent season than those with low values. These findings are consistent with work by Delahunt and colleagues,[3] who reported that professional Gaelic football players who scored poorly (less than 87.5) on the function in sport and recreation subscale of the HAGOS were approximately 9-fold more likely to suffer a groin injury than those with

TABLE 6 MULTIVARIABLE LOGISTIC REGRESSION

	Odds Ratio[a]	*P* Value
Whole model[b]		.0086
PC 1: peak adduction and abduction strength	0.71 (0.51, 1.00)	.0445
PC 2: between-limb abduction imbalance[c]	0.58 (0.38, 0.90)	.0111
PC 3: between-limb adduction imbalance[c]	1.32 (0.77, 2.29)	.3042
PC: HAGOS	0.77 (0.62, 0.96)	.0217
Age	1.09 (0.98, 1.22)	.1124
Prior hip/groin injury (self-reported)	0.43 (0.09, 1.98)	.2554

Abbreviations: HAGOS, Copenhagen Hip and Groin Outcome Score; PC, principal component.
[a]*Values in parentheses are 95% confidence interval.*
[b]*No association (collinearity) between any variables in the model was observed.*
[c]*Calculated as strength of preferred limb minus strength of nonpreferred limb.*

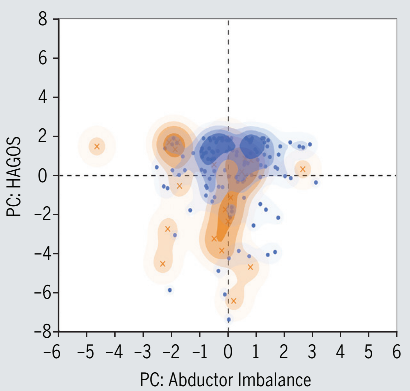

FIGURE 2. Principal-component scores for the HAGOS and hip abductor imbalance (preferred kicking limb – nonpreferred limb) for players who suffered a subsequent hip/groin injury (orange shading and X marks) and those who remained injury free (blue shading and blue dots). Positive values indicate better HAGOS scores and greater hip abductor strength in the preferred than in the nonpreferred limb. Abbreviations: HAGOS, Copenhagen Hip and Groin Outcome Score; PC, principal component.

higher scores. The current study is the first to explore the association between all HAGOS subscale scores and the development of hip/groin injury. We also observed moderate to high correlations between all subscale scores (**APPENDIX C**), which suggests that it may not be necessary to measure all of these variables when assessing an athlete's risk for injury. Our data support the use of the HAGOS as a preseason and in-season monitoring tool and suggest that the HAGOS may be useful in identifying elite soccer players who are at risk of sustaining a future hip/groin injury.

Age, Prior Hip/Groin Injury, and Future Injury

We did not find any effect of advancing age or prior hip/groin injury on future injury risk. Although age is a commonly cited risk factor for injury among other running-based sports,[4,15] high-quality prospective studies of soccer players have not found a relationship between age and hip/groin injury.[5,12] Nevertheless, previously injured soccer players have been shown to be 1.81 to 2.65 times more likely to suffer a future hip/groin injury than players with no such history. In the current study, players who self-reported a history of hip/groin injury were not at increased risk of reinjury. Given the relatively small number of previously injured athletes in our study (n = 24) and the heterogeneity of injury subtypes, our study was possibly underpowered to detect small to moderate effects. However, the A-League does not have a centralized injury reporting system, so it was also impossible to reliably confirm player reports of prior injuries with club medical records. Given the limitations of player recall, the results of this analysis should be interpreted with caution.

Limitations

We only included professional soccer players, and it remains unclear whether the results are generalizable to other athletic populations. Further, the absence of player load data does not allow hip/groin injury rates to be expressed relative to the total exposure to injurious activities. Future work should seek to clarify the effect of total match and training exposure time on the incidence of hip/groin injury in elite soccer players.

Strength and HAGOS values were only measured at a single time point in the preseason. While this is consistent with most other prospective cohort studies in the hip/groin literature, these variables may change over time, and longitudinal assessments may provide a more robust measure of player risk[28]; however, the geographic diversity of soccer clubs included in this study precluded follow-up assessments.

Last, we reported strength values as force outputs (Newtons) rather than joint torques (Newton meters), because it was not possible to measure limb lengths for all players at the time of testing. While the assessment of joint torques may provide additional information, the testing method performed is wholly representative of how these data are collected and interpreted in the field.

Clinical Implications

To facilitate the clinical application of these data, we have provided additional regression analyses (**APPENDIX E**) that plot the relationship between principal-component scores and the raw scores from the original variables; these are for illustrative purposes only. For example, when the principal component for peak strength is equivalent to zero, supine adduction strength is equal to 206.1 N. A 1-unit change in the principal component can be calculated by adding or subtracting 23.84 N, as described in the formula provided. Similar relationships are reported for the other strength and imbalance measures in addition to all HAGOS subscales. This calculation is not exact, and provides the clinician with a guide only.

Odds ratios do not indicate the probability of sustaining a hip/groin injury. In our study, the probability of hip/groin injury ranged from 1% to 76%. For example, a 27-year-old player with no history of injury, with an abductor strength 62 N stronger in the preferred limb than in the nonpreferred limb (tested in the 60°/90° position), a high adductor and abductor strength (60°/90° adduction, 550 N; 60°/90° abduction, 525 N), and an excellent HAGOS total score (all subscales, 100), has an estimated probability of future hip/groin injury of less than 3%. In contrast, a 29-year-old player with no history of injury, who is 27 N weaker in the abductors of the preferred limb than in the nonpreferred limb when tested in the same position, has lower levels of strength (60°/90° adduction, 361 N; 60°/90° abduction, 352 N), and a poorer HAGOS total score (symptoms, 79; pain, 88; function in activities of daily living, 100; function in sport and recreation, 97; participation in physical activities, 75; hip and/or groin-related quality of life, 85), has an estimated probability of future injury of 43%. While these data may be of some clinical value, they are preliminary findings that are specific to this cohort, and the model requires further validation.

CONCLUSION

Hip abduction imbalance favoring the preferred kicking limb, higher levels of hip adductor and abductor strength, and superior HAGOS values (indicative of better hip/groin health), obtained at preseason, were associated with a reduced likelihood of subsequent hip/groin injury in male professional soccer players. ◉

KEY POINTS

FINDINGS: This study demonstrated that (1) a between-limb imbalance in abduction strength that favors the preferred kicking limb, (2) higher hip adductor and abductor strength, and (3) high Copenhagen Hip and Groin Outcome Score (HAGOS) values in the preseason reduce the likelihood of subsequent hip/groin injury in male professional soccer players.

IMPLICATIONS: These findings may have implications for injury screening and may inform the design of interventions targeted at reducing hip/groin injuries in professional soccer players.

CAUTION: These observations may not be generalizable to other athletic populations. Future work should determine whether interventions targeted at improving preseason hip adduction and abduction strength (particularly abduction strength in the preferred kicking limb) and HAGOS values result in a reduction in hip/groin injury rates in sport.

STUDY DETAILS

AUTHOR CONTRIBUTIONS: Dr Bourne was the principal investigator and was involved with study design, recruitment, analysis, and manuscript write-up. Mr Jackson and Drs Timmins and Pizzari were involved in data collection. Drs Williams, Timmins, and Pizzari, Mr Jackson, and Dr Williams were involved with the study design, analysis, and manuscript preparation. All authors had full access to all data (including statistical reports and tables) in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

DATA SHARING: There are no data available. Consent was not obtained for data sharing. But the presented data are anonymous and the risk of identification is low.

PATIENT AND PUBLIC INVOLVEMENT: Athletes/public partners were not involved in the design, conduct, interpretation, and/or translation of this research.

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APPENDIX A

PAIRWISE CORRELATIONS BETWEEN HIP ADDUCTOR AND ABDUCTOR STRENGTH MEASURES[A]

	60°/90° Adduction Imbalance[b]	Supine Abduction Imbalance[b]	60°/90° Abduction Imbalance[b]	Supine Adduction Imbalance[b]	60°/90° Mean Adduction	60°/90° Mean Abduction	Supine Mean Adduction	Supine Mean Abduction
60°/90° adduction imbalance[b]	1	−0.0734	−0.1565	0.18	0.09	−0.0638	−0.0007	−0.1309
Supine abduction imbalance[b]	−0.0734	1	0.5823	−0.1092	0.1642	0.0397	0.1774	0.0904
60°/90° abduction imbalance[b]	−0.1565	0.5823	1	−0.092	0.1129	0.1807	0.1914	0.147
Supine adduction imbalance[b]	0.18	−0.1092	−0.092	1	0.0252	0.0453	−0.041	−0.0474
60°/90° mean adduction	0.09	0.1642	0.1129	0.0252	1	0.5551	0.7027	0.5696
60°/90° mean abduction	−0.0638	0.0397	0.1807	0.0453	0.5551	1	0.513	0.7946
Supine mean adduction	−0.0007	0.1774	0.1914	−0.041	0.7027	0.513	1	0.5919
Supine mean abduction	−0.1309	0.0904	0.147	−0.0474	0.5696	0.7946	0.5919	1

[a]*The 60°/90° position is defined as 60° of hip flexion and 90° of knee flexion, and the supine position is defined as 0° of hip and knee flexion.*
[b]*Calculated as strength of preferred limb minus strength of nonpreferred limb.*

APPENDIX B

PRINCIPAL COMPONENT ANALYSIS LOADING MATRIX FOR ADDUCTOR AND ABDUCTOR STRENGTH MEASURES[a]

	PC 1	PC 2	PC 3	PC 4	PC 5	PC 6	PC 7	PC 8
60°/90° adduction imbalance[b]	−0.09147	−0.39475	0.70649	−0.48104	0.3191	−0.02143	0.05089	0.02011
Supine abduction imbalance[b]	0.30948	0.75713	0.37694	−0.04321	−0.08355	0.41564	0.06647	−0.05359
60°/90° abduction imbalance[b]	0.36464	0.75348	0.25504	0.16028	0.2042	−0.39613	−0.07447	0.0663
Supine adduction imbalance[b]	−0.05062	−0.39246	0.57068	0.70361	−0.14448	0.01373	0.03432	0.02076
60°/90° peak adduction	0.80973	−0.20537	0.15155	−0.189	−0.30202	0.01846	−0.3839	0.06736
60°/90° peak abduction	0.82405	−0.2132	−0.12451	0.1929	0.37211	0.05493	−0.07615	−0.27475
Supine peak adduction	0.82044	−0.09882	0.05865	−0.1833	−0.35423	−0.21063	0.31808	−0.09517
Supine peak abduction	0.85672	−0.16573	−0.21521	0.10624	0.23557	0.14841	0.14663	0.28627

Abbreviation: PC, principal component.

[a]*The 60°/90° position is defined as 60° of hip flexion and 90° of knee flexion, and the supine position is defined as 0° of hip and knee flexion. Principal component 1 captured the peak adduction and abduction strength, principal component 2 captured the between-limb abduction imbalance, and principal component 3 captured the between-limb adduction imbalance.*

[b]*Calculated as strength of preferred limb minus strength of nonpreferred limb.*

APPENDIX C

PAIRWISE CORRELATIONS BETWEEN THE COPENHAGEN HIP AND GROIN OUTCOME SCORE SUBSCALES

	Symptoms	Pain	Function in ADL	Function in Sport/Rec	Participation in PA	Hip and/or Groin-Related QoL
Symptoms	1.0000	0.7554	0.5326	0.7090	0.4704	0.6539
Pain	0.7554	1.0000	0.7216	0.7344	0.5371	0.7387
Function in ADL	0.5326	0.7216	1.0000	0.7752	0.5538	0.6800
Function in sport/rec	0.7090	0.7344	0.7752	1.0000	0.6196	0.7518
Participation in PA	0.4704	0.5371	0.5538	0.6196	1.0000	0.5708
Hip and/or groin-related QoL	0.6539	0.7387	0.6800	0.7518	0.5708	1.0000

Abbreviations: ADL, activities of daily living; PA, physical activities; QoL, quality of life; sport/rec, sport and recreation.

APPENDIX D

PRINCIPAL COMPONENT ANALYSIS LOADING MATRIX FOR THE COPENHAGEN HIP AND GROIN OUTCOME SCORE SUBSCALES

	PC 1	PC 2	PC 3	PC 4	PC 5	PC 6
Symptoms	0.81511	−0.39073	0.35637	0.13706	−0.09514	0.16763
Pain	0.89059	−0.21742	−0.00441	0.06868	0.35062	−0.17862
Function in ADL	0.84484	0.1133	−0.45668	0.17308	0.03624	0.18327
Function in sport/rec	0.91018	0.01535	−0.09315	0.07663	−0.33312	−0.21403
Participation in PA	0.72721	0.60578	0.31247	0.04388	0.06535	0.01917
Hip and/or groin-related QoL	0.87134	−0.04373	−0.04955	−0.48289	−0.01107	0.05564

Abbreviations: ADL, activities of daily living; PA, physical activities; PC, principal component; QoL, quality of life; sport/rec, sport and recreation.

APPENDIX E

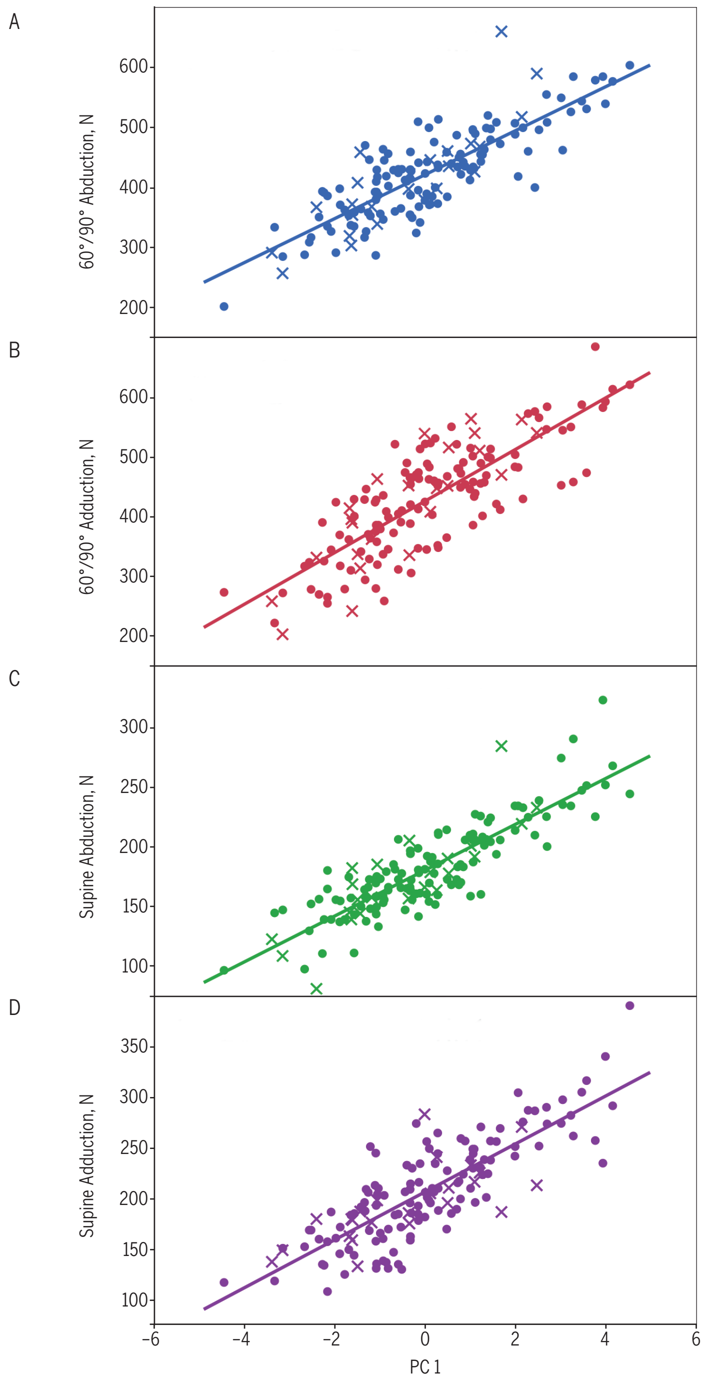

FIGURE 1. Regression analyses illustrating the relationship between PC 1 (peak hip adductor and abductor strength) in (A) the 60°/90° position for abduction (y = 419.4 + 36.81 × PC 1; R^2 = 0.689), (B) the 60°/90° position for adduction (y = 424.8 + 43.41 × PC 1; R^2 = 0.647), (C) the supine position for abduction (y = 179.4 + 19.19 × PC 1; R^2 = 0.738), and (D) the supine position for adduction (y = 206.1 + 23.84 × PC 1; R^2 = 0.665) and the raw scores from the original variables. The 60°/90° position is defined as 60° of hip flexion and 90° of knee flexion, and the supine position is defined as 0° of hip and knee flexion. Abbreviation: PC, principal component.

APPENDIX E

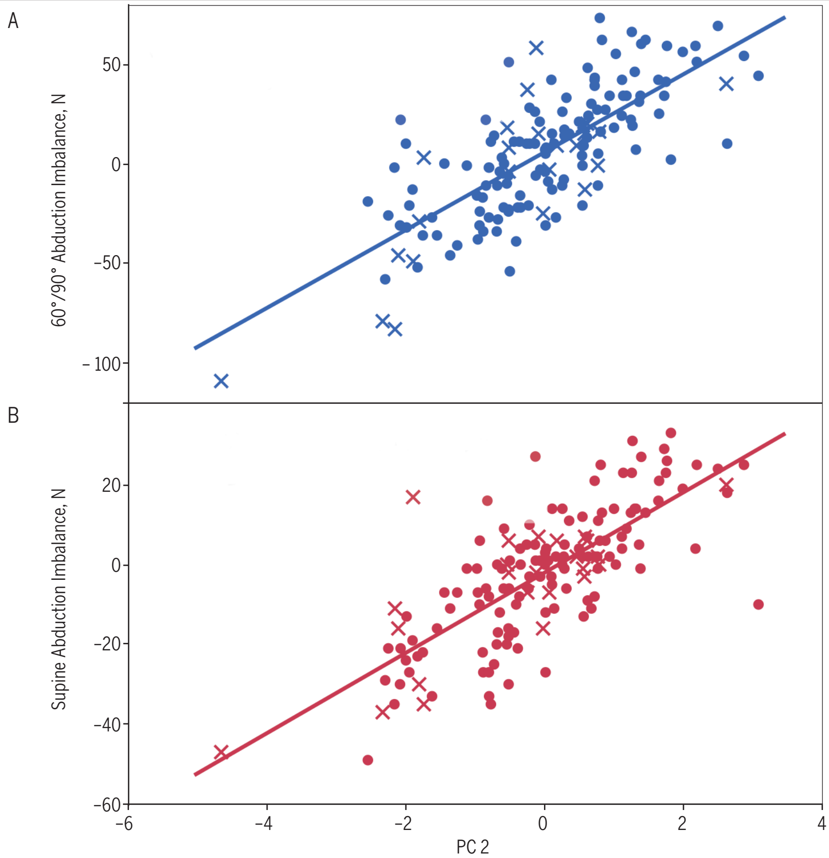

FIGURE 2. Regression analyses illustrating the relationship between PC 2 (between-limb hip abduction imbalance) in (A) the 60°/90° position (y = 5.264 + 19.5 × PC 2; R^2 = 0.566) and (B) the supine position (y = –2.253 + 10.05 × PC 2; R^2 = 0.566) and the raw scores from the original variables. The 60°/90° position is defined as 60° of hip flexion and 90° of knee flexion, and the supine position is defined as 0° of hip and knee flexion. Abbreviation: PC, principal component.

APPENDIX E

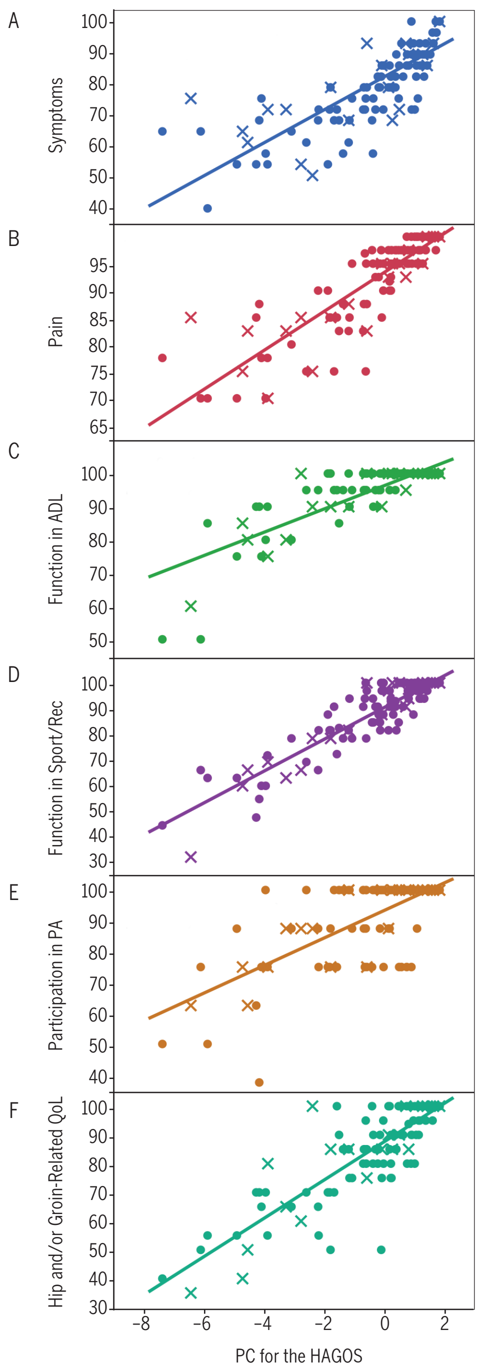

FIGURE 3. Regression analyses illustrating the relationship between the PC for the HAGOS and the raw scores from each HAGOS subscale: (A) symptoms (y = 81.83 + 5.347 × PC; R^2 = 0.651), (B) pain (y = 93.24 + 3.609 × PC; R^2 = 0.773), (C) function in ADL (y = 96.21 + 3.506 × PC; R^2 = 0.684), (D) function in sport/rec (y = 90.05 + 6.258 × PC; R^2 = 0.848), (E) participation in PA (y = 93.21 + 4.465 × PC; R^2 = 0.538), and (F) hip and/or groin-related QoL (y = 87.39 + 6.65 × PC; R^2 = 0.743). Abbreviations: ADL, activities of daily living; HAGOS, Copenhagen Hip and Groin Outcome Score; PA, physical activities; PC, principal component; QoL, quality of life; sport/rec, sport and recreation.