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Author: Andrea B. Mosler Kay M. Crossley Kristian Thorborg Rod J. Whiteley Adam Weir Andreas Serner Per Hölmich

PII: S1440-2440(16)30106-2
DOI: http://dx.doi.org/doi:10.1016/j.jsams.2016.05.010
Reference: JSAMS 1338

To appear in: *Journal of Science and Medicine in Sport*

Received date: 21-9-2015
Revised date: 17-5-2016
Accepted date: 23-5-2016

Hip strength and range of motion: normal values from a professional football league

Andrea B Mosler [a,b,c], Kay M Crossley[b,c], Kristian Thorborg[d], Rod J Whiteley[a], Adam Weir[e], Andreas Serner[e], Per Hölmich[d,e]

a) Aspetar Orthopaedic and Sports Medicine Hospital, Doha, Qatar; Rehabilitation Department

b) University of Queensland, Brisbane, Australia; School of Health and Rehabilitation Sciences

c) La Trobe University, Victoria, Australia; School of Allied Health

d) Copenhagen University Hospital, Amager-Hvidovre, Denmark; Sports Orthopedic Research Center – Copenhagen (SORC-C), Arthroscopic Center, Department of Orthopedic Surgery

e) Aspetar Orthopaedic and Sports Medicine Hospital, Doha, Qatar; Sports Groin Pain Centre

Correspondence:

Andrea B Mosler

Rehabilitation Department, Aspetar Orthopaedic and Sports Medicine Hospital

PO Box 29222

Doha, Qatar

Phone number: +97470641807

Email: andrea.mosler@aspetar.com

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Word count: 2959

Abstract word count: 248

Number of tables: 2

Number of figures: 0

Abstract

Objectives:

To determine the normal profiles for hip strength and range of motion (ROM) in a professional football league in Qatar, and examine the effect of leg dominance, age, past history of injury, and ethnicity on these profiles.

Design:

Cross-sectional cohort study

Methods:

Participants included 394 asymptomatic, male professional football players, aged 18-40 years. Strength was measured using a hand held dynamometer with an eccentric test in side-lying for hip adduction (ADD) and abduction (ABD), and the squeeze test in supine with 45° hip flexion. Range of motion measures included: hip internal (IR) and external rotation (ER) in 90° flexion, hip IR in prone, bent knee fall out (BKFO) and hip ABD in side-lying. Demographic information was collected and the effect on the profiles was analysed using linear mixed models with repeated measures.

Results:

Strength values (mean±SD) were: ADD=3.0±0.6 Nm/kg, ABD=2.6±0.4 Nm/kg, ADD/ABD ratio=1.2±0.2, Squeeze test=3.6±0.8 N/kg. ROM values: IR in flexion=32±8°, ER=38±8°, IR in prone=38±8°, BKFO=13±4.4cm, ABD in side-lying=50±7.3°. Leg dominance had no clinically relevant effect on these profiles. Multivariate analysis demonstrated that age had a minor influence on squeeze strength (-0.03N/kg/year), ER (-0.30°/year) and ABD range (0.19°/year) but past history of injury, and ethnicity did not.

Conclusions:

Normal values are documented for hip strength and ROM that can be used as reference profiles in the clinical assessment, screening, and management of professional football players. Leg dominance, recent past injury history and ethnicity do not need to be accounted for when using these profiles for comparison purposes.

Key words: groin; sports; injury; soccer; flexibility

Introduction

Hip and groin injuries are common in football, causing time loss and performance reduction for a player and their team.[1–3] Measurement of hip strength and range of motion (ROM) are key features of clinical assessment to determine both treatment response and inform the clinician on the footballer's readiness to return to play. Weakness of hip adduction (ADD) has previously been identified as a risk factor for groin injury in football,[4,5] while there is conflicting evidence of reduced ROM being a risk factor.[5] Normal values for hip strength and ROM, using reliable tests with low measurement error, are therefore essential to both the screening and management of hip and groin pain in football.

Hip strength assessment is recommended for the clinical evaluation of athletes with hip/groin pain,[6] as well as for other lower limb injuries such as anterior cruciate ligament injury[7] and patellofemoral pain syndrome.[8] Consequently, many different methods of assessing ADD[9] and abduction[8] (ABD) strength have been described.[10–12] Methodology differs in: population studied, mode of testing, devices used, number of repetitions, rest time between contractions, and the use of an average or maximum score, making comparison between studies difficult.

Eccentric ADD strength assessment has been found to be better than isometric at differentiating players with hip/groin pain from those without.[12] In a prospective study that used similar test methods, professional ice hockey players that developed groin pain had lower eccentric ADD/ABD strength ratios than the asymptomatic players.[11] Similarly, reduced squeeze strength was found to precede the development of groin pain in Australian football players.[13] While good to excellent reliability has been demonstrated for these methods,[10,14,15] the practicing clinician is hampered by a lack of normal comparison data to use in the daily management of football players.

Hip joint ROM has been examined extensively, but also with considerable variation in positions tested,[12,16,17] devices used[15,18] and population studied.[15,19] These variations make it difficult for such data to be useful for clinical reference purposes. Additionally, there have been relatively few reports of hip ROM in the football population. Establishing normal values for hip ROM in professional football players may assist in the management of hip and groin pain.

The primary aim of this study was to determine the normal profiles for strength and ROM relevant to hip and groin pain in professional football players. Secondary aims were to determine the effect that limb dominance, age, past history of time loss hip/groin injury from the previous season, and ethnicity had on these profiles.

Methods

All study participants were male professional football players, over 18 years of age, playing in the Qatar Stars League (QSL). Players presented to the Rehabilitation Department of Aspetar Sports Medicine and Orthopaedic Hospital for their annual, Fédération Internationale de Football Association (FIFA) compliant, pre-competition medical assessment during the 2014-15 season as previously described.[20] The majority of players were tested either in the pre-season (37%) or in the early competition phase (54%), with the remaining 9% of the cohort tested around the club transfer window between December-March. All players who competed for QSL clubs that season were screened, and if they were asymptomatic they were eligible for inclusion in the study. Demographic information pertaining to age, height, weight, leg dominance, current and past history of hip/groin pain, and ethnicity was obtained prior to testing. Leg dominance was defined as the limb preferred for a penalty kick. Data were excluded from any player reporting current hip or groin pain either during training or match play, regardless of whether the pain resulted in time loss, to ensure that the strength and ROM profiles are for asymptomatic football players. Past history was defined as a time loss hip or groin injury sustained in the previous season. All participants provided informed consent for the study and ethical approval was obtained from the Institutional Review Board, Anti-doping Lab Qatar on 22/7/2013, Approval number: F2013000003.

All test procedures were performed by sports physiotherapists who had received a minimum of 5 hours training in the methods. Standardized data collection forms were used to record all data. For detailed descriptions of the equipment and procedures used for the data collection, please see Appendix 1. Inter-rater reliability for the adductor squeeze and all ROM measures was examined in the screening setting with two testers used from a pool of six trained sports physiotherapists. Eccentric ADD and ABD strength inter-rater reliability was examined outside the screening setting to prevent fatigue of the football players potentially affecting the reliability results. Two testers conducted these strength measures on 21 physically active men (≥ 3hrs physical activity per week).

Eccentric ADD and ABD strength were measured in the side-lying position (Appendix 1) using a hand-held dynamometer (HHD) (PowerTrack II Commander, JTECH Medical) and the break test as described previously.[10] The rest time between contractions was shortened to 30 seconds as recommended in a subsequent paper.[6] Eccentric strength measures were normalized to body weight and lever arm and reported as Newton-metres per kg (Nm/kg), with the maximum score used for data analysis. Bilateral ADD strength was normalised to body weight and measured using a single test with the HHD placed between the knees with hip flexion 45°, as previously described.[9,21,22]

Hip ROM was measured using the following tests; internal rotation (IR) in both 90° hip flexion and prone, external rotation (ER) in 90° hip flexion, ABD in side-lying and bent knee fall out (BKFO), based on previously described methods.[15,18] Hip IR and ER in 90° flexion were measured using a goniometer[18] and two repetitions were taken for each measure (Appendix 1). Hip IR in prone[15] was measured using digital inclinometers, and three repetitions were taken. The pelvis was deemed to be level by visual assessment of the tester (Appendix 1). BKFO was measured with a single test.[15] Hip ABD range was measured in side-lying with a newly developed test (Appendix 1) using a digital inclinometer, and three repetitions were taken. The average score for each ROM measure were used for data analysis.

All analyses were performed using IBM SPSS Statistics, version 21. Inter-rater reliability results are included in Appendix 2. The demographic data and the data for each strength and ROM measure were first examined for normality using the Shapiro-Wilk test and visual inspection of data distribution histograms, and found to be normally distributed. Descriptive statistics were conducted for all the demographic, strength, and ROM variables. Comparison between the participant and non-participant groups for demographic data was conducted using independent t-tests. The effect of dominance on each strength and ROM measure (apart from adductor squeeze strength) was determined using linear mixed model analysis to generate pairwise comparisons between the dominant and non-dominant leg with Bonferroni adjustment for multiple comparisons. The strength and ROM measure were entered as the dependent variable, and dominance entered as the fixed effect. To investigate the effects of age, past injury history, and ethnicity, linear mixed model analysis was performed with each measure entered as the dependent variable: age, past injury history, and ethnicity entered independently as fixed effects, and side as a repeated measure to account for the correlation between the right and left legs of each individual. The data file was split by side to analyse adductor squeeze strength. For measures where more than one fixed effect was found to significantly influence the dependent variable, a multivariate analysis was performed.

Results

A total of 419 male footballers presented for screening for the 2014-15 QSL season. Five football players refused consent for their screening data to be used for research purposes, one player was under 18 years of age and 19 players presented with current hip or groin pain, resulting in 394 study participants. Demographic data for the cohort are summarised in table 1 and the ethnic distribution of the cohort is shown in Appendix 3 (Table A). There were no statistically significant differences in demographics found between the participant and non-participant groups, Table 1. A total of 71 (18%) study participants presented with a past history of time loss hip/groin injury in the season prior to screening.

The results for inter-rater reliability (ICC) and measurement error for all strength and ROM measures are summarised in Appendix 2.

Normal strength values are presented in Table 2, with division in leg dominance for eccentric ADD, ABD and ADD/ABD ratio. No statistically significant differences between the dominant and non-dominant legs were found for eccentric ADD, ABD strength or ADD/ABD ratio. There was no effect of age found on eccentric hip ADD or ABD strength (p=0.17-0.30), however age had a very small, but statistically significant, negative influence on the ADD/ABD ratio (slope=-0.005/year, p=0.01). Age also had a statistically significant, though small, negative influence on adductor squeeze strength (slope=-0.03N/kg/year, p<0.001). Past history of injury did not have a statistically significant effect on strength scores for eccentric ADD, ABD, ADD/ABD ratio or adductor squeeze (p=0.15-0.56). There were no statistically significant influences of ethnicity on the eccentric ADD, ABD or ADD/ABD ratios in our cohort (Appendix 3, Table A). The football players of Black ethnicity demonstrated lower squeeze strength scores than the Arabic players (mean difference=0.32 Nm/kg, p=0.029), however this effect was not significant when age was added as a covariate to the multivariate model (p=0.802, Appendix 3, Table A).

Normal ROM values are presented in Table 2 and did not differ between the dominant and non-dominant leg for hip ER, BKFO and ABD. There was a small, statistically significant difference between legs for hip IR when measured in flexion ($p=0.012$) and in prone ($p<0.001$). The differences between the means was 0.9° for hip IR in flexion and 2.1° for hip IR in prone. Age had a significant, negative influence on ER (slope=-0.29°/year, $p<0.001$) and ABD range (slope=-0.19°/year, $p=0.009$). Past history of injury influenced both ER (mean difference=2°, $p=0.032$) and BKFO range (mean difference=1.5cm, $p=0.008$). There were inconsistent patterns of the effect of ethnicity on the ROM measures (Appendix 3, Table A). Multivariate analysis for the ROM measures including the co-variable of age found that the only fixed effect that remained statistically significant was age for ER and BKFO.

Discussion

We examined the normal profiles for hip strength and range of motion measures of relevance to hip and groin pain in 394 asymptomatic, male professional football players. There were no clinically relevant differences found between the dominant and non-dominant leg for these measures. Age, past history of time loss injury from the previous season, and ethnicity were all found to have small, but statistically significant, effects on some of the normative profiles when analysed as univariate factors. However, with multivariate analysis, the small effect of past history and ethnicity were found to be covariates with age.

Eccentric ADD strength normalized to body weight and limb length was 3.0±0.6 Nm/kg, with no differences between the dominant and non-dominant leg. A previous study[12] on eccentric ADD strength in football players using the same method found a mean value of 3.1Nm/kg, similar to our data. Eccentric ABD strength was 2.6±0.4 Nm/kg in our cohort, which is the first reporting of this measurement in a large population of professional footballers. Another study that examined nine young (19.5±1.5yrs) football players found lower mean scores than our cohort for ADD (dominant=2.8 Nm/kg, non-dominant=2.5 Nm/kg) but similar scores for ABD (2.5 Nm/kg), and a difference of 13% for ADD between the dominant and non-dominant legs of their participants.[10] However, the differences between these findings and those of our study might be explained by the differences in sample size, and the lower mean age of the participants in the previous study. Low ADD strength has been shown to be a risk factor for hip and groin injury,[4,5] so the normal range to one SD and two SD (Table 2) presented in this study can now be used to identify football players who may be at risk of injury, or have failed to regain normal strength following injury. For these weaker players, simple exercises can be used to improve eccentric ADD strength[23] and may be an effective injury prevention strategy.

The ratio of hip ADD/ABD in our study was found to be 1.2±0.2, which is higher than the previously reported ADD/ABD ratio of asymptomatic professional ice hockey players (mean=0.95).[11] These differences might be explained by the differing sport specific demands of football compared with ice hockey, and consequently the risk profile for groin injuries in football may also differ. Tyler et al[11] found that ice hockey players with an ADD/ABD ratio of less than 0.8 were 17 times more likely to sustain a groin injury. The data in our cohort suggests that the injury risk threshold might be higher in football players.The normal (within 1SD) range for the ADD/ABD ratio was 0.9-1.4, therefore a player found to have a ratio less than 0.9 may be recommended to strengthen their adductors to potentially reduce their risk of hip and groin injury.

The normal strength range for the adductor squeeze test was 3.6±0.8 Nm/kg in our cohort. This test has been examined previously,[15,17,21] however our study is the first to demonstrate adductor squeeze strength values normalized to body weight. Since weight strongly correlates with strength scores, it is difficult to compare our results with previous literature. We have presented a normal range for asymptomatic football players using a single HDD measure, providing a very useful reference value for clinicians working with football players.

Age did not influence eccentric ADD and ABD strength scores. A statistically significant effect was found on the ADD/ABD ratio, but with an effect size that is likely to be clinically meaningless (-0.005/year). A statistically significant negative effect of age on adductor squeeze strength score was determined, also with a small slope (-0.03N/kg/year). This implies that for a 10 year increase in age, the adductor squeeze score can be expected to be lower by 0.3Nm/kg, or approximately 9% of the mean, a value that is within measurement error. Therefore, age would only need to be taken into account when comparing normal squeeze strength in a football population of wide age range.

Past history of time loss injury had no effect on the strength profiles. All included participants were currently asymptomatic for hip or groin pain, indicating that the 71 players who reported a time loss hip/groin injury from the previous season were likely to have regained any potential strength loss that may have resulted from the previous injury. Eccentric ADD, ABD, and ADD/ABD ratio were not different between the various ethnic groups included in our cohort. Adductor squeeze strength score was also consistent between ethnicities, once the effect of age was accounted for in the multivariate model. Therefore clinicians can be confident that these strength values, which are normalized to body weight (all tests) and limb length (eccentric tests), represent normal profiles of use for clinical comparison purposes.

Hip ROM for our cohort was similar to that reported in previous football studies.[12,15,24] Dominance only affected the ROM for hip IR in both flexion and prone. However, the mean difference between the dominant and non-dominant leg was only 1° for hip IR in flexion and 2° for hip IR in prone. These differences are well within the measurement error, and therefore unlikely to be of clinical significance, despite statistical significance being reached due to the large cohort size. While abnormal hip ROM appears not to be a clear risk factor for hip/groin injury, reduced ROM is found in athletes with current hip/groin pain.[25] The detection of musculoskeletal conditions requiring treatment or follow-up is a key aim of musculoskeletal screening.[20] Therefore measurement of hip ROM is still important to include in musculoskeletal screening in order to potentially detect current hip/groin symptoms and also relevant for the clinical management of other injuries seen in football players. such as back pain.[26,27] We have provided normal ranges that can be used for clinical comparison purposes in this athletic population.

Age had a statistically significant effect on hip ER (slope = -0.29°/year) and ABD range of motion (slope= -0.19°/year). This means that for a 10 year increase in age, ER can be expected to decrease by a mean of 3° and ABD by 2°, which is still within the measurement error. Past history of injury had a small influence on the ROM profiles with BKFO (1.5cm) and ER (2°) greater in those players that had sustained a time loss injury in the previous season. However, this effect was no longer significant when age was taken into account in the multivariate model. These findings are supported by a recent systematic review that found consistent level 2 evidence that reduced hip ROM is not associated with a greater risk of developing hip and groin injury.[5] Similarly, ethnic differences in ROM were not significant when age was taken into account in the multivariate model. Accordingly, clinicians are encouraged to consider age (but not ethnicity, dominance, or past history of injury) when interpreting ROM findings, though age only requires consideration when comparing ROM in a football population of wide age range.

The relatively small numbers of football players in some of the ethnic groups means that further work is required before we can definitively discount ethnicity as a correlate of the strength or ROM measures described in this study. Furthermore, our definition of past injury history combined categories of diagnoses and severity of time-loss injuries that were mostly confirmed by established injury surveillance methods conducted in the QSL. However, further delineation of past history by diagnosis and/or severity may reveal greater effects of this variable on the normal profiles.

Conclusion

The normal profiles for hip strength and range of motion determined for our cohort can be used as references in the clinical assessment, screening, and management of football players. Leg dominance, past history of injury, and ethnicity had no clinically relevant effect on these values, so these normal profiles can be used with confidence across cohorts of professional football players.

Practical Implications

- These normal values for hip strength and range of motion can be used for comparison purposes in the clinical assessment, screening, and management of football players.
- The diverse age, height, weight and ethnicity of our cohort ensures that these normal profiles have broad clinical generalisability
- Leg dominance, past history of injury and ethnicity had no clinically relevant effect on these normal values, indicating generalisability across football populations.

Acknowledgements

The authors thank Mohammed Farooq for his assistance with the statistical analysis for this study. The authors would also like to sincerely thank all the staff and athletes at Aspetar Orthopaedic and Sports Medicine Hospital and the National Sport Medicine Program of Qatar who contributed to the data collection.

References

1 Hagglund M, Walden M, Magnusson H, et al. Injuries affect team performance negatively in professional football: an 11-year follow-up of the UEFA Champions League injury study. *Br J Sports Med* 2013; 47(12):738–742. Doi: 10.1136/bjsports-2013-092215.

2 Werner J, Hagglund M, Walden M, et al. UEFA injury study: a prospective study of hip and groin injuries in professional football over seven consecutive seasons. *Br J Sports Med* 2009; 43(13):1036–1040. Doi: 10.1136/bjsm.2009.066944.

3 Hagglund M, Walden M, Ekstrand J. Risk Factors for Lower Extremity Muscle Injury in Professional Soccer: The UEFA Injury Study. *Am J Sports Med* 2012; 41(2):327–335. Doi: 10.1177/0363546512470634.

4 Ryan J, DeBurca N, Mc Creesh K. Risk factors for groin/hip injuries in field-based sports: a systematic review. *Br J Sports Med* 2014; 48(14):1089–1096. Doi: 10.1136/bjsports-2013-092263.

5 Whittaker JL, Small C, Maffey L, et al. Risk factors for groin injury in sport: an updated systematic review. *Br J Sports Med* 2015; 49(12):803–809. Doi: 10.1136/bjsports-2014-094287.

6 Thorborg K, Serner A, Petersen J, et al. Hip Adduction and Abduction Strength Profiles in Elite Soccer Players: Implications for Clinical Evaluation of Hip Adductor Muscle Recovery After Injury. *Am J Sports Med* 2010; 39(1):121–126. Doi: 10.1177/0363546510378081.

7 Powers C. The Influence of Abnormal Hip Mechanics on Knee Injury: A Biomechanical Perspective. *J Orthop Sports Phys Ther* 2010; 40(2):42–51. Doi: 10.2519/jospt.2010.3337.

8 Ferber R, Kendall K, Farr L. Changes in knee biomechanics after a hip-abductor strengthening protocol for runners with patellofemoral pain syndrome. *J Athl Train* 2011; 46(2):142–149.

9 Fulcher M, Hanna C, Raina Elley C. Reliability of handheld dynamometry in assessment of hip strength in adult male football players. *J Sci Med Sport* 2010; 13(1):80–84. Doi: 10.1016/j.jsams.2008.11.007.

10 Thorborg K, Couppe C, Petersen J, et al. Eccentric hip adduction and abduction strength in elite soccer players and matched controls: a cross-sectional study. *Br J Sports Med* 2009; 45(1):10–13. Doi: 10.1136/bjsm.2009.061762.

11 Tyler T, Nicholas S, Campbell R, et al. The association of hip strength and flexibility with the incidence of adductor muscle strains in professional ice hockey players. *Am J Sports Med* 2001; 29(2):124–128.

12 Thorborg K, Branci S, Nielsen MP, et al. Eccentric and Isometric Hip Adduction Strength in Male Soccer Players With and Without Adductor-Related Groin Pain: An Assessor-Blinded Comparison. *Orthop J Sports Med* 2014; 2(2):1–7. Doi: 10.1177/2325967114521778.

13 Crow J, Pearce A, Veale J, et al. Hip adductor muscle strength is reduced preceding and during the onset of groin pain in elite junior Australian football players. *J Sci Med Sport* 2010; 13(2):202–204. Doi: 10.1016/j.jsams.2009.03.007.

14 Delahunt E, McEntee B, Kennelly C, et al. Intrarater reliability of the adductor squeeze test in gaelic games athletes. *J Athl Train* 2011; 46(3):241–245.

15 Malliaras P, Hogan A, Nawrocki A, et al. Hip flexibility and strength measures: reliability and association with athletic groin pain. *Br J Sports Med* 2009; 43(10):739–744.

16 Ibrahim A, Murrell GA, Knapman P. Adductor strain and hip range of movement in male professional soccer players. *J Orthop Surg Hong Kong* 2007; 15(1):46–9.

17 Nevin F, Delahunt E. Adductor squeeze test values and hip joint range of motion in Gaelic football athletes with longstanding groin pain. *J Sci Med Sport* 2014; 17(2):155–159. Doi: 10.1016/j.jsams.2013.04.008.

18 Nussbaumer S, Leunig M, Glatthorn J, et al. Validity and test-retest reliability of manual goniometers for measuring passive hip range of motion in femoroacetabular impingement patients. *BMC Musculoskelet Disord* 2010; 11(1):194–204.

19 Verrall GM, Hamilton IA, Slavotinek JP, et al. Hip joint range of motion reduction in sports-related chronic groin injury diagnosed as pubic bone stress injury. *J Sci Med Sport* 2005; 8(1):77–84.

20 Bakken A, Targett S, Bere T, et al. Health conditions detected in a comprehensive periodic health evaluation of 558 professional football players. *Br J Sports Med* 2016:bjsports–2015.

21 Hanna C, Fulcher M, Elley R, et al. Normative values of hip strength in adult male association football players assessed by handheld dynamometry. *J Sci Med Sport* 2010; 13(3):299–303. Doi: 10.1016/j.jsams.2009.05.001.

22 Jansen J, Weir A, Dénis R, et al. Resting thickness of transversus abdominis is decreased in athletes with longstanding adduction-related groin pain. *Man Ther* 2010; 15(2):200–205. Doi: 10.1016/j.math.2009.11.001.

23 Jensen J, Holmich P, Bandholm T, et al. Eccentric strengthening effect of hip-adductor training with elastic bands in soccer players: a randomised controlled trial. *Br J Sports Med* 2012; 48(4):332–338. Doi: 10.1136/bjsports-2012-091095.

24 Engebretsen AH, Myklebust G, Holme I, et al. Intrinsic Risk Factors for Groin Injuries Among Male Soccer Players: A Prospective Cohort Study. *Am J Sports Med* 2010; 38(10):2051–2057. Doi: 10.1177/0363546510375544.

25 Mosler AB, Agricola R, Weir A, et al. Which factors differentiate athletes with hip/groin pain from those without? A systematic review with meta-analysis. *Br J Sports Med* 2015; 49(12):810–821. Doi: 10.1136/bjsports-2015-094602.

26 Murray E, Birley E, Twycross-Lewis R, et al. The relationship between hip rotation range of movement and low back pain prevalence in amateur golfers: An observational study. *Phys Ther Sport* 2009; 10(4):131–135. Doi: 10.1016/j.ptsp.2009.08.002.

27 Almeida GPL, de Souza VL, Sano SS, et al. Comparison of hip rotation range of motion in judo athletes with and without history of low back pain. *Man Ther* 2012; 17(3):231–235. Doi: 10.1016/j.math.2012.01.004.

Table 1 Demographic data for study participants

	Participants (n=394)			Non-participants (n=25)			
	Mean±SD	Minimum	Maximum	Mean±SD	Minimum	Maximum	p-value
Age (years)	26±4.8	18	39	25±5.1	16	37	0.21
Height (cm)	177±6.8	156	204	177±6.8	164	194	0.79
Weight (kg)	73±9.3	47	99	73±9.7	57	98	0.76
BMI (kg/m^2)	23±3.4	18	76	23±2.3	20	28	0.97

SD= standard deviation, BMI= body mass index

Table 2 Normal values for strength and range of motion (n=394)

	Dominant	Non-dominant			Profile Ranges				
	Mean±SD	Mean±SD	Mean difference	p value	Very low (<2SD)	Low (1-2SD)	Normal	High (1-2SD)	Very high (>2SD)
Strength									
Squeeze (N/kg)	3.6±0.8				<1.9	1.9-2.8	2.8-4.4	4.4-5.3	>5.3
Adduction (Nm/kg)	2.99±0.6	2.98±0.6	0.01	0.73	<1.7	1.7-2.4	2.4-3.6	3.6-4.3	>4.3
Abduction (Nm/kg)	2.59±0.4	2.56±0.4	0.02	0.3	<1.7	1.7-2.2	2.2-3.0	3.0-3.4	>3.4
ADD/ABD ratio	1.17±0.3	1.18±0.2	0.01	0.73	<0.7	0.7 - 0.9	0.9-1.4	1.4-1.7	>1.7
Range of Motion									
IR with 90° hip flexion (°)	31.7±7.9	32.6±8.1	-0.9	0.01	<16	16-24	24-40	40-48	>48
ER with 90° hip flexion (°)	38.4±8.4	37.9±8.5	0.50	0.10	<21	21-30	30-47	47-55	>55
IR in prone (°)	39.4±8.1	37.3±8.1	2.10	p<0.001	<22	22-30	30-47	47-55	>55
BKFO (cm)	13.1±4.5	13±4.3	0.13	0.26	<4.2	4.2-8.6	8.6-17.4	17.4-21.9	>21.9
Abduction (°)	49.7±7.5	49.8±7.2	-0.20	0.50	<35	35-42	42-57	57-65	>65

SD= standard deviation, ADD= adduction, ABD= abduction, IR= internal rotation, ER= external rotation, BKFO= bent knee fall out