The precision and torque production of common hip adductor squeeze tests used in elite football

Objectives: Decreased hip adductor strength is a known risk factor for groin injury in footballers, with clinicians testing adductor strength in various positions and using different protocols. Understanding how reliable and how much torque different adductor squeeze tests produce will facilitate choosing the most appropriate method for future testing. In this study, the reliability and torque production of three common adductor squeeze tests were investigated.

Design: Test-retest reliability and cross-sectional comparison.

Methods: Twenty elite level footballers (16-33 years) without previous or current groin pain were recruited. Relative and absolute test-retest reliability, and torque production of three adductor squeeze tests (long-lever in abduction, short-lever in adduction and short-lever in abduction/external rotation) were investigated. Each participant performed a series of isometric strength tests measured by hand-held dynamometry in each position, on two test days separated by two weeks.

Results: No systematic variation was seen for any of the tests when using the mean of three measures (ICC = 0.84-0.97, MDC% = 6.6-19.5). The smallest variation was observed when taking the mean of three repetitions in the long-lever position (ICC = 0.97, MDC% = 6.6). The long-lever test also yielded the highest mean torque values, which were 69% and 11% higher than the short-lever in adduction test and short-lever in abduction/ external rotation test respectively (p <0.001).

Conclusions: All three tests described in this study are reliable methods of measuring adductor squeeze strength. However, the test performed in the long-lever position seems the most promising as it displays high test-retest precision and the highest adductor torque production.

Keywords: soccer**,** groin, injury, measurement, strength, rehabilitation

Introduction

Decreased adductor (Add) muscle strength has been indicated to precede the onset of groin pain in young athletes[1] with football (soccer) players in particular, four times more likely to sustain a new groin injury when performing with Add strength deficits.[2] Therefore Add strength testing constitutes an important screening tool in football (soccer) not only to identify players at risk, but also for the early detection of players about to develop groin injury. For screening and monitoring of Add strength in athletes, several methods and testing positions exist today[1-4] with no consensus on which are most suitable.[5] Such a method needs to be objective, reliable[6] and capable of maximizing adductor torque production, which is associated with improved kicking performance[7-9] and may increase stress to the muscle-tendon complex.[9]

During the traditional squeeze test, the participant lies in supine with their knees together and force output is measured via short-lever resistance from the clinician’s fist, dynamometer or pressure cuff.[10-14] When performed with 45° hip flexion, this test has been found to be sensitive in detecting groin pain in athletes[3,14] and in recording greater levels of intra-rater reliability and Add muscle electromyography (EMG) activity when compared to positions of higher / lower degrees of hip flexion.[10-11] Hip flexion angle aside, many studies to date have assessed isometric Add strength from a relatively adducted (knees together) hip position,[10,14] yet clinicians often perform Add tests in varied degrees of hip abduction and external rotation. Despite this, no studies have investigated the use of such positions as a relevant squeeze test option. Altering hip joint position and the associated placement of resistance (lever-arm) will influence muscular activity and torque production during muscle strength tests.[15] In comparison to short-lever positions where resistance is applied between knees, long-lever Add testing applies resistance just proximal to the ankle.[5,15] This form of testing has demonstrated higher levels of reliability and torque production in hip adductor and abductor muscles when compared with short-lever positions,[12,15] whilst weakness in Add muscles assessed using this position has been reported to increase the risk of future groin injury by a factor of four.[2] It seems therefore that providing resistance via a longer lever could be more challenging and stressful than the traditional short-lever squeeze position, whilst longer lever resistance is arguably more reflective of most football kicking actions and hence better suited for testing Add strength in footballers. Subsequently, the need to establish the reliability and examine torque outputs for the available Add squeeze tests is evident and will facilitate the clinician in adopting the best-suited Add squeeze test for their clinical needs.

The primary aim of this study was to examine relative and absolute test-retest reliability of three hip Add testing positions using a hand held dynamometer (HHD). Proposed guidelines for reporting reliability and agreement studies (GRRAS) were followed.[16] The selected test positions included two that have received the most research attention (0° and 45° hip flexion)[3,11-15] and a test position combining hip flexion, abduction and external rotation. The secondary aim was to assess the degree of variation in torque measures across the three different Add squeeze tests.

Methods

N= 21 male Professional Footballers from two clubs in the English Football League gave their informed consent to participate in the study, Mean ± SD age = 21.3 ± 5 years (range 16-33 years), height = 180 ± 6 cm, body mass = 75 ± 6 kg. As youth football players are commonly included in the senior playing squads and often experience groin pain from an early age, we decided to include players aged under-18. All participants were outfield players (8 defenders, 8 midfielders and 5 forwards).To achieve an acceptable Intra Class Correlation Coefficient (ICC) of at least 0.70 (alpha level, a = 0.05 and beta level, b = 0.20)[17] we needed to include at least 19 participants.[18]

Included players were required to be ‘fully fit’, defined as being available for match selection and competing in full training throughout the testing period. Only players with no history of injury to the hip and groin region for 6 months were included. The participants maintained their regular training regimens throughout the experimental period and had no prior HHD test experience. The University of Chichester Ethics Committee approved the study and prior to testing each player read a participant information leaflet and signed informed consent was obtained from all players, including guardians of those under the age of 18.

All testing was performed in designated physiotherapy assessment rooms at football club training grounds. The testing set up included a portable HHD and an examination table. Muscle strength was tested with the Commander Muscle tester dynamometer (JTECH Medical, Utah, USA). The dynamometer was calibrated on each test day and all test procedures were standardized.

The same Physiotherapist (N.L) performed all measurements and HHD strength tests. All strength tests were isometric strength tests or 'make tests'.[19] Tests and retests were performed with a 2-week interval, on the same weekday and at the same time of the day. Each participant performed a number of maximal voluntary contractions (MVC) for hip adduction, in the three testing positions described below and visualized in figure 1. The long-lever test was performed in 0° hip flexion with the HHD placed 5cm superior to the Medial Malleoli.[5,15] The participants' legs were abducted to the length of the testers (NL) forearm. The short-lever in adduction position is a 45° squeeze test, measured unilaterally via the HHD. The short-lever in abduction/external rotation position again requires 45° hip flexion but participants' legs are abducted to the length of the testers forearm whilst their feet remained together.

Immediately prior to testing, participants completed a 5 min stationary bike warm-up of 80 revolutions per minute at a medium intensity. No other warm-up activity (including stretching) was permitted. Participant positioning was standardized during all trials. This included lying in the supine position with no trunk or cervical flexion and arms extended by their sides with forearms supinated. The test sequence was randomized at the initial testing session by an assistant drawing the tests and their order, blindly from a sealed envelope. The sequence was maintained in the same order for the retest session.

One sub-maximal voluntary contraction into the investigator's hand was performed for procedure familiarization. The individuals then performed three MVC's lasting 5 s each, with the peak output

(N) recorded for each trial. A standardized command by the examiner of ‘‘go ahead-push-push-push-push and relax” was adopted for the MVC[5] and the participants were not informed of their individual scores.

A 30 s rest period between trials with a 2 min rest period between test positions was introduced to avoid a decline in strength due to fatigue. No form of stretching or other intervention was permitted during rest periods. Participants rested in a comfortable supine position for the long-lever test, and their knees were passively held together held the tester (NL) for the short-lever tests. Lever length was measured from the Anterior Superior Iliac Spine (ASIS) to the point of force application (HHD placement) and recorded in cm allowing for torque calculation with all force values weight adjusted (Nm/kg).[4] Testing in all three positions, performed with the dynamometer placed on each side to measure squeeze values on both left and the right legs in each individual (18 squeeze trials in total) took approximately 20 min per player.

Distributions of variables are presented as mean ± 1 standard deviation (SD). The first, best and the average scores of three repetitions (reps) are presented for both legs, along with mean differences from test and re-test days. All the dependent variables demonstrated normal distribution (Kolmogorov-Smirnov) and parametric tests were used. Relative reliability was assessed by calculating intra-class correlation coefficient (ICC) (2.1) coefficients (two way random model, consistency definition) with corresponding 95% confidence interval (95% CI). Absolute reliability is expressed as the standard error of measurement (SEM) calculated as SD x $\sqrt{1\text{-ICC}}$, where SD is the SD of all scores from the participants.[20] SEM is also shown as SEM% by dividing the SEM with the average of the test and retest values. Minimal detectable change (MDC) was calculated as SEM x 1.96 x $\sqrt{2}$ to gain a 95% CI[20] and is also presented as a percentage (MDC%) of the average of test and retest scores. A 95% CI for the MDC% and SEM% was calculated using the upper and lower confidence limits of the ICC used to derive the SEM. A repeated measures ANOVA test with post-hoc Bonferroni correction was used to assess for statistically significant differences in torque production between test positions. A level of $P<0.05$ was used to indicate statistical significance.

Results

One participant reported non-specific groin pain prior to commencing their retest session and was therefore excluded resulting in 20 participants.

Reliability measures of the three test positions for both legs are presented in Table. 1. No statistically significant variation between test and retest values were found for any of the test positions (MDC% = 6.6–26.6%). The long-lever position yielded the least variation (MDC% = 6.6-13.7), followed by the short-lever in adduction (MDC% = 11.1-18.6) and short-lever in abduction/external rotation position (MDC% = 18.9-26.6). The smallest test-retest variation was observed when taking the mean of three reps in the long-lever position (MDC% = 6.6). Indeed for all test positions the mean of three reps showed the least variation range (MDC% = 6.6-19.5), whilst the first rep value range showed the highest (MDC% = 13.6-26.6).

Torque output (Nm/kg) of the test positions is shown in figure 2. The long-lever test yielded 69% more torque (2.43 ± 0.34) than the short-lever in adduction (1.44 ± 0.37) and 11% more than the short-lever in abduction/ external rotation (2.18 ± 0.36). This was a statistically significant difference, determined by repeated measures ANOVA, $p < 0.001$ with post hoc tests using Bonferroni correction revealing the difference between all three-test positions was statistically significant ($p < 0.001$).

Discussion

In the present study we have investigated the relative and absolute reliability for common positions of Add squeeze testing using HHD, and compared the torque values between tests in elite football players.

All test positions demonstrated small test-retest measurement variation, indicating their potential for use in the clinical setting. The least variation of each test occurred when taking the mean of three reps. The long-lever test yielded just 6.6% (MDC) followed by the short-lever in adduction (MDC% = 11.1-13.2) then the short lever in abduction/external rotation (MDC% = 18.9-19.5). Similarly, all tests demonstrated excellent relative reliability with the long-lever and short-lever in adduction tests recording the best ICC values of 0.90-0.97 and 0.93-0.97 respectively. Previous studies obtained comparable ICC values ranging between 0.81 and 0.94 for varying short-lever squeeze test positions.[10,14] The least promising test for ICC values was the short-lever in abduction/external rotation (ICC = 0.68-0.97). This position generated very high force outputs, potentially due to the added rotatory component of the test with the tester (NL) reporting difficulty maintaining dynamometer placement in this position, possibly contributing to these findings.

Whereas relative reliability (ICC) reflects variation in measures at group level, absolute reliability (MDC) is a more valuable measure for analyzing individual test scores. MDC values represent the minimal change of an individual's test scores that can be detected and therefore interpreted as real, facilitating valid clinical decisions.[21] MDC values therefore demonstrate the discriminative capabilities of tests and should be considered when monitoring or screening Add strength in individuals. A key finding of the present study is the low MDC values reported for the mean of three reps in the long-lever position (MDC% = 6.6) in comparison to the short-lever in adduction (MDC% = 11.1-13.2) and the short-lever in abduction/external rotation (MDC% = 18.9-19.5). Whilst traditional short-lever squeeze tests have discriminated between patients with and without groin pain,[3,14] the low long-lever MDC values presented here, suggest this test may be more precise and capable of detecting more subtle changes in squeeze strength.

In order to detect such clinically relevant changes in strength, the adopted Add squeeze test must be capable of challenging the musculature in a way that generates maximal available torque. Our findings show the long-lever test yielded significantly higher torque output (69%) compared to the short-closed position supporting previous study findings where long-lever test positions produced more force in comparison to short-lever positions.[12,15] Higher torque production is reflective of joint angles that optimize the muscle moment arm, motor unit activation and importantly muscle length.[22] This force-length relationship is attributed to the muscles active contractile and passive elastic components[23] and cross-bridge interaction,[24] with previous research showing that elongated muscles develop greater torque than when shortened during isometric strength tests.[22,25] Notably, the long-lever test in the present study was performed with hip abduction to the length of the tester's forearm (26.5 cm). This may optimize the Add muscles moment arm and force-length relationship, allowing for a more efficient working position than the traditional short-lever squeeze test and explain our findings.

A further factor that may contribute to increased Add torque generation from an abducted position is the proximal Add tendon histology. Up to 62% of Add longus pubic attachment may be composed of muscular fibres[26] whilst many fibers of Add brevis insert directly onto the bone.[27] Subsequently, these proximal fibres may remain sub-optimally lengthened when tested in the traditional short-lever in adduction squeeze position.

The traditional short-lever in adduction squeeze position has previously demonstrated greater levels of Add EMG activity when compared with other test positions.[11-12] This has led to the suggestion that this position is likely to place optimal stress to the Add musculature and across the pubis [10-11.] However, as EMG activity has been shown to reduce with muscle elongation whilst torque generation increases (and vice-versa),[22] it should not be considered as a direct reflection of anatomical stress during squeeze tests. Our findings suggest anatomical stress should also be reflective of lever-length, test joint positioning and the subsequent muscle elongation.

Whilst this study indicates that the long-lever test is favorable for both reliability and torque production, there are other clinical implications for the data presented. Firstly, our analyses of three different measures within each test may hold clinical implications, such as the 'first' rep values in the long-lever position (MDC% = 13.6-13.7) suggestive of a precise measure that is obtainable with just one trial. This is potentially ideal for daily monitoring when time efficiency is important (a single MVC could be completed in less than 30 s). Ultimately if a large reduction is strength is observed with one trial, repeating the test to gain three measures will generate a more precise, meaningful change that can be related to baseline or future measures. Secondly, the lower Add torque generated in the traditional squeeze test position (short-lever in adduction), indicates the use of this less stressful test in the presence of pain or when monitoring Add strength during early stage rehabilitation, with a view of progressing onto the more stressful long-lever test. Thirdly, the short-lever in abduction/external rotation test demonstrated reasonable reliability, suggesting that this test may be used to assess musculature in a combined hip movement position, arguably reflective of muscle activation during running and kicking. Indeed assessing the Add muscles in various positions due their multi-functional roles has previously been advised.[10]

A limitation of the present study is the absence of examining the inter-tester reliability which has been shown to be influenced by the sex and upper extremity strength of testers when using HHD.[28] It is important to note however that squeeze tests have been found to be less prone to systematic variation when compared with HHD with no fixed resistance.[10,15,29] Secondly, hip abduction for testing in both the long-lever and short lever in abduction/external rotation positions was standardized to the testers (N.L) forearm. Therefore, variation in participant leg length may result in slight changes in hip abduction angle during testing. However, the length of the adult ulna bone varies minimally[30] and dynamometer placement could be regulated by being placed further up or down the leg to attain similar abduction angles, regardless of the length of the tester's forearm or the participant's leg.

Conclusion

Three commonly utilized squeeze tests described in this study are reliable methods of Add strength testing. However, the squeeze test in the long-lever position seems the most promising as it displays high test-retest precision and the highest Add torque production. Ultimately, this test is precise, challenging and stressful for the adductor muscle-tendon complex, potentially capable of detecting subtle weaknesses that may dispose to future Add injury.

Practical Implications

- Long-lever Add testing demonstrates excellent test-retest reliability with high ICCs and low MDC values indicative of very high test precision.
- Precise measures can be obtained by recording the mean of just three MVC reps, ideal for baseline screening where a single player can complete testing in less than 2 minutes and a squad of 25, in approximately one hour.
- Long-lever Add testing results in much higher levels of torque in comparison to short-lever test positions, maximising stress to Add musculature and pubic complex and potentially alluding to more subtle strength deficits.

Acknowledgements

The authors thank Sean Duggan (Physiotherapist) and Andrew Proctor (Physiotherapist) for technical assistance.

References

1) Crow JF, Pearce AJ, Veale JP 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

2) 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

3) 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

4) 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. *Ortho J Spor Med* 2014; 2(2): 1-7

5) Thorborg K, Peterson J, Magnusson, S.P, Holmich, P. “Clinical assessment of hip strength using a hand-held dynamometer is reliable” *Scand J Med Sci Spor* 2010; 20: 493-501

6) Delahunt E, Thorborg K, Khan KM, et al. Minimum reporting standards for clinical research on groin pain in athletes. *Br J Sports Med* (2015); 49(12): 775-781

7) Masuda K, Kikuhara N, Demura S et al. Relationship between muscle strength in various isokinetic movements and kick performance among soccer players. *J Sports Med Phys Fit* 2005; 45: 44–52

8) Charnock BL, Lewis CL, Garrett WE et al. Adductor longus mechanics during the maximal effort soccer kick. *Sports Biomech* 2009; 8: 223–234

9) Jensen J, Bandholm T, Holmich P et al. Acute and sub-acute effects of repetitive kicking on hip adduction torque in injury-free elite youth soccer players. *J Sports Sci* 2014; 32(14): 1357-1364

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

11) Delahunt E, Kennelly C, McEntee BL et al. The thigh adductor squeeze test: 45 degrees of hip flexion as the optimal test position for eliciting adductor muscle activity and maximum pressure values. *Man Ther* 2011; 16(5): 476–480

12) Lovell GA, Blanch PD, Barnes, CJ. EMG of the hip adductor muscles in six clinical examination tests. *Phys Ther Sport* 2012; 13: 134-140

13) Coughlan GF, Delahunt E, Caulfield BM et al. Normative adductor squeeze test values in junior rugby union players. *Clin J Sport Med* 2014; 24(4): 315-319

14) 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): 739–74

15) Krause DA, Schlagel SJ, Stember BM et al. Influence of lever arm and stabilization on measures of hip abduction and adduction torque obtained by hand-held dynamometry. *Arch Phys Med Rehabil* 2007; 88: 37–42

16) Kottner J, Audige L, Brorson, S et al. Guidelines for Reporting Reliability and Agreement Studies (GRRAS) were proposed. *Int J Nurs Stud* 2011; 48: 661-671

17) Terwee CB, Bot SDM, De Boer MR, et al. Quality criteria were proposed for measurement properties of health status questionnaires. *J Clin Epidemiol* 2007; 60:34–42

18) Walter SD, Eliasziw M, Donner A. Sample size and optimal designs for reliability studies. S*tat Med* 1998; 17:101–110

19) Sisto SA, Dyson-Hudson T. Dynamometry testing in spinal cord injury. *J Rehabil Res Dev* 2007; 44: 123–136

20) Weir JP. Quantifying test–retest reliability using the intraclass correlation coefficient and the SEM. *J Strength Cond Res* 2005; 19: 231–240

21) Hachana Y, Chaabene H. Test-retest reliability, criterion-related validity, and minimal detectable change of the illionois agility test in male team sport athletes. *J Strength Cond Res* 2013; 27(10): 2752–2759

22) Lunnen JD, Yack J, LeVeau BF. Relationship between muscle length, muscle activity, and torque of the hamstring muscles. *Phys Ther* 1981; 61(2): 190-195

23) Morrison JB. The mechanics of muscle function in locomotion. *J Biomech* 1970; 3: 437-451

24) Del Valle A, Thomas CK. Motor unit firing rates during isometric voluntary contractions performed at different muscle lengths. *Can J Physiol Pharmacol* 2004; 82: 769-776

25) Neumann DA, Soderberg GL, Cook TM. Comparison of maximal isometric hip abductor muscle torques between hip sides. *Phys Ther* 1988; 68(4): 496-502

26) Robertson BA, Barker PJ, Fahrer M et al. The anatomy of the pubic region revisited. Implications for the pathogenesis and clinical management of chronic groin pain in athletes. *Sports Med* 2009; 39(3): 225-234

27) Davis JA, Stringer MD, Woodley SJ. New insights into the proximal tendons of adductor longus, adductor brevis and gracilis. *Br J Sports Med* 2012;46: 871–876

28) Thorborg K, Bandholm T, Schick M et al. Hip strength assessment using handheld dynamometry is subject to intertester bias when testers are of different sex and strength. *Scand J Med Sci Sports* 2013; 23: 487-493

29) Thorborg K, Bandholm T, Holmich P. Hip- and knee-strength assessments using a hand-held dynamometer with external belt-fixation are inter-tester reliable. *Knee Surg Sports Traumatol Arthrosc* 2013; 21(3):550-555

30) Ilayperuma I, Nanayakkara G, Palahepitiya N. A model for the estimation of personal stature from the length of forearm. *Int J Morphol* 2010; 28(4):1081-1086

Figure legends

Figure 1. Add test positions: A) long-lever B) short-lever in adduction C) short-lever in abduction/external rotation

Figure 2. Box plot for mean torque (Nm/kg) values of each test position (Long lev = long-lever; Short Add = short-lever in adduction; Short Abd/ER = short-lever in abduction/external rotation)