

Original Research

Maximal Strength Testing Using the Long-Lever Hip Adduction Squeeze Test in Youth Elite Football (Soccer) Players: A Four-Week Reliability Study

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Introduction

The long-lever hip adduction squeeze test is a feasible and quick way to measure maximal hip adduction strength, which is associated with groin injury risk. Excellent week-to-week reliability has been established in senior elite football. Youth elite players often engage in physical activities outside of the football academy, which may affect reliability. This study aimed to investigate the week-to-week reliability of the long-lever hip adduction squeeze strength in a youth elite academy football setting using a novel groin strength testing device.

Materials and Methods

Seventy-nine youth elite male football players from the U13 to U19 teams of a youth elite football academy were included. During four consecutive weeks, players were tested weekly at the same day each week (match day +2), using a long-lever hip adduction squeeze device with maximal strength recorded. Players who reported groin pain of >2 out of 10 during testing were excluded.

Results

No systematic bias was observed between the different testing weeks ($p > 0.5$). Good and consistent relative week-to-week reliability was observed (ICC: 0.916-0.933). Absolute reliability (SEM %) ranged from 7.6-8.6%, with MDCind % and MDCgroup % ranging from 21.2-24 % and 3.3-5.8 %, respectively.

Conclusion

Week-to-week measures of long-lever hip adduction strength showed good relative and absolute reliability, and thus can be used in the academy setting to reliably screen for groin injury risk.

INTRODUCTION

Groin pain represents a significant challenge in football (soccer) with a weekly seasonal prevalence of up to 12 % in senior players¹ and 20% of elite youth football players reporting groin pain during a mid-season screening.² Primary

prevention strategies, such as team-wide implementation of the FIFA 11+ and/or the Copenhagen Adduction exercise, have shown promising effectiveness in decreasing injury risk by 40 %.^{3,4} In addition, secondary prevention strategies through hip adduction strength assessments⁵ during both the in-season period⁶⁻⁸ and season breaks^{5,9} has been proposed as a relevant and practical tool to identify players at

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increased risk. Elite youth Australian Football players participated in weekly in-season screening of hip adduction strength using the short-lever hip adduction squeeze test.⁶ Players who reported previous week groin pain for two consecutive weeks were classified as having a groin injury, and at the week of onset players had 11% lower strength compared to baseline, while 6 % lower in the preceding week.⁶ Recent studies in youth elite football players corroborate these findings. Across 14-weeks of weekly monitoring of hip adduction squeeze strength, a 17% drop was found in the week groin pain was reported.⁷ Furthermore, Wollin et al. showed that early intervention based on a weekly monitoring framework including strength assessments and self-reported hip and groin pain resulted in gradually higher hip adduction strength, thus mitigating the injury risk, coinciding with a lower groin injury rate across 2-years.⁸

In youth elite football, weekly monitoring of hip adduction strength may be particularly relevant considering the high prevalence of groin pain in this population.^{2,10} For an objective serial monitoring system to be effective, high reliability and low measurement error are paramount. Maximal hip adduction squeeze strength in the long-lever position with slightly abducted hips produces a high force output^{11, 12} and is sensitive to detect groin pain compared to testing in 0 degrees abduction as seen in the ForceFrame device.^{12, 13} The test can be obtained using a handheld dynamometer placing the forearm between the ankles with high reliability (Intraclass Correlation Coefficient (ICC): 0.92-0.95) and low Standard Error of Measurement (SEM) of 3.2-7.7 % in elite male football players¹¹ and recreational athletes.¹⁴ However, the week-to-week reliability of the long-lever hip adduction squeeze test in youth elite football players remains unexplored. Given the presence of external stressors,¹⁵ unregulated football load outside the academy setting,¹⁶ and potential underreporting of groin pain during testing,¹⁷ all of which may introduce significant random error, determining the reliability in real-world settings are important. This will help clinicians understand the usefulness of the testing in a serial monitoring framework to aid early detection of groin pain in football. This study aimed to investigate the week-to-week reliability of the long-lever hip adduction squeeze strength in a youth elite academy football setting using a novel groin strength testing device.

METHODS

STUDY DESIGN

The present study investigated week-to-week reliability of long-lever hip adduction peak force using a novel portable long-lever hip adduction squeeze device (ForceMate, CC Athletics, Odense Denmark). All tests were conducted by two physiotherapist students who prior to the study initiation 1) received dedicated supervision by an experienced physiotherapist, and 2) practiced the testing setup for three weeks. Subjects were included by a convenience sampling from a youth elite football academy in the Greater Copenhagen Region, Denmark. The reporting follows the Proposed Guidelines for Reporting Reliability and Agreement

Studies (GRRAS).¹⁸ Ethical approval was obtained from the Danish Ethics Committee of the Capital Region as part of a larger project (ID: H-19026064). Information on the study was distributed to relevant stakeholders at the club prior to study initiation, who all provided consent on the study.

SUBJECTS

Seventy-nine youth elite male football players (mean age 16.4 y, mean body mass 64.3 kg) from the U13 to U19 teams were included from a youth elite football academy in the Greater Copenhagen Region, Denmark. All players who were fit for training and match selection were eligible for inclusion. Exclusion criteria on each testing session were: provoked pain in the hip and groin region during the long-lever hip adduction squeeze test >2 on a 0-10 Numeric Rating Scale,^{7,19} or any other pain during testing that was considered by the player to influence their ability to perform a maximal muscle contraction of the adductors.

DATA COLLECTION

All tests were conducted at the facilities of the football academy as part of routine check-in of players on Mondays (typically matchday +2) during four consecutive weeks (11th of April to 15th of May 2023), and before any pitch sessions. For each testing session, all eligible players of the respective teams underwent testing. Peak isometric long-lever hip adduction squeeze strength was recorded using a novel portable groin strength device with a sampling frequency of 960 Hz (GroinMate, CC Athletics, Odense, Denmark). Peak force was measured as Newtons, and transmitted to an accompanying software program (ForceMate, CC Athletics, Odense Denmark) via a USB connection, which also calculated peak force of each trial based on a 200 ms smoothing running window. The testing protocol followed previously established testing protocols for assessing long-lever hip adduction squeeze strength, which has shown high inter-session reliability (ICC=0.97, MDC_%=6.6) in elite male football players.¹¹ In the supine position with hips and knees at 0 degrees flexion, players positioned their ankles at the load cells corresponding to 5 cm proximal to the most prominent point the medial malleolus. From this position, the players were instructed to perform a bilateral hip adduction squeeze test. Prior to testing, one trial at 100% of perceived voluntary hip adduction squeeze effort were performed, followed by two maximal trials at the rate of one trial every 30-60 seconds. Players were instructed to push as hard as possible, but to build up force gradually and reach maximal force within 5 seconds.¹¹ Standardized verbal encouragement was provided during each maximal voluntary contraction (MVC) trial by the tester, as: "ready-go-1-2-3-4-5-and relax." The peak force for each trial was used for analyses.

STATISTICAL METHODS

All statistical analyses were calculated in R Studio (v. 3.6.1). Systematic bias between weeks was assessed as differences in mean values using paired t-tests with a significance level set at p<0.05. Relative reliability was assessed as Intraclass

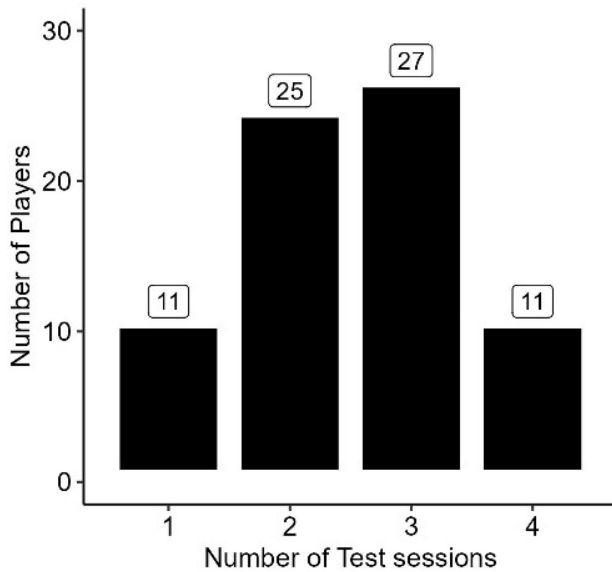


Figure 1. Number of test sessions per player.

Correlation Coefficient (ICC) with a two-way random effects model and absolute agreement definition using the *irr* package. Absolute agreement was chosen as this examines the relative reliability without incorporating a systemic error term (this means that the ICC value reflects any systematic variation that may be present between sessions). The relative reliability was interpreted as poor ($ICC < 0.50$), moderate ($0.50 \leq ICC < 0.75$), and good ($ICC > 0.7$). Absolute reliability was expressed as 1) the standard error of measurement (SEM) calculated as: $SD(\text{pooled}) \times \sqrt{1 - ICC}$, and 2) SEM% calculated as: $\left(\frac{SEM}{\text{Mean}(\text{pooled})}\right) \times 100$. Minimal detectable change % (MDC%) was calculated using SEM%, both at the individual level ($MDC_{\text{ind}} \% = SEM\% \times 1.96 \times \sqrt{2}$) and group level ($MDC_{\text{group}} \% = \frac{SEM\% \times 1.96 \times \sqrt{2}}{\sqrt{n}}$, where n is the sample).

RESULTS

PARTICIPANTS

A total of 79 youth elite football players from U13-U19 (U13, n = 17; U14, n = 6; U15, n = 17; U17, n = 24; U19, n = 15) underwent a total of 208 tests. Of those, 186 tests in 74 players were considered pain-free, with the distribution of the number of tests for each player shown in [Figure 1](#). Players with only a single test or non-consecutive tests were removed leaving a total of 161 tests from 53 players in the final analyses, with 15 players in week 1-2, 41 players in week 2-3, and 44 players in week 3-4.

INTER-WEEK RELIABILITY

No systematic bias was observed between the different testing weeks ($p > 0.5$) ([Table 1](#); [Figure 2](#)).

Good and consistent relative week-to-week reliability was observed ($ICC: 0.916-0.933$). Absolute reliability (SEM %) ranged from 7.6-8.6%, with $MDC_{\text{ind}} \%$ and $MDC_{\text{group}} \%$ ranging from 21.2-24 % and 3.3-5.8 %, respectively ([Table 2](#)). Bland-Altman plots are depicted in [Figure 3](#).

DISCUSSION

This study assessed week-to-week reliability over four consecutive weeks of the long-lever hip adduction squeeze test in a real-world setting of an elite youth football academy. Based on the good relative ($ICC: 0.916-0.933$) and absolute (SEM %: 7.7-8.7) reliability, practitioners working with youth elite football players can expect to obtain relatively consistent week-to-week measures of hip adduction long-lever squeeze strength. However, the minimal detectable change of ~ 22 % highlights the challenges in capturing subtle changes in strength at the individual level.

COMPARISON TO PREVIOUS RESEARCH

To the authors' knowledge, this is the first study to assess week-to-week reliability of the long-lever hip adduction test in youth elite football players. Previous studies in similar populations, have investigated either week-to-week reliability of the short-lever test with 45 degrees hip flexion ($ICC: 0.93$, $MDC\%: 23$)²⁰ or the long-lever test during consecutive days ($ICC: 0.85$, $SEM\%: 8$)²¹ with comparable relative and absolute reliability reported. A novel long-lever hip adduction testing device was used with the distance between load cells corresponding to the length of an adult person's forearm, allowing the player to be tested with slightly abducted hips; a test setup comparable to the Copenhagen 5-Second Squeeze Test.¹⁹ This contrasts with the ForceFrame device, used in previous studies,^{20,21} which uses a narrower distance between load cells resulting in the long-lever hip adduction squeeze test being performed in 0 degrees hip abduction limiting the force production capabilities of the hip adductors.¹² The long-lever test with slightly abducted hips optimizes the length-tension relationships of the adductor muscles,²² resulting in 15 % higher hip adduction torque compared to the long-lever test performed in the ForceFrame.¹² In addition, the long-lever test with slightly abducted hip also seems to lead to increased sensitivity to pain being reported, likely due to the higher torque stressing the groin.¹² While these differences in testing setup do not seem to impact reliability,^{20, 21} it may be relevant to consider in the context of period monitoring of strength and pain, where practitioners aim to capture the highest possible force output and potential pain associated with the effort.^{7,8}

The present findings show lower reliability and higher measurement error compared to a similar study with the same testing methodology, but performed in senior male football ($ICC: 0.92$; SEM %: 4.3).¹¹ The authors can only speculate that this discrepancy may be related to the different settings of academy versus senior level football. Unlike senior players, academy players often attend classes during the day before participating in football training in

Table 1. Week to week comparison of long-lever bilateral hip adduction squeeze strength.

	# Subjects	Test ^a	Retest ^a	Difference ^b	95% CI ^c	p-value
Week 1 to 2	15	253.5 (66.8)	259.4 (64.3)	-5.9	-22, 10	0.5
Week 2 to 3	41	250.6 (76.0)	253.4 (73.2)	-2.8	-12, 5.8	0.5
Week 3 to 4	44	240.0 (77.9)	237.3 (73.1)	2.7	-6.3, 12	0.5

^aMean Newtons (SD)

^bPaired t-test

^cCI = Confidence Interval

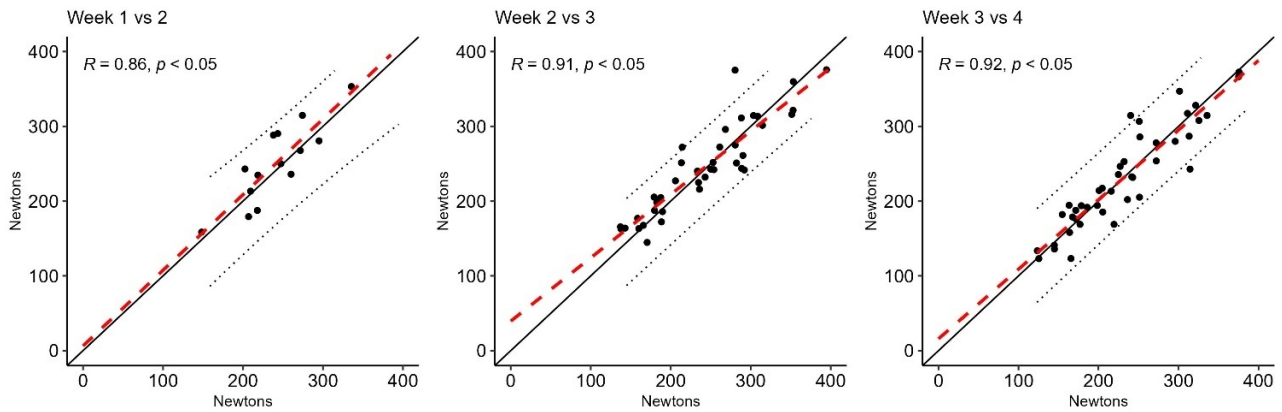


Figure 2. Week-to-week associations in hip adduction strength. The dashed lines depict the prediction interval. The black line represents the optimal non-biased association.

Table 2. Week to week relative and absolute reliability of maximal strength obtained using the long-lever bilateral hip adduction squeeze test.

	#Subjects	ICC	Lower CI	Upper CI	SEM	SEM %	SEM _{ind} %	SEM _{group} %
Week 1 to 2	15	0.90	0.78	0.96	20.6	8.0	22.3	5.8
Week 2 to 3	41	0.93	0.89	0.96	19.3	7.7	21.2	3.3
Week 3 to 4	44	0.92	0.88	0.95	20.8	8.7	24.1	3.6

ICC (Intraclass Correlation Coefficient); CI (Confidence Interval); SEM (Standard Error of Measurement)

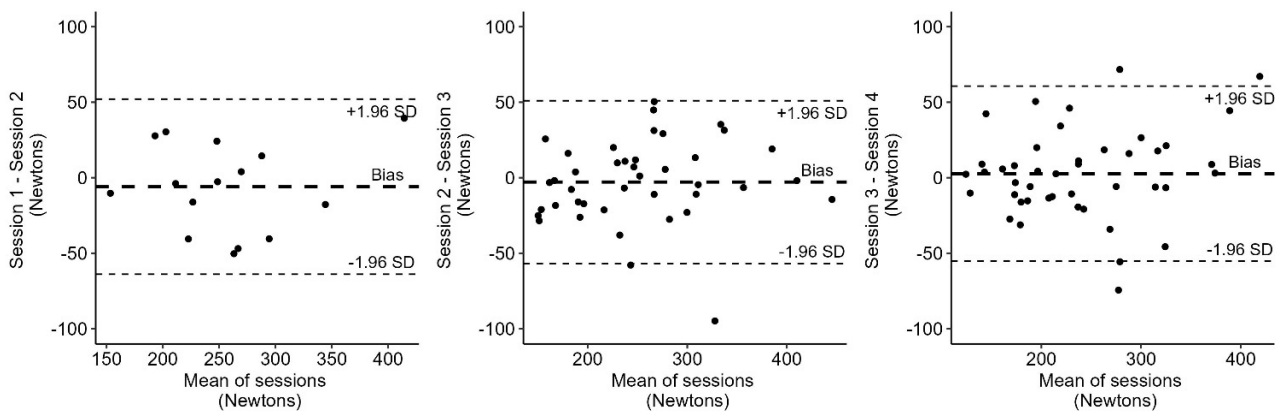


Figure 3. Bland-Altman plot showing agreement between test sessions of consecutive weeks. The solid line indicates mean bias; dashed lines represent 95% limits of agreement.

the afternoon/evening, and it is likely that mental fatigue may be a factor. In addition, Johnson et al.¹⁶ showed that academy football players often engage in additional football outside of the academy, suggesting that the daily load may vary a lot, and it is also not uncommon for players to not report pain during testing when having pain.¹⁷ It would not be surprising if such factors increased the random error around the true strength score potentially affecting reliability.

IDENTIFYING PLAYERS AT RISK OF GROIN PAIN

One of the main goals of period monitoring of hip adduction strength and screening of symptoms is to identify potential at-risk players early during the in-season period before they become more severe or transition into time-loss injuries.^{8, 17, 23} In a 39-week prospective study conducted in semi-professional senior players, the average weekly prevalence of non-time-loss groin injuries was 10.4 % compared to 1.3 % reported as time-loss.¹ Interestingly, self-reported hip and groin sport function, measured using the Copenhagen Hip and Groin Outcome Score (HAGOS Sport),²⁴ was equally impaired in players with and without time-loss groin injury compared to pain-free players, emphasizing the relevance of identifying non-time-loss injuries.¹ In youth elite football, a midseason screening protocol consisting of self-reported groin pain and clinical examination, found that 20 % had non-time-loss groin pain, while 40 % reported palpation tenderness as part of the clinical examination but no self-reported groin pain.² Importantly, players with groin pain had worse HAGOS scores for the majority of subscales compared to players with no groin pain.² In addition to the associated self-reported deficits reported by players having non-time-loss groin pain, such a state also seems to increase the risk of time-loss groin injury.²⁵ In a prospective season-long study in semi-professional football, reporting a non-time-loss groin complaint was subsequently associated with a 3.5 relative risk of a time-loss groin injury,²³ emphasizing the need for an early detection as part of risk management. A consistent monitoring framework⁸ may be particularly relevant to implement in the youth football population due to the high prevalence during the ages of 13-17^{2, 10} and due to the fact that progression throughout the academy system towards the senior level is often associated with rapid spikes in loads negatively affecting the injury risk profile.²⁵ If not managed appropriately, it is likely that such high-load periods may manifest as groin pain with the risk of transitioning into time-loss injuries²³ and potentially hinder progression towards the senior team.²⁶ Light et al.¹⁰ observed that young football players experience a spike in groin injury incidence around the ages of 13-15 years, coinciding with the period of peak physical growth. This period is also associated with a rapid increase in both hip adduction strength²⁷ and adductor muscle forces produced during kicking.²⁸ While such changes in force production capabilities are indicative of natural physical development, it may also increase the risk for groin injuries due to the increased biomechanical demands, suggesting that periodic monitoring of hip adduc-

tion strength may be relevant already from 13 years of age.^{10, 27}

PRACTICAL APPLICATIONS

In an optimal weekly groin pain monitoring framework, both strength and self-reported symptoms are used to identify players with groin pain or at increased risk of progressing towards a clinical state.⁸ However, self-reported pain during weekly screenings may not always be reliable, as large discrepancies seem to exist between anonymous (higher prevalence of groin pain) versus non-anonymous player feedback mainly due to players' fear of being sidelined when reporting groin pain.¹⁷ In such situations, week-to-week changes or changes compared to a fixed pain-free reference in hip adduction strength may become the primary identifying factor. The MDC_{ind} % in the current study ranged from 21.2-24% indicating that changes in hip adduction strength from week-to-week exceeding this can be obtained with 95% confidence. In the context of weekly monitoring of strength, DeLang et al.⁷ observed a 17.3% drop in hip adduction strength in the same week as players reported groin pain, and a 10% drop in the preceding week. Using a post-hoc cut-off of a 15 % drop in strength,⁸ 55 % of players progressing on to have groin pain in the subsequent week would have been identified (true positives), while this was only the case for 9 % of players not progressing on to have groin pain (false positives).⁷ By using the MDC% of the current study as a cut-off (~22%), which allows the clinician to be confident on a true change in change, it is apparent that less true positive cases would be identified (i.e. players need to exceed a strength drop of 22%), while likely also reducing the false positives rates. This has the clear advantage of limiting identification of players with just a transient strength decrease without truly having an increased risk of injury, thus avoiding unnecessary sidelining of players. However, by using a high cut-off value, players at increased risk could go unnoticed, which underlines the challenges of weekly monitoring of hip adduction strength for risk management. Nonetheless, using a MDC% of ~30% for hip adduction strength decrease as an alert during weekly monitoring of strength led to a 25% reduction in time-loss groin injury burden in professional male football players.²⁹

LIMITATIONS

The present study is associated with limitations. Firstly, while the authors attempted to perform tests on the same day of the week (Monday, typically match day +2), there were no inclusion / exclusion criteria based on match minutes played and/or other activities between tests. As previous days' training load may affect hip adduction strength³⁰ the decision to not control for football load likely affected the reported reliability, however, such random error reflects the nature of a weekly monitoring system. Secondly, the authors did not anonymize pain ratings provided by players during testing, and thus it cannot be ruled out that some players may have been erroneously included in the analyses due to hiding of their pain.¹⁷

CONCLUSION

Week-to-week measures of long-lever hip adduction strength in elite youth football players showed good relative and absolute reliability. Applied to a secondary prevention strategy to detect early groin pain in individual players, an objective adduction squeeze strength deficit exceeding ~20% may be recommended.

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CONFLICTS OF INTEREST

The authors report no financial conflicts of interest, but LI and MDD have offered feedback in the development of the testing device used in the present study.

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