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LETTER

Inter- and intra-session variability of compression strain gauge for the adductor groin squeeze test on soccer athletes

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Abstract

The importance of hip adductor strength for injury prevention and performance benefits is well documented. The purpose of this study was to establish the intra- and inter-day variability of peak force (PF) of a groin squeeze protocol using a custom-designed compression strain gauge device. Sixteen semi-professional soccer players completed three trials over three separate testing occasions with at least 24-h rest between each session. The main findings were that the compression strain gauge was a reliable device for measuring PF within and between days. All intraclass correlations were higher than 0.80 and coefficients of variations were below 10% across the different sessions and trials. Due to the information gained through the compression strain gauge, the higher sampling frequency utilized, portability, and the relatively affordable price, this device offers an effective alternative for measuring maximal strength for hip adduction.

1 | INTRODUCTION

The importance of hip adductor strength for sport performance is well established [1–14], especially within sports requiring high-speed changes of direction such as soccer, rugby, and hockey [1–3, 6, 10–12, 14, 15]. Researchers have also shown a relationship between maximal hip adductor strength and injury [2, 3, 6, 8, 10, 12]. Peak maximal isometric adductor strength lower than 465 N within soccer athletes increased the probability of suffering a groin injury by 72% [10]. Within soccer players, hip adduction strength levels appear significantly lower when compared to other sports [2, 3, 7, 10, 11], as the specific demands for soccer require athletes to spend less time in deep flexed hip positions [2]. Given that groin injuries account for a substantial percentage (12%–16%) of all soccer injuries per season [16], it would seem important to measure, monitor, and manage changes in hip adductor strength in soccer athletes to understand potential risks for groin injuries. For this to happen, easy to use, reliable, and affordable technology is needed.

The groin squeeze test is a reliable indicator of overall hip adductor strength [1–12, 17]. This test requires athletes to lie in a supine position, with their hips flexed at 45 or 90 degrees, and thereafter maximally squeeze their thighs together. Typically, maximal groin strength has been measured using handheld dynamometers (HHD) [2, 6, 8, 11, 18] and sphygmomanometers (SPH) [4, 5, 7, 9, 12, 19]. However, these devices can only measure one limb at a time. To assess total maximal groin strength, the ability to assess both limbs simultaneously is more time efficient [20, 21].

The Groinbar is a relatively new device that can assess both unilateral and bilateral hip adductor strength and has shown acceptable reliability [20–22]. However, only intra-session reliability has been quantified with this device. Therefore, quantifying the inter-session variability of hip adductor strength is needed to gain a better understanding of the utility and accuracy of this measurement. Furthermore, the affordability and utility of such a device are problematic for many.

Given this information, an in-house compression strain gauge device was designed as a low-cost, high-accuracy, and high-utility device. The device overcomes the standardization, tester influence, and unilateral measurement issues observed in the HHDs and SPHs. Also, the device used in the current study collects data at a higher sampling rate (1000 Hz) as compared to the Groinbar (400 Hz), meaning that the device can identify changes in force more accurately, which is especially important if both devices progress to measuring the rate of force development. The new technology may have advantages over the existing technology in the market, including price point; however, the reliability of the device has not yet been established. Therefore, the purpose of this study was to evaluate both intra- and inter-session reliability of a custom-designed compression strain gauge device for measuring peak hip adductor force on a groin squeeze test in soccer athletes.

2 | METHODS

2.1 | Experimental approach

A repeated-measures experimental design that quantified the variability of a custom-designed compression strain gauge device over three testing occasions in soccer players was implemented. Peak hip adductor force from a groin squeeze was the variable of interest, the variability of which was quantified via coefficients of variation (CVs) and intra-class correlation coefficients (ICCs).

2.2 | Participants

Twenty-four semi-professional male soccer players (age 20.4 ± 5.02 years, height 176.76 ± 14.78 cm, weight 78.13 ± 6.66 kg) from the same team were recruited for this study. Of the cohort, 16 completed the entire study, due to injuries or failure to complete all three testing sessions. The study was voluntary, and each participant completed and signed either a written or an electronic consent form. Ethics was approved through the Auckland University of Technology Ethics Committee (20/358).

2.3 | Procedures

Before each testing session, participants completed a 10-min soccer-specific standardized dynamic warm-up, with a focus placed on hip mobility to ensure that the hip-groin area was adequately warmed up and stretched before the groin squeeze test. Participants were then asked to adopt the correct set-up position (see Figure 1). Participants were instructed to remove their shoes and lie with their back, buttocks, and head on the floor, arms parallel to their torso, legs hip-width apart, and knees bent with feet on the floor. They were then asked not to move from the position during the full session. If the participant moved, the testing administrator re-measured the hip angle and ensured they were placed back into the correct position. To align with best practice from previous research, participants had their hip flexion angle measured using a goniometer and set at 45 degrees [1, 2, 5, 8]. The compression strain gauge device was then placed between the adductor tubercle of the femurs with the device facing upwards.

Participants completed three trials during each testing session, with a warm-up trial before the first trial. For the warm-up trial, participants were instructed to squeeze the compression strain gauge device for 2 s at approximately 50% to 80% of their maximum effort. This was followed by three trials performed at maximal effort. For each of these trials, participants were instructed to squeeze the compression strain gauge device for 5 s 'as hard as possible'. After each trial, 1 min of recovery was given. The same testing procedures were replicated for all subsequent testing sessions.

FIGURE 1 Schematic of hip adductor strength testing.

Participants were tested on three occasions with the minimum time between a session being 1 day and the maximum being 60 days. The time between testing was not standardized. As such, random variation was introduced into the testing.

2.4 | Instrumentation

Force data were collected with a custom-designed (SPRINZ Laboratories, Auckland University of Technology) compression strain gauge device (see Figure 2), containing a single-axial load cell (MT501, Millennium Mechatronics, Auckland, NZ) sampling at 1000 Hz and interfaced with custom-designed data acquisition software. Custom-designed pads were attached to either side of the device for data collection. For each trial, the participant was required to hold a pre-tension of roughly 50 N prior to any contraction.

2.5 | Data analyses

All data were imported into MATLAB (MathWorks, Natick, MA) for analysis. Each trial was trimmed to length to include a steady pre-tension period of at least 0.5 s, force onset, an isometric contraction for at least 2 s, and a force offset. The onset of force was determined using expert manual selection [23]. Peak force (PF) was calculated as the absolute maximum force recorded during the entirety of the 2-s contraction.

2.6 | Statistical analyses

All statistical analyses were conducted using RStudio IDE (Version 1.4.869, 2009–2020 RStudio, PBS) to examine the reliability

TABLE 1 Intra- and Inter-session reliability of peak force.

	Mean ± SD			Change in mean		CV [95% CI]		ICC [95% CI]	
	S1	S2	S3	S1–S2	S2–S3	S1–S2	S2–S3	S1–S2	S2–S3
Intrasession									
Peak force (N)	385 ± 78.1	395 ± 76.4	392 ± 76.7	9.82	−3.29	5.47 [1.51, 7.59]	4.47 [3.28, 5.40]	0.93 [0.82, 0.97]	0.95 [0.88, 0.98]
Intersession									
Peak force (N)	409 ± 86.9	398 ± 96.1	410 ± 80.3	−11.1	12.1	9.48 [5.58, 12.1]	8.94 [4.03, 11.9]	0.83 [0.59, 0.93]	0.86 [0.66, 0.94]

FIGURE 2 In-house strain gauge device for assessing hip adductor strength.

of PF within and across three sessions (S1, S2, and S3). Group mean and standard deviations were calculated for intra- and inter-session PF to describe the centrality and spread of data. Intra-session variability was assessed using a minimum of two trials during the participant's first testing session. Inter-session variability of PF was analyzed using the average of a minimum of two trials per session across the three testing occasions. Normality was visually assessed using Q–Q plots and confirmed using the Shapiro–Wilks test ($p > 0.05$). The change in mean, within-subject CV, and ICC—two-way mixed effects, single, absolute agreement were used to analyze systematic change, absolute, and relative consistency, respectively. Confidence intervals of 95% were reported.

3 | RESULTS

The intra- and inter-session variability of PF can be observed in Table 1. In terms of systematic change, the change in PF ranged from 385 to 410 N with the greatest change observed in intersession variability, between sessions 2 to 3 (12.1 N). With regards to absolute consistency (CV), greater variability was associated with intersession (∼9.2%) compared to intra-session (∼5.0%) values. This trend of greater variability was also associated with the relative consistency measures, the ICCs less for between-session (∼ 0.85) compared to within-session (∼ 0.94) measures.

4 | DISCUSSION

The purpose of this study was to investigate the intra- and inter-session variability of a custom-designed compression strain gauge device for measuring hip adduction PF in semi-professional soccer players. The main findings were: (1) low systematic change (< 12.1 N) was observed between sessions and within trials; (2) absolute consistency for all measures was less than 10%; and (3) relative consistency was high with all the ICC values being above 0.80.

For a full true appreciation of the variability of a measure, it has been recommended that a systematic change in the mean, as well as measures of absolute and relative consistency (i.e. within-subject variation and retest correlations, respectively), should be reported [24]. When looking at the mean data and the change in the mean, it is apparent that there is very little change between testing occasions (< 3%). This is noteworthy, especially in terms of between-session variability as retesting was as long as 60 days apart from the first tests for some subjects. The intra-session systematic change compares favourably with other devices such as a HHD—6.6% to 19.5% [14], SPH— < 7% [4, 7, 15], and Groinbar—(0.1–3 N) [8, 22]. In terms of this study, the learning effect appears minimal, and players can be tested with as little as one familiarization session before the first testing session.

Although there is no preset standard for acceptable CV values, many researchers set a goal of < 10% for 'good' reliability [25]. As expected, greatest variability was associated with the inter-session testing; however, all CVs were less than 10%. Other researchers have reported absolute consistency for: SPH = ∼9% [8], HHD = 11.3% [1], and Groinbar = 4.9–9.0% [22]. The absolute consistency of the technology used in this study is comparable to other devices used to measure groin strength.

With regards to relative or rank order consistency, all ICCs were greater than 0.80. As expected, greater variability was once more associated with inter-session testing. Correlations greater than 0.80 are thought high and sufficiently reliable [25]. Other researchers quantifying relative consistency have reported values of: HHD = 0.40 to 0.97 [2, 17, 18, 26], SPH = 0.61 to 0.96 [4, 9, 17, 19, 26], and Groinbar intra-session reliability = 0.81 to 0.94 [20, 22]. Once more the results of this study are comparable to other devices.

One limitation of this study is that only one variable, PF, was investigated. Other variables such as time to PF, impulse, or rate of force development could provide greater insight into the risk of groin injuries among this population. To gain an understanding of how reliable the compression strain gauge is for measuring these other variables during a groin squeeze test will require further algorithm development and research.

4.1 | Practical applications

To our knowledge, this was the first study to use a compression strain gauge as a device to measure groin adduction strength. The methodology is highly reliable and provides an alternative to the previously used technology, while still being portable and easy to use. The squeeze test has been used in multiple studies before with the use of a HHD, Groinbar, or a SPH, all of which have also been shown to be reliable. Due to the information gained through the compression strain gauge, the higher frequency utilized, the portability, and the affordable price, this device offers an effective alternative for measuring maximal strength for hip adduction.

AUTHOR CONTRIBUTIONS

Kieran J. McMinn: Data curation; investigation; methodology; writing—original draft; writing—review and editing. **Shelley N. Diewald**: Data curation; software; writing—review and editing. **Craig Harrison**: Investigation; methodology; supervision; writing—review and editing. **John B. Cronin**: Investigation; methodology; supervision; writing—review & editing. **Dana Ye-Lee**: Writing—review and editing.

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CONFLICT OF INTEREST STATEMENT

John B. Cronin owns stock in Kiwi Texas LLC, a funder of this research. Dana Ye-Lee is an employee for associated projects, funded by Kiwi Texas LLC. The remaining authors have no conflicts of interest to declare.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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