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To cite this article: Liam Anthony Toohey, Marcos de Noronha, Carolyn Taylor & James Thomas (2017): The validity and reliability of the sphygmomanometer for hip strength assessment in Australian football players, Physiotherapy Theory and Practice, DOI: 10.1080/09593985.2017.1374492

To link to this article: http://dx.doi.org/10.1080/09593985.2017.1374492

Published online: 11 Sep 2017.
The validity and reliability of the sphygmomanometer for hip strength assessment in Australian football players

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\textbf{ABSTRACT}

\textbf{Objectives:} To investigate the intra-rater and inter-rater reliability of the sphygmomanometer for the assessment of the adductor squeeze test and isometric hip abduction strength and to investigate the concurrent validity of the sphygmomanometer for the assessment of hip muscular strength. \textbf{Method:} Thirty-two healthy adult male community Australian football players (age 23.9 ± 4.5 years) were assessed by two blinded raters that measured the strength of the adductor squeeze test and isometric hip abduction, using a commercially available sphygmomanometer. Concurrent validity was calculated using handheld dynamometry as the reference standard. \textbf{Results:} Moderate to high intra-rater reliability (ICC = 0.61 to 0.92) and high inter-rater reliability (ICC = 0.77 to 0.91) were found. High concurrent validity (Pearson’s r = 0.77 to 0.91) was established. Sixteen of the participants reached the maximal reading of the sphygmomanometer, demonstrating a ceiling effect. \textbf{Conclusions:} A sphygmomanometer is a cost-efficient device that appears to be both reliable and valid for the assessment of hip strength, offering clinicians an alternate and easily accessible option to obtain objective strength data. A ceiling effect may limit the application of the sphygmomanometer as a strength measurement device in stronger individuals.

\textbf{Introduction}

Measurement of hip isometric muscle strength is a common component of a clinician’s physical examination of football players presenting with hip or groin pain (Crow et al. 2010; Malliaras et al. 2009). Hip abduction and abduction isometric strength measures are commonly used to screen athletes to identify those at an increased risk of injury (Crow et al. 2010; Tyler et al. 2001) and offer an objective measure when evaluating an athlete’s ability to return to sport (Thorborg et al. 2011). Established instrument validity and reliability is essential to ensure that the initial diagnostic values collected are relevant and follow-up assessment measures are precise to allow for accurate interpretation and analysis (Portney and Watkins 2009).

Handheld dynamometry provides objective assessment results comparable with isokinetic dynamometry for the assessment of isometric muscle strength (Stark et al. 2011). High reliability has been established for the handheld dynamometer (HHD) for the assessment of hip isometric strength across different football codes (Fulcher et al. 2010; Light and Thorborg 2016). Despite accuracy and practicality, the cost of an HHD ($1,000 AUD) precludes wider clinical use (Toohey et al. 2015). The sphygmomanometer, a tool used to commonly measure blood pressure, has been used as a cost-efficient ($30 AUD) alternative to provide objective strength values for the adductor squeeze test performed in football populations (Malliaras et al. 2009; Roe et al. 2016; Taylor et al. 2011). Normative strength values for the adductor squeeze test using the sphygmomanometer have been established in asymptomatic youth (Coughlan et al. 2014) and adult rugby populations (Hodgson et al. 2015). Adductor squeeze test values for Gaelic football players with long-standing groin pain have also been established with comparison to non-injured players using the sphygmomanometer (Nevin and Delahunt 2014).

Despite common clinical use, the psychometric properties of the sphygmomanometer for the assessment of hip muscle strength have not been comprehensively evaluated (Toohey et al. 2015). Three studies have adequately demonstrated high reliability findings (ICC ≥ 0.8) for the assessment of adductor isometric strength using the squeeze test in football populations (Delahunt et al. 2011b; Malliaras et al. 2009; Roe et al. 2016). No studies...
have investigated the reliability of the sphygmomanometer for measurement of hip strength in adult Australian football (AF) players, who will likely have greater strength than junior AF players assessed previously (Malliaras et al. 2009). To date, the reliability of the sphygmomanometer for the assessment of hip abductor strength in athletic populations has not been established. No studies have investigated the validity of the sphygmomanometer for assessment of hip muscle strength in healthy or sporting populations.

Therefore, our aims were to investigate: 1) the intra-rater and inter-rater reliability of the sphygmomanometer for the assessment of the adductor squeeze test and isometric strength of the hip abductor muscles; and 2) to establish the concurrent validity of the sphygmomanometer for the assessment of the same measures compared with the reference standard of handheld dynamometry.

Methods

Participants

Thirty-two adult male community level AF players (age 23.9 ± 4.5) volunteered for the study. A sample size of 25 players was required to power the study based on a power analysis rationale (De Vet et al. 2011), and a pilot study was conducted with 13 AF players. Players were eligible to participate if they were fluent in English and aged between 18 and 40 years. Players were excluded if they had any current groin or pelvic symptoms or had sustained an injury within the last month to the groin or pelvic region. Ethical approval was granted by the Faculty of Health Sciences, Human Ethics Committee, La Trobe University (FHEC13/064), and participants provided signed informed consent.

Apparatus

A standard commercially available aneroid sphygmomanometer (Cumper and Robbins, Australia Medical Diagnostic Equipment Supplier) was used for testing, which recorded pressure from 0 mmHg to 300 mmHg. The sphygmomanometer’s cuff was folded into thirds and preinflated to 10 mm Hg for the assessments (Taylor et al. 2011). The highest peak score displayed on the measurement dial to the nearest 5 mmHg was recorded. If a player scored over 300 mmHg, the result was recorded as 300 mmHg. A Lafayette HHD (Model 01163, Lafayette Instrument Company, Lafayette, IN) that records muscle strength in kilograms was used as the reference standard. All devices were calibrated prior to the initial testing session.

Procedure

A test-retest design was used, with an interval of seven days between sessions. Two raters performed the testing after receiving three hours of training. Rater A was a final year undergraduate physiotherapy student, and Rater B was a senior physiotherapist. The raters and participants were blinded to the results through the use of two independent observers who read and recorded the readings from the devices. The order of device used, muscle group tested, and side of hip abduction to be tested for each participant were randomly assigned during the initial testing session. All testing was performed at the club where players normally practiced, with the intention to replicate normal field based physiotherapy practice in regular assessment or screening sessions.

Hip adduction strength was assessed bilaterally using the adductor squeeze test (Fulcher et al. 2010; Taylor et al. 2011). The participant was positioned in supine, arms across their chest, knees at 90° flexion, and hips at 45° flexion (Figure 1) (Taylor et al. 2011). The squeeze test was performed in 45° hip flexion as this position has been demonstrated to elicit the greatest degree of adductor activity (Delahunty et al. 2011a). The center point of the device was placed between the most prominent point of each femoral condyle. The participant was then instructed to squeeze the device with maximal force for 5 seconds.

Hip abduction strength was assessed unilaterally as there is no statistically significant difference between sides for isometric hip abduction strength in adult Australian football players (Prendergast et al. 2016). The participant was positioned in side lying, with the
test lower limb uppermost in 0° of flexion and abduction at the hip, and full knee extension. The underneath knee was flexed to 90° to provide stability. The center of the device was placed 5 cm proximal to the lateral malleolus (Figure 2) (Steffen et al. 2008). The participant was instructed to maximally push upward into the device for 5 seconds that was stabilized by the rater’s hands to create a make test procedure, which has been demonstrated to be more accurate than a break test for hip abduction assessment (Schmidt et al. 2013). A rest period of 60 seconds was provided between each maximal contraction of both tests, allowing adequate time for muscle restoration (Hébert et al. 2011).

**Data analysis**

The statistical software IBM SPSS (Version 21.0; IBM SPSS Inc, Chicago, IL) was used to calculate the reliability and validity correlations. Intraclass correlation coefficients (ICC$_{2,1}$) were used to calculate inter- and intra-rater reliability. The standard error of the measurement (SEM) and the minimum detectable change at the 90% confidence level (MDC$_{90}$) were also calculated. Pearson’s product moment correlation (r) was used to calculate validity for the data collected from Rater A in the initial testing session. Correlation values were interpreted as good if they were greater than 0.75, moderate if they were 0.50–0.75, and poor if they were less than 0.50 (Portney and Watkins 2009).

**Results**

Thirty-two participants were eligible for testing, with 25 completing both the test and retest sessions. Reasons for dropout were the development of groin pain between testing sessions and inability to attend the retest session. Sixteen participants reached the maximal reading for the sphygmomanometer of 300 mmHg during the squeeze test, and therefore, the results for these tests are presented separately; values are inclusive and exclusive of the maximal scores (Table 1-3).

Intra-rater reliability calculated for the squeeze test was found to be good for both raters, while the intra-rater reliability for assessment of hip abduction was found to be good for Rater A and moderate for Rater B (Table 1). The inter-rater reliability correlations calculated for both testing positions were found to be good (Table 2). Pearson’s r values for concurrent validity were calculated to be good for each of the testing positions (Table 3).

**Discussion**

This study, to our knowledge, reports the first findings on validity for the use of the sphygmomanometer to assess hip muscular strength in either an athletic or a healthy population. The satisfactory values for reliability and concurrent validity suggest the sphygmomanometer can be used in a clinical setting as an alternative to HHD for objective hip strength assessment.

Good concurrent validity correlations were found between the sphygmomanometer and HHD for both the adductor squeeze test and the isometric hip abduction test. The results found in this study are consistent with those of a previous study that equated hip isometric strength scores of stroke patients obtained from a sphygmomanometer and HHD (r = 0.75–0.89) (Martins et al. 2014). Similar findings in grip strength (Agniew and Maas 1991; Balogun et al. 1990) and upper limb muscle groups have also been reported (Martins et al. 2015). For clinical purposes, it is possible to transform data between the sphygmomanometer (mmHg) and the HHD (kg) using formulas developed through linear regression techniques (Pagano and Gauvreau 2000).
Table 1. Intra-rater reliability results.

<table>
<thead>
<tr>
<th>Measures</th>
<th>Rater A</th>
<th>Rater B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sphygmomanometer squeeze (mmHg)</td>
<td>0.92 (0.84–0.97)</td>
<td>0.87 (0.71–0.94)</td>
</tr>
<tr>
<td>Sphygmomanometer squeeze (excluding ≥300) (mmHg)</td>
<td>0.89 (0.71–0.96)</td>
<td>0.80 (0.48–0.93)</td>
</tr>
<tr>
<td>Sphygmomanometer hip abduction (mmHg)</td>
<td>0.82 (0.63–0.92)</td>
<td>0.61 (0.29–0.81)</td>
</tr>
</tbody>
</table>

Note: ICC = intraclass correlation coefficient; SD = standard deviation; CI = confidence interval; SEM = standard error of measurement; MDC<sub>90</sub> = minimal detectable change

Table 2. Inter-rater reliability results.

<table>
<thead>
<tr>
<th>Measures</th>
<th>Rater A</th>
<th>Rater B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sphygmomanometer squeeze (mmHg)</td>
<td>261 (39)</td>
<td>266 (38)</td>
</tr>
<tr>
<td>Sphygmomanometer squeeze (excluding ≥300) (mmHg)</td>
<td>238 (37)</td>
<td>240 (40)</td>
</tr>
<tr>
<td>Sphygmomanometer hip abduction (mmHg)</td>
<td>188 (33)</td>
<td>201 (33)</td>
</tr>
</tbody>
</table>

Note: ICC = intraclass correlation coefficient; SD = standard deviation; CI = confidence interval; SEM = standard error of measurement; MDC<sub>90</sub> = minimal detectable change at the 90% confidence interval

Table 3. Validity results.

<table>
<thead>
<tr>
<th>Measures</th>
<th>Sphygmomanometer (mmHg)</th>
<th>HHD (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Squeeze test</td>
<td>261 (39)</td>
<td>27.1 (6.3)</td>
</tr>
<tr>
<td>Squeeze test (excluding ≥300)</td>
<td>243 (34)</td>
<td>24.7 (4.9)</td>
</tr>
<tr>
<td>Hip abduction</td>
<td>188 (33)</td>
<td>16.7 (3.6)</td>
</tr>
</tbody>
</table>

SD = standard deviation; Pearson’s r = Pearson product moment correlation; CI = confidence interval; HHD = handheld dynamometer

The following formulae represent the conversions between the two devices:

\[
HHD (Kg) = 0.12 \times \text{sphygmomanometer (mmHg)} - 5.53 \text{ (SEM = 2.58 Kg)}
\]

\[
\text{sphygmomanometer (mmHg)} = \frac{6.76 \times HHD (Kg) + 75.30}{\text{SEM = 19.29 mmHg}}
\]

Practically, this means that a 300 mmHg reading obtained using the sphygmomanometer equates to a reading of 30.47 Kg on the HHD.

The reliability findings of our study support previous findings that sphygmomanometer has acceptable reliability to be used clinically to assess hip muscular strength. The good intra-rater reliability findings (ICC = 0.80 to 0.92) of the adductor squeeze test performed in 45 degrees hip flexion are similar to the previous findings in: elite junior AF and soccer players (ICC = 0.94) (Malliaras et al. 2009); adult Gaelic Games players (ICC = 0.92) (Delahunt et al. 2011b); and adult rugby players (ICC = 0.95) (Roe et al. 2016). The good inter-rater reliability (ICC = 0.89 to 0.91) found for the adductor squeeze test is also similar to the findings in elite junior AF and soccer players (ICC = 0.83) (Malliaras et al. 2009), demonstrating the highly reproducible results between raters.

The moderate to good intra-rater reliability for hip abduction found in the present study is comparable to the findings of two previous studies that have assessed hip abduction strength using the sphygmomanometer. These studies found good intra-rater reliability correlations for hip abduction in healthy university students (ICC = 0.93) (Perossa et al. 1998) and in postoperative hip fracture patients (ICC = 0.75 to 0.86) (Sherrington and Lord 2005). This is the first study that has assessed the inter-rater reliability of sphygmomanometer for the assessment of hip abduction strength (ICC = 0.77), which provides further confidence for its clinical use with this muscle group.

The use of the sphygmomanometer for hip muscle strength assessment in strong individuals was potentially limited by a ceiling effect. Sixteen of the participants (50%) reached the maximal reading during the squeeze test with the sphygmomanometer. Adult AF players appear to be substantially stronger than junior football players and adult Gaelic Games players, who did not appear to reach a maximal reading during the squeeze test in previous studies (Delahunt et al. 2011b; Malliaras et al. 2009). However, the adductor squeeze test strength values of professional rugby union players published in a recent study contained mean cohort values greater than 300 mmHg (Roe et al. 2016). Values exceeding 300 mmHg were not recorded in this study as the manufacturer of the sphygmomanometer that was used in this study suggests that values exceeding 300 mmHg are not accurate, while the measurement intervals on the dial were also not continuous from 300 mmHg back to the starting point of 0 mmHg.
A preseason adductor squeeze test score below 225 mmHg was recently found in Gaelic football players to increase the probability of sustaining a groin injury by almost eight fold compared with players who achieved a score of 225 mmHg or more (Delahunt, Fitzpatrick, and Blake, 2017). This finding suggests that clinicians could continue to use the sphygmomanometer to screen athletic populations to identify individuals with lower adductor strength scores who are at risk of injury. If precise strength readings above the maximal reading of 300 mmHg were required, an HHD may be a more suitable option.

This study has overcome common limitations of previous studies that have investigated the reliability of the sphygmomanometer for assessment of hip strength. Both raters in this study were blinded to findings reducing the risk of reporting bias. Randomization of the testing order was performed to help prevent selection bias impacting the results. The results of the study are limited due to half of the participants reaching a ceiling effect of the sphygmomanometer, and hence the results should be interpreted with some caution.

**Conclusion**

The sphygmomanometer appears to be valid and reliable for the assessment of the adductor squeeze test and hip abduction isometric strength in community adult AF players. Its use may be restricted in stronger individuals due to a ceiling effect.

**Acknowledgments**

The authors would like to thank the players and clubs who participated in this study and Mr. Keegan FitzGerald who assisted in the study design and data collection.

**Declaration of Interest**

The authors report no declarations of interest.

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Perossa DR, Dziak M, Vernon HT, Hayashiita K. 1998. The intra-examiner reliability of manual muscle testing of the hip and shoulder with a modified sphygmomanometer: a


