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The use of a sphygmomanometer to measure shoulder isometric strength: a validity and reliability study

O uso do esfigmomanômetro para mensurar força isométrica do ombro: um estudo de validade e confiabilidade

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Abstract

Introduction: A sphygmomanometer is an instrument commonly used to measure blood pressure that can potentially be used to objectively assess shoulder isometric muscle strength. **Objective**: To establish the criterion validity and the intra-rater reliability of the sphygmomanometer for the assessment of shoulder isometric muscular strength compared to the handheld dynamometer. To determine if there is a statistically significant difference for shoulder strength between dominant and non-dominant sides. **Methods**: A test-retest study design was developed, where a rater assessed shoulder flexion and abduction isometric strength of 13 healthy university students, using a commercially available sphygmomanometer and a handheld dynamometer. **Results**: The criterion validity of the sphygmomanometer was found to be good for both right and left shoulder flexion and abduction strength assessment (Pearson's r = 0.90-0.97). The intra-rater reliability of the sphygmomanometer was calculated to be good for both right and left flexion and abduction (ICC = 0.96-0.99). The handheld dynamometer also showed good intra-rater reliability for each of the strength measures assessed (ICC = 0.94-0.98). Significant differences ($p < 0.01$) were identified between dominant and non-dominant sides for shoulder strength. **Conclusion**: A sphygmomanometer is a simple and easily accessible tool that provides clinicians with accurate objective values for isometric shoulder strength assessment.

Keywords: Muscle Strength. Reproducibility of Results. Validity of Tests. Shoulder.

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Resumo

Introdução: *O esfigmomanômetro é um instrumento usado para mensurar pressão arterial que pode potencialmente ser utilizado para avaliação objetiva da força muscular isométrica do ombro.* ***Objetivo:*** *Estabelecer critérios de validade e confiabilidade intra-avaliador do esfigmomanômetro em relação ao dinamômetro manual para avaliação da força muscular isométrica do ombro. Determinar se há diferença estatisticamente significante entre a força do ombro entre o lado dominante e não dominante.* ***Métodos:*** *Um estudo de confiabilidade teste reteste foi desenvolvido onde um avaliador mensurou a força isométrica de flexão e abdução do ombro de 13 universitários saudáveis utilizando um esfigmomanômetro comercialmente disponível e um dinamômetro manual.* ***Resultados:*** *Como critério de validade, o esfigmomanômetro mostrou-se adequado para avaliação da força isométrica de flexão e abdução de ombro tanto do lado direito como do lado esquerdo (r de Pearson = 0,90-0,97). Quanto à confiabilidade intra-avaliador, o esfigmomanômetro apresentou boa confiabilidade para flexão e abdução em ambos os lados (CCI = 0,96-0,99) e o dinamômetro manual também apresentou boa confiabilidade para todas as medidas (CCI = 0,94-0,98). Foram identificadas diferenças significativas entre o lado dominante e não dominante para força de ombro (p < 0,01).* ***Conclusão:*** *O esfigmomanômetro é uma ferramenta simples e acessível que fornece a clínicos medidas objetivas com acurácia da avaliação da força isométrica do ombro.*

Palavras-chave: *Força Muscular. Reprodutibilidade dos Testes. Validade dos Testes. Ombro.*

Introduction

Assessment of shoulder muscular strength is a key diagnostic component of a clinician's physical examination for shoulder pathology. Measurement of shoulder strength also allows for intervention program effectiveness to be evaluated and can be used to help screen athletes at risk of shoulder injury (1). Assessment of both dominant and non-dominant shoulder strength can provide an insight into specific regions of weakness in some sporting populations and assist in injury prevention (2). Objective strength measurements have superior levels of reliability and validity compared with subjective assessments, such as manual muscle testing, providing greater confidence in clinical assessment findings (3, 4).

Handheld dynamometry (HHD) provides the clinician working in a clinical setting with objective assessment results comparable to isokinetic dynamometry for shoulder strength assessment (5). Despite the established reliability and validity of a HHD, the disadvantage of its use is inaccessibility with each unit often exceeding $1,000AUD. A potentially viable option is the sphygmomanometer. A sphygmomanometer, costing approximately $30AUD, is a tool used to measure blood pressure that has also been used to measure isometric muscle strength (6).

The application of a sphygmomanometer to assess shoulder muscular strength has not been thoroughly evaluated. To date, there are no studies that have investigated the validity of the sphygmomanometer for assessment of shoulder muscles, while 2 studies have shown promising results regarding reliability, with intraclass correlation coefficients (ICC) ranging between 0.86-0.97 (7, 8). The preliminary evidence from these studies is encouraging, but in each of these studies the sphygmomanometer had been modified in an attempt to improve accuracy, meaning their results are not a true representative of the standard sphygmomanometer accessible to the average clinician.

Therefore, our aims were to 1- investigate the criterion validity of a standard commercially available sphygmomanometer for the assessment of isometric strength of the shoulder flexor and abductor muscles, compared with the reference standard of HHD; 2- determine the intra-rater reliability of the sphygmomanometer and the HHD for the same measurements, and 3- identify if there was a statistically significant difference for shoulder strength between dominant and non-dominant sides.

Methods

Participants

A sample size of 13 was required determined from a power analysis rationale, where an ICC of 0.8 and a 95% CI from 0.60-1.00 could be expected (9). Seven male and six female university students (aged 18-26) volunteered to participate in the study. Of the 13 students, 12 were right hand dominant and 1 was left hand dominant. The students were recruited through advertising posters displayed at the university and were selected in consecutive order. The students were eligible to participate in the study if they were over 18 years of age and fluent in English. Students were excluded if they had sustained a shoulder injury within the preceding month or had any ongoing shoulder pathology assessed through self-report. The participants were blinded to their results in each session. Ethical approval to conduct the study was granted by the Faculty of Health Sciences, Human Ethics Committee, La Trobe University (FHEC13/064) and participants provided signed informed consent.

Rater

One rater, a final year undergraduate physiotherapy student, completed the testing. The rater received 1 hour of training from 2 senior physiotherapists in the use and application of both devices prior to conducting the testing.

Apparatus

The cuff of a standard commercially available aneroid sphygmomanometer (Cumper and Robbins, Australia Medical Diagnostic Equipment Supplier) was folded into thirds and pre-inflated to 10 mmHg for the assessment procedure (10). The peak score displayed on the measurement dial to the nearest 5 mmHg was recorded. A Lafayette HHD (Model 01163, Lafayette Instrument Company, Lafayette, Indiana), which records peak muscle strength as a unit of force in kilograms (kg) over a range of 0-136.1 kg with an accuracy of ± 1% over the full scale, was used as the reference standard. Both devices were calibrated prior to the initial testing session.

Research Design

A test-retest design was conducted. Testing of the participants occurred across 7 days to ensure that sufficient muscle recovery had taken place and to prevent changes in muscle strength that may have occurred over a greater time period due to other factors (11). The order of device used, muscle group tested and the side of the body initially tested for each participant was randomly assigned by selecting an envelope that had previously been prepared by flipping a coin as described by Doig and Simpson (12), with the same order used for the repeat testing session.

Procedure

Single measure isometric muscle strength testing was performed maximally for shoulder flexion and abduction on the left and right side of each participant, using both measurement devices. Single measure testing was selected instead of multiple testing measures to allow for the results to be directly applicable to the average clinician in a standard clinical practice. The more highly reproducible protocol of performing 3-5 trials with a 1-2 minute break between trials, where the mean score is used, is not a realistic option in standard clinical practice due to clinical consultation time restrictions. A sub-maximal practice effort for each shoulder movement was performed prior to the first testing session to allow the participants to familiarise themselves with the testing process. Participants were then instructed to perform a maximal contraction for 5 seconds, with a rest period of 1 minute provided between each contraction.

Shoulder flexion was assessed with the participant seated on a standard stool without a back rest. Each participant was asked to sit in a comfortable upright posture with their shoulder blades lightly drawn backward. The participant was asked to raise their arm to 90° of flexion in neutral shoulder rotation and pronation so that their thumb was facing upward. The measurement device was placed 5cm proximal to the distal radial articular surface (Figure 1). Shoulder abduction was assessed as above, however, the participant was asked to raise their arm into 90° abduction rather than flexion (Figure 2).

Figure 1 - Measurement procedure for shoulder flexion strength.

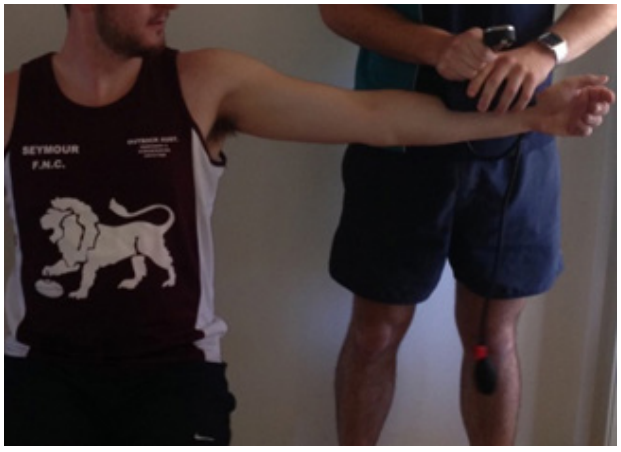

Figure 2 - Measurement procedure for shoulder abduction strength.

Data Analysis

Reliability and validity correlations were calculated using IBM SPSS (version 21.0; IBM SPSS Inc, Chicago, IL). Pearson's product moment correlation (r) was used to determine criterion validity. $ICC_{2,1}$ were used to calculate intra-rater reliability. The standard error of the measurement (SEM) and the minimum detectable change at the 90% confidence level (MDC_{90}) were calculated. Interpretation of criterion values were considered 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 (13). Paired t tests were performed to identify any significant differences between dominant and non-dominant sides, with the level of significance set at $p = 0.05$.

Results

All 13 participants completed both testing sessions with no adverse reactions being reported.

The sphygmomanometer was found to have good intra-rater reliability, with $ICCs_{2,1}$ between 0.96 to 0.99 found for left and right shoulder flexion and abduction (Table 1). Similarly the $ICCs_{2,1}$ found for the HHD assessment of the right and left shoulders demonstrated good correlation that ranged from 0.94 to 0.98 for flexor and abductor muscle strength (Table 1).

Pearson's r values for criterion validity demonstrated good correlation with values of 0.96 (0.85-0.99) and 0.97 (0.86-0.99) for right and left shoulder flexion respectively, and 0.90 (0.78-0.99) and 0.97 (0.97-1.00) for right and left shoulder abduction (Table 2).

Significant differences ($p \leq 0.01$) were identified between the dominant and non-dominant sides, when using either measurement device, for assessment of both shoulder flexion and abduction (Table 3).

Table 1 - Intra-rater reliability results

Measures	Right Shoulder			Left Shoulder		
	ICC2,1 (95% CI)	SEM	MDC90	ICC2,1 (95% CI)	SEM	MDC90
Sphygmomanometer shoulder flexion (mmHg)	0.99 (0.96 - 1.0)	4.85	11.24	0.96 (0.67 - 0.99)	10.50	24.36
Sphygmomanometer shoulder abduction (mmHg)	0.97 (0.90 - 0.99)	8.72	20.22	0.98 (0.93 - 0.99)	7.25	16.80
HHD shoulder flexion (kg)	0.96 (0.86 - 0.99)	1.13	2.62	0.98 (0.93 - 0.99)	0.79	1.84
HHD shoulder abduction (kg)	0.95 (0.84 - 0.98)	0.98	2.27	0.94 (0.82 - 0.98)	1.19	2.77

Note: Abbreviations: $ICC_{2,1}$ = intraclass correlation coefficient; CI = confidence interval; SEM = standard error of measurement; MDC_{90} = minimal detectable change; HHD = handheld dynamometer.

Table 2 - Validity results

Measures	Sphygmomanometer (mmHg) Mean ± SD	HHD (kg) Mean ± SD	Pearson's r (95% CI)
Right shoulder flexion	130 ± 48	11.0 ± 5.7	0.96 (0.85-0.99)
Left shoulder flexion	119 ± 53	10.2 ± 5.6	0.97 (0.86-0.99)
Right shoulder abduction	124 ± 50	9.7 ± 4.4	0.90 (0.78-0.99)
Left shoulder abduction	115 ± 51	9.1 ± 4.8	0.97 (0.91-1.0)

Note: SD = standard deviation; Pearson's r = Pearson product moment correlation; CI = confidence interval.

Table 3 - Mean measures of isometric shoulder strength in both sides

	Dominant shoulder Mean ± SD	Non-dominant Shoulder Mean ± SD
Sphygmomanometer Flexion (mmHg)	130 ± 47	124 ± 54
Sphygmomanometer Abduction (mmHg)	126 ± 53	112 ± 49
HHD Flexion (kg)	11.0 ± 5.3	10.1 ± 5.7
HHD Abduction (kg)	10.3 ± 4.6	8.7 ± 4.7

Note: SD = standard deviation; HHD = hand held dynamometer. All p values <0.01 for the dominant and non-dominant arms.

Discussion

This study, to our knowledge, reports the first findings on validity for the use of the sphygmomanometer to assess shoulder muscle strength. The good correlations found for criterion validity and intra-rater reliability, implies that the sphygmomanometer can confidently be used by the standard clinician in the everyday clinical setting for accurate objective shoulder strength assessment. The sphygmomanometer offers clinicians a cheap and time efficient device that can be easily utilised in various clinical settings as an alternative to the expensive and often inaccessible HHD.

The good intra-rater reliability correlations ($ICC_{2,1}$ = 0.96-0.99) found for the assessment of shoulder flexion and abduction strength using a sphygmomanometer are comparable with the existing literature that has investigated shoulder reliability. One study has previously investigated the intra-rater reliability of the sphygmomanometer for the assessment of shoulder flexion and abduction finding good correlations for both the left and right sides (ICCs = 0.87-0.95) (8). One other study has investigated the inter-reliability (ICC = 0.93) of the sphygmomanometer for the assessment of shoulder abduction strength of 5 rheumatoid arthritis patients (7).

The sphygmomanometers used in both of these studies had been modified. The installation of a one way pressure valve to save the peak value reached on the measurement dial during the testing procedure was used in 1 of the studies (8). The other study chose to modify the cuff of the sphygmomanometer in an attempt to improve consistency of application (7). While these modifications may provide additional ease in equipment use, they do not seem necessary for reliable measurements to be achieved given the results of this study. Equipment modification was deliberately avoided in this study so the results would be applicable to any health professional in clinical practice who can simply purchase and use a readily available standard sphygmomanometer.

Calculation of the intra-rater reliability of the HHD for shoulder flexion and abduction strength also revealed good correlations ($ICC_{2,1}$ = 0.94-0.98). These findings are similar to previous intra-rater reliability correlations calculated for flexion and abduction using a HHD, with ICCs ranging from 0.66 to 0.98 (14-16). Issues surrounding difficulties with participant stabilisation and superior levels of muscular strength compared with the rater were not encountered in our study when using either measurement device.

Good correlations (r = 0.90-0.97) for criterion validity were demonstrated from shoulder flexion and shoulder abduction. These correlations are comparable with criterion validity findings for grip

strength that has previously been assessed, with 2 studies finding good correlations (r = 0.83-0.84) (17, 18). It is possible to translate the different strength measurement units between the sphygmomanometer and the HHD to allow for comparisons to be made. The following equations, developed using linear regression techniques (19), demonstrate the correlation between the 2 devices and the associated SEM with each equation:

1) Sphygmomanometer (mmHg) = 9.25 x HHD (kg) + 29.67 (SEM = 16.23mmHg)

2) HHD (kg) = 0.10 x sphygmomanometer (mmHg) – 1.82 (SEM = 1.66kg)

Findings from this study also highlighted that there was a significant difference ($p \leq 0.01$) between dominant and non-dominant sides for both flexion and abduction when using either of the measurement devices. This finding is consistent with results previously reported for use of a HHD for the assessments of shoulder flexion and abduction where significant differences were also identified between sides (16, 20). This finding suggests that between side differences in shoulder strength may be attributable to the side dominance of the individual, which should be considered during a clinician's physical assessment and clinical reasoning when comparing strength variation between opposite shoulders.

Conclusion

The findings of this study suggest that the sphygmomanometer is both valid and reliable for the assessment of shoulder flexion and abduction isometric strength. The sphygmomanometer is an easily accessible tool that clinicians can use to obtain accurate objective isometric shoulder strength values in everyday clinical practice.

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