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ABSTRACT

Background: Shoulder strength evaluation is a recommended procedure in musculoskeletal rehabilitation.

Aim: To examine hand-held sphygmomanometer (HHS) and hand-held dynamometer (HHD) intra- and inter-rater reliability during isometric shoulder external and internal rotation strength testing in prone rotation position in asymptomatic participants, and to compare these two testing modalities.

Design: Reliability study

Methods: A total of 20 asymptomatic participants (27.7±7.4 years; 77.1±10.1 kg) attended a strength assessment consisting of HHS and HHD tests. Reliability was assessed using the intra-class correlation coefficient (ICC) with 95% confidence intervals (CI), coefficient of variation (CV) with 95%CI, and standard error of measurement (SEM). Pearson correlation and linear regression analysis were used to compare HHS and HHD testing modalities.

Results: “Good” to “excellent” intra (ICC range = 0.896 to 0.979) and inter-rater reliability scores (ICC range = 0.850 to 0.978) were displayed during both HHS and HHD tests during internal and external rotation strength assessments. Linear relationships between HHS and HHD measures were found, with coefficients of determination (R^2) ranging between 0.60 to 0.79.

Conclusion: HHS and HHD resulted to be reliable strength assessment modalities for clinical practice. These assessment modes can be equally valid in assessing intra and inter-limb asymmetries in isometric shoulder rotation strength. The affordability and availability of HHS in ordinary clinical settings can facilitate its implementation in musculoskeletal practice.

Keywords

Sphygmomanometer, hand-held dynamometer, reliability, shoulder

1.0 INTRODUCTION

Muscle strength is a fundamental physical quality for efficient human performance and musculoskeletal system health [1-3]. Weakness of the rotator cuff muscles and an increase in the strength ratio between internal rotators (IR) and external rotators (ER) have been identified as potential intrinsic risk factors for the development of shoulder injuries (i.e., rotator cuff and biceps tendinopathies, labral lesions and acromioclavicular joint pain) in overhead athletes [4-6]. External rotation strength deficits and imbalances in external/internal rotation strength ratios have also been associated with shoulder pain in athletic and non-athletic populations [4, 7-13].

Not surprisingly, clinical guidelines contain specific recommendations regarding the assessment of shoulder strength in musculoskeletal rehabilitation [14]. Healthcare professionals have adopted a variety of strength assessment modalities (i.e., manual muscle testing, force plates, isokinetic and hand-held dynamometer [HHD]) to determine the magnitude of shoulder strength [15-18]. Among these, HHD has been demonstrated to be a reliable and validated tool to measure shoulder strength [19, 20]. Isometric IR and ER strength assessment using HHD was reported to highly correlate ($r > 0.8$) with isokinetic dynamometry testing by different studies [21, 22].

Furthermore, the validity of a hand-held sphygmomanometer (HHS) to measure shoulder strength has been recently explored [23-25]. Indeed, The HHS is an inexpensive tool available in varied clinical settings. To our knowledge only one study [25] investigated the validity and reliability of shoulder strength assessment during ER and IR using a HHS compared to HHD testing. Measures were collected in standing position, and both HHD and HHS were fixed to a belt anchored to a Swedish ladder. The obtained findings showed that the HHS is a valid and reliable alternative tool when HHD strength testing is unavailable.

Different testing positions requiring only HHD or HHS have been more commonly used to measure IR and ER isometric strength in non-athletic cohorts and in overhead athletes presenting with or without shoulder pain [7, 10, 15, 16, 26]. The prone rotation position (with the shoulder abducted to 90° and elbow flexed at 90°) has been shown to preferentially recruit the rotator cuff muscles [27], and thus can provide an accurate reflection of the rotator cuff muscles maximal voluntary isometric capacity. To date, no studies have been conducted with the aim to assess reliability of strength testing methods with either HHD or HHS in this specific position, and, to elucidate if these testing modalities can be considered interchangeable within this setup. Obtaining further information regarding these assessment procedures is therefore necessary. Hence the aims of our study were twofold: 1) to evaluate in asymptomatic participants the intra-rater and inter-rater reliability of both HHD and HHS during ER and IR cuff muscles isometric strength testing in prone rotation position; 2) to compare HHS and HHD strength testing procedures.

2.0 MATERIAL AND METHODS

Study design and population

Participants were recruited voluntarily from a private clinic between February and March 2021. All participants gave written informed consent to participate in the study. This study complied with the Declaration of Helsinki and ethical approval was obtained from the ethics committee of Bergamo (Italy) (Reg. 331/20). Eligibility criteria for the study included: 1) age over 18 years old, 2) full range of motion (ROM) in internal and external shoulder rotation, and 3) absence of pain in the upper quadrant. Exclusion criteria were: 1) presence of pain in the upper quadrant over the past 3 months, 2) neurological disorders, 3) previous shoulder surgery, and 4) discomfort affecting their ability to generate force during the HHD and HHS strength testing.

Procedure

Age (years), weight (kilograms), height (centimetres), and gender were collected for each participant before the testing procedure. Two trained testers (FB, LM) measured maximal shoulder ER and IR isometric strength using an electronic HHD (JTECH Commander, PowerTrack, Utah) and a manual aneroid HHS (Boso Clinicus II, Vitamed, Germany). The isometric testing was performed in prone position with the arm supported in 90° of abduction and neutral rotation. For each test the participant was asked to perform glenohumeral ER or IR against resistance of the HHD/HHS. A “make contraction” was used and participants were asked to build their force gradually up to a maximum voluntary effort over a three-second period, and then hold the maximal voluntary effort for five-seconds [7, 16]. The HHS was pressured at 20mmHg before the test, as reported in the current literature [28], and unordinary variation of the contact area between the cuff and the participant was checked during the test. Increments of 2 mmHg (minor lines) are displayed on the sphygmomanometer scale (major lines are displayed every 10 mmHg), with 300 mmHg being the maximum value that can be recorded.

The examiner kept the HHD/HHS in place, two centimetres proximal to the wrist joint line, by matching the force exerted by the participant (Figure 1). Minimal external fixation was provided with the other hand on the elbow to minimize involuntary movements. Three measurements for each performance were collected, with a 30-second rest between tests. All participants were verbally encouraged. Measures between devices (i.e., HHD and HHS) were separated by 5 minutes rest periods. The device (HHD or HHS), side (left or right) and direction (ER or IR) of the first test were randomly chosen; subsequently, the same testing order was repeated with the other device.

*****Insert Figure 1 about here*****

Statistical analysis

All data was recorded as mean and standard deviation (SD) in SPSS (version 25.0; SPSS, Inc., Armonk, NY). Normal distribution was checked by using Shapiro-Wilk normality test. The intra-rater and inter-rater reliability were analysed using intraclass correlation coefficient (ICC) with 95% confidence intervals (95%CI), based on mean-rating (k = 3), consistency, 2-way random effects model [29]. Coefficient of variation (CV) and 95%CI, and the standard error of measurement (SEM) were further calculated, as reported in the current literature [25, 30]. Reliability scores were categorized as acceptable if the CV was ≤ 10% [31], and were further categorized as “excellent” if ICC was > 0.90, “good” between 0.75 and 0.90, “moderate” between 0.50 and 0.75, and “poor” < 0.50 [29]. Correlation coefficient *r* (with 95%CI) was categorized as follows: 0.00 - 0.19 “very weak”, 0.20 - 0.39 “weak”, “0.40 - 0.59 “moderate, 0.60 - 0.79 “ strong”, 0.80-1.00 “very strong” [22]. The validity between HHD and HHS strength testing was analysed using Pearson correlation coefficient *r* (95%CI) and coefficient of determination R^2 in a linear regression model. Significance level was established at $p < 0.05$. Similarly and according to previous studies [22, 24, 26], a sample size of 19 subjects was required for a power of 95% and a significance level of 5%, for an expected ICC of 0.94, and a minimum acceptable ICC of 0.75 [32].

3.0 RESULTS

Twenty participants were recruited in this study (27.7 ± 7.4 years; 77.1 ± 10.1 kg, 1.78 ± 8 cm; female = 2 and male = 17). One participant did not meet the inclusion criteria leaving 19 participants available for analysis. Raw HHS scores (reported as mean ± SD from both tester 1 and tester 2) were: right ER isometric strength = 148 ± 23.1 mmHg, left ER isometric strength = 140 ± 22.5 mmHg, right IR isometric strength = 163 ± 29.8 mmHg and left IR isometric strength = 158 ± 26.8 mmHg. Raw HHD scores (reported as mean ± SD from both tester 1 and tester 2) were: right ER isometric strength = 14 ± 2.5 Kg, left ER isometric strength = 13.7 ± 2.3 kg, right IR isometric strength = 17.1 ± 4.1 kg and left IR isometric strength = 15.2 ± 3.5 Kg.

3.1 Intra-rater reliability

Hand-held sphygmomanometer (HHS)

ER isometric strength of left and right shoulder displayed "excellent" reliability with ICC ranging from 0.940 to 0.979, and CV between 3.2 and 3.7% (Table 1).

IR isometric strength of left and right shoulder showed "good" to "excellent" reliability with ICC ranging from 0.896 to 0.974, and CV between 3.2 and 4.2% (Table 1).

Hand-held dynamometer (HHD)

ER isometric strength of left and right shoulder displayed "excellent" reliability with ICC ranging from 0.954 to 0.977, and CV between 5.5 and 7.9% (Table 1).

IR isometric strength of left and right shoulder demonstrated "excellent" reliability with ICC ranging from 0.961 to 0.978, and CV between 5.4 and 6.1% (Table 1).

*****Insert Table 1 about here*****

3.2 Inter-rater reliability

Hand-held sphygmomanometer (HHS)

ER isometric strength of right and left shoulder showed “good” to “excellent” reliability (HHS right: ICC = 0.932, 95%CI = 0.824 to 0.974; $r = 0.87$, 95%CI = 0.68 to 0.95, $p \leq 0.0001$. HHS left: ICC = 0.907, 95% CI = 0.608 to 0.970; $r = 0.88$, 95%CI = 0.71 to 0.95, $p \leq 0.0001$) (Table 2).

IR isometric strength of right and left shoulder demonstrated “good” to “excellent” reliability (HHS right: ICC = 0.850, 95%CI = 0.175 to 0.956; $r = 0.84$, 95%CI = 0.62 to 0.94, $p \leq 0.0001$. HHS left: ICC = 0.900, 95%CI = 0.672 to 0.965; $r = 0.86$, 95%CI = 0.66 to 0.94, $p \leq 0.0001$) (Table 2).

Hand-held dynamometer (HHD)

ER isometric strength of right and left shoulder displayed “good” to “excellent” reliability (HHD right: ICC = 0.968, 95%CI = 0.919 to 0.987; $r = 0.94$ 95%CI = 0.84 to 0.97, $p \leq 0.0001$. HHD left: ICC = 0.878, 95%CI = 0.668 to 0.953; $r = 0.81$, 95%CI = 0.57 to 0.92, $p \leq 0.0001$) (Table 2).

IR isometric strength of right and left shoulder showed “good” to “excellent” reliability (HHD right: ICC = 0.934, 95%CI = 0.712 to 0.979; $r = 0.93$, 95%CI = 0.81 to 0.97, $p \leq 0.0001$. HHD left: ICC = 0.910, 95%CI = 0.742 to 0.966, $r = 0.87$, 95%CI = 0.69 to 0.95, $p \leq 0.0001$) (Table 2).

*****Insert Table 2 about here*****

3.3 Validity

Linear relationships between HHS and HHD measures were found, with coefficients of determination (R^2) ranging between 0.60 to 0.79, indicating that at least 60% of the strength values obtained with the HHD were explained by the measures collected by the HHS. In details, the following coefficients were found for isometric ER ($r = 0.89$, 95%CI = 0.79 to 0.94, $p \leq 0.0001$, $R^2 = 0.78$ for Tester 1, and $r = 0.78$, 95%CI = 0.61 to 0.88, $p \leq 0.0001$, $R^2 = 0.60$ for Tester 2) and IR strength testing ($r = 0.82$, 95%CI = 0.67 to 0.90, $p \leq 0.0001$, $R^2 = 0.67$ for Tester 1, and $r = 0.89$, 95%CI = 0.79 to 0.94, $p \leq 0.0001$, $R^2 = 0.79$ for Tester 2) (Table 3).

*****Insert Table 3 about here*****

*****Insert Figure 2 and 3 about here*****

4.0 DISCUSSION

The aim of this study was to assess in asymptomatic participants the intra-rater and inter-rater reliability of HHD and HHS ER and IR cuff muscles isometric strength testing in prone rotation position, and compare HHS and HHD strength testing modalities.

Intra-rater and inter-rater reliability

ER and IR shoulder strength measures assessed with both HHD and HHS displayed “excellent” reliability scores, except for IR strength measured with HHS which achieved “good” to “excellent” scores. Our results showed scores similar to the available literature [15, 23, 33, 34], albeit adopting a different testing position. Only Riemann et al. [16] used the HHD in prone rotation position, and showed “good” reliability scores. Interestingly, HHD CV values were slightly higher than HHS ones. However, HHD devices tend to automatically report the CV score after a set of tests, and therefore clinicians should collect more measures if the CV score is high (not acceptable if > 10% [29]).

Similarly, our results showed “good” to “excellent” inter-rater reliability scores for both HHD and HHS in measuring isometric ER and IR shoulder strength. These are in line with previous research [23-25], and thus may improve the confidence in adopting HHS in ordinary clinical practice. However, owing to a wider ICC confidence interval reported in HHS IR strength measures, more caution in interpreting IR results from different testers may be recommended.

Validity

To our knowledge this was the first study that compared HHD and HHS in ER and IR isometric shoulder strength testing in prone rotation position. Our data indicated that the HHS can generate valid and reliable measure as an alternative to HHD. Previous research [24, 33] corroborates our findings although different testing positions were used.

The described calibration procedures used during HHS testing are heterogeneous in the available literature [33, 35]; therefore, universal conversion from mmHg to kilograms (kg) or Newtons (N) would require a detailed description of the pre-inflation value and the remaining contact area after folding the pressure cuff. With these details, healthcare professionals may create benchmark data according to age, gender, occupation or practised sports for example, thus having reference values available when assessing different individuals. Until normative values will be available, our data indicate that the HHS can be used in alternative to HHD to assess intra-limb and inter-limb asymmetries in ER and IR isometric strength. HHS impedes the expression of absolute strength values using conventional metrics (i.e., N) as well as strength values in relation to bodyweight ($kg \cdot kg^{-1}$), which is one of the advantages of HHD testing. Considering the availability and affordability of HHS in common clinical settings, healthcare professionals can reliably use HHS for isometric ER and IR shoulder strength assessment.

This study is not without limitations. First, only healthy participants were recruited in this study. Further studies are needed to understand the reliability and validity of these measurement tools in populations presenting with shoulder disorders. In addition, our sample was mainly based on male subjects. Stratification by gender is required in future research if considered necessary. Second, independently of the device used, isometric testing in one position only is not sufficient to thoroughly assess shoulder function, and different points in range (e.g., inner / outer range) need to be considered. Finally, although the minimal stabilization described in this study is simple and time efficient for clinical practice, and does not negatively influence reliability scores, clinicians should evaluate on individual basis (e.g., if the CV is not acceptable) the need of external stabilisation in their clinical practice.

5.0 CONCLUSION

HHD and HHS isometric ER and IR shoulder strength testing procedures demonstrated “good” to “excellent” intra and inter-rater reliability scores. These assessment modalities can be equally valid in evaluating intra and inter-limb asymmetries in isometric shoulder rotation strength. The affordability and availability of HHS in ordinary clinical settings can facilitate its implementation in musculoskeletal practice.

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