Inter-Rater and Test-Retest Reliability of Hand Held Dynamometer in Shoulder Dysfunction

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ABSTRACT

Physical Therapists usually test muscle strength in anti-gravity positions that yield inaccurate measurements. The purpose of this study was to examine inter-tester, and test- retest reliability of hand-held dynamometer in measuring strength of shoulder muscles in gravity-minimized positions. Twenty five participants (10 men and 15 women) with diagnosed shoulder dysfunction participated in this study. Four shoulder muscles were tested: internal rotators, external rotators, middle trapezius and lower trapezius. A hand-held dynamometer was used to determine maximal isometric strength. Participants participated in two sessions. One examiner measured muscle strength in a random order in the first session. Two examiners measured muscle strength separately in a random order. Inter-tester and test-retest strength measurements on the shoulder muscle groups showed excellent reliability ($ICC_{2,1}$=.83-.95). In conclusion, the hand held dynamometer is reliable in measuring strength of shoulder muscles in gravity-minimized positions.
Key words: *reliability, dynamometer, shoulder, inter-tester, test-retest.*

INTRODUCTION

Measuring muscle strength is essential for differential diagnosis, determining irritability of the condition, determining functional impairment, measuring improvement or deterioration, and for developing an effective plan of care. The strength measurement must be reliable for meaningful measurement[19]. Strength testing methods include manual muscle testing (MMT), hand-held dynamometer (HHD), and isokinetic dynamometry. MMT is considered objective until manual resistance is applied, and then inconsistencies can result because the tests depend on the experience, physical strength, and judgment of examiner[7].

Alternative methods of strength testing are required because of the questionable validity and reliability of MMT[3]. Isokinetic dynamometry and HHD are reliable alternative strength testing methods[20]. Isokinetic dynamometry is the golden standard for strength measures. However, it is uncommon in clinical settings due to the costs and low accessibility[6].

Hand-held dynamometers have been used to measure muscle strength and have demonstrated great sensitivity to muscles that are strong enough to complete the range against gravity and tolerate resistance[23]. It is inexpensive and portable, making it a practical alternative to isokinetic dynamometry[7]. It has also been shown reliable to be used in cancer patients, pediatric patients, patients with orthopedic dysfunction, dementia patients, patient with traumatic brain injury, patients with chronic obstructive pulmonary disease, and geriatric patients[16,21].

Gravity is often used with a HHD as is with a manual muscle tester. When strength is tested in against-gravity positions, the weight of the arm affects the test results as each subject's arm varies in weight. Because of the arm weight, the data cannot be considered ratio scale data and does not accurately reflect the muscle's capacity to produce force[2]. Having a reliable tool to measure shoulder muscle strength is fundamental in determining shoulder muscle strength changes. Most investigators who tested the HHD in reliability studies tested the muscles in anti-gravity positions[7,16,21]. A group of authors tested shoulder abductor, internal rotator, and external rotator by MMT in gravity-minimized positions in normal subjects[5]. However, the middle and lower trapezius play an important role in shoulder and posture stabilization. They are a vital part of proper scapular motion that is critical for normal scapular motion that is critical for normal shoulder movement. The reliability of middle and lower trapezius strength measurements in the gravity-minimized position has not been performed. The purpose of this study was to determine the inter-tester and the test-retest reliability of shoulder muscle strength measurements consisting of the shoulder internal rotators, shoulder external rotators, middle trapezius and lower trapezius in gravity-minimized positions in the dominant and non-dominant arms using a HHD in adults with shoulder disorders.

MATERIALS AND METHODS

Design

The study evaluated inter-tester and test-retest reliability of HHD isometric strength testing of shoulder muscles in adults with shoulder dysfunction. Two examiners with more than 10 years of clinical physical therapy experience were responsible for obtaining the HHD strength measurements in this study.

Participants

Twenty five participants (10 men and 15 women) between the ages of 22 and 40 years participated in the study. Participants had to have a muscle grade of at least fair to qualify for the study. The inclusion criteria included self-reported shoulder pain, self-reported loss of shoulder function, and diagnosis of shoulder disorder by a physician. Exclusion criteria included the inability to raise the arm to 135 degrees of shoulder elevation, because this amount of elevation was required for the performance of the scapular muscle tests. Participants who reported more than 5/10 as measured by a visual analogue scale were also excluded from the study. Other exclusion criteria included pain referral from a source other than the shoulder, fractures or dislocations around the shoulder joint or systemic inflammatory disease. Participants completed a questionnaire to determine age, medical history, and arm dominance. All participants were informed of potential risks and benefits from participating in the study.

Instrumentation

A Chatillon model DFG-100 HHD (Ametek, Largo, FL) was used to determine the maximal isometric force, measured in peak pounds. The force gauge has a range of 0 to 115 lb and measures to the nearest 10th of a pound. It was calibrated prior to start of data collection.

A cushion covered adjustable wooden wedge was also used. It was set up at a 45 degree angle. The wedge was used to help support the participant's arm in a proper resting position so that the participant could be in a gravity-minimized position for measuring the lower trapezius.

Procedure

All testing occurred in an outpatient physical therapy clinic in Texas. Prior to data collection, participants were informed of the procedures and risks of the study and gave their consent to participate in the study. Participant's information was then taken including the participant's name, weight, height, hand dominance, gender and age.

The study consisted of two sessions which were taken 4 to 6 days apart. Each session lasted approximately 20 minutes. Testing the four muscle groups was randomized by drawing numbers from a hat. Before testing, the examiners demonstrated the appropriate muscle movements to the participants. The data collected by one examiner was blinded from the other examiner.

Each examiner assessed each muscle group. Both dominant and non-dominant arms were measured. Examiners measured the muscles on the dominant arm followed by the non-dominant arm in the same order as the dominant arm. A 2-minute rest period was provided between each muscle group and each arm. In each session examiner 1 and examiner 2 measured. The order of the examiner on both sessions was randomized by drawing an examiner name from a hat. The examiner drawn measured first.

The participants were instructed to maintain the testing position during the maximal isometric effort for 6 seconds. The participants were instructed to give their maximum effort while applying a 6-second isometric effort into the HHD. The examiners did not provide any verbal encouragement during testing and the instructions remained consistent.

Arm and forearm length were measured after completion of the strength measurements to calculate the torque. Measurements were measured using a plastic tape measured in meters while the participant was in the anatomic position. The upper arm length was measured from the inferior aspect of the lateral acromion to the lateral humeral epicondyle. The forearm length was measured from the distal ulna styloid process to the olecranon.

Testing Internal Rotators: The participant laid on a high-low table in supine with the testing arm abducted to 90 degrees. A towel was rolled up and placed under the humerus so that the arm was level with the torso. The elbow was flexed to 90 degrees and the humerus was rotated so that the forearm was perpendicular to the floor. The palm of the hand was facing toward the participant's feet. The examiner stood with the dynamometer on the palmer side of the participant's hand. The examiner stood with a wide base of support with the dynamometer in a fixed position. The dynamometer was placed just proximal to the wrist of the participant. The participant was then asked to give a maximal isometric contraction of internal rotation pushing a cephalic force into the dynamometer for 6 seconds.

Testing External Rotators: Testing was the same as testing for the internal rotators except that the dynamometer was placed on the dorsal side of the participant's wrist, proximal to the ulnar styloid process. Participants were then asked to give a maximal isometric contraction of external rotation pushing a caudal force against the dynamometer for 6 seconds.

Testing Middle Trapezius: The participant sat in a chair with the testing arm resting on a high low table so that the shoulder was abducted to 90 degrees. The elbow was fully extended with the forearm in a neutral position. A towel was placed under the humerus to allow for clearance of the dynamometer during the measurement. The examiner stood with the dynamometer behind the participant. The dynamometer was placed just proximal to the lateral epicondyle of the humerus. The participant was then asked to squeeze his shoulders blades together and give a maximal isometric contraction of shoulder adduction force into the dynamometer for 6 seconds.

Testing Lower Trapezius: The test was tested in a manner similar to the middle trapezius except that the shoulder being tested was in 135 degrees abduction resting on a cushion covered wooden wedge adjusted at a 45 degree angle.

Data Analysis

SPSS statistical software was used for the statistical analysis (SPSS Inc., Chicago, IL). The mean and the standard deviations for each muscle strength test were calculated and presented in a descriptive format. The inter-tester reliability is defined as the degree to which two or more testers could obtain the same rating for a given variable. Using the intra-class correlations coefficients (ICC) is appropriate for assessing reliability as it accounts for variability between participant scores[9]. The $ICC_{2,1}$ for inter-rater reliability were computed.

Test-retest reliability can be defined as the reliability of tests repeated within a short period of time by either the same tester or different tester[9]. The $ICC_{2,1}$ for test re-test reliability were then calculated for each muscle strength test for both the dominant and non-dominant arms.

RESULTS

Age of the 25 participants ranged from 22 to 40 years with an average of 30.2. The average height was 173.52 cm and weight was 79.21 Kg. The average torque of each muscle group measured in Newton meters (Nm) is displayed in table 1. The arm and forearm length of each participant measured in meters is displayed in table 2. The inter-tester intraclass correlation coefficients were displayed in Table 3 to show reliability results when both examiners measured the participants in the second session. The test-retest intraclass correlation coefficients were also displayed in Table 3 to show reliability measured by the same tester and different tester.

Table (1): Descriptive Torque Data (Mean ± SD).

Muscle Torque (Nm)	Examiner 1 (session 1)	Examiner 1 (session 2)	Examiner 2 (session 2)
Internal Rotators	5.99 ± 2.20+ 6.31 ± 2.72 ++	6.22 ± 2.88+ 5.88 ± 3.01 ++	6.33 ± 3.58+ 6.11 ± 3.10++
External Rotators	6.34 ± 3.70+ 6.02 ± 4.59++	5.94 ± 2.90+ 6.11 ± 3.36++	6.11 ± 3.011+ 6.12 ± 3.23++
Middle Trapezius	6.95 ± 2.72+ 7.15 ± 2.60++	7.02 ± 3.86+ 6.43 ± 2.60++	6.21 ± 3.11+ 7.4 ± 2.64++
Lower Trapezius	6.49 ± 2.45+ 6.88 ± 3.46++	6.17 ± 3.25+ 6.32 ± 3.64++	6.12 ± 3.21+ 6.23 ± 2.91++

+Dominant arms ++ Non-Dominant arms

Table (2): Participant's Arm Length and Forearm Length (Mean ± SD).

Length (Meters)	Examiner 1 (session 1)	Examiner 1 (session 2)	Examiner 2 (session 2)
Arm Length	0.29± 0.02	0.28 ± 0.02	0.29± 0.03
Forearm Length	0.27± 0.03	0.26± 0.02	0.27± 0.03

Table (3): Inter-tester and Test-rest Intra Class Correlation Coefficients ($ICC_{2,1}$).

Muscle Groups	$ICC_{2,1}$ (inter-tester)	$ICC_{2,1}$ (test-retest, same tester)	$ICC_{2,1}$ (test-retest, different tester)
Internal Rotators	.94+ .92++	.95+ .94++	.93+ .90++
External Rotators	.91+ .93++	.90+ .85++	.92+ .91++
Middle Trapezius	.92+ .85++	.87 .89++	.83+ .86++
Lower Trapezius	.90+ .84++	.92+ .94++	.94+ .92++

+Dominant arms ++ Non-Dominant arms

DISCUSSION

The results of the study demonstrated high inter-tester and test-retest reliability of the internal rotators, external rotators, middle and lower trapezius strength measurements in gravity-eliminated positions in the dominant and non-dominant arms using a hand held dynamometer in adults with shoulder dysfunction. The ICCs revealed excellent inter-tester reliability for the strength measurements in the dominant ($ICC_{2,1}$= 0.90-0.94) and non-dominant arms ($ICC_{2,1}$=0.84-0.93).

The results of this study agree with the studies by Bohannon and Andrews (1987)[2] who determined inter-tester reliability of the hand held dynamometer on three upper extremity muscle groups (shoulder external rotators, elbow flexors and wrist extensors) and found the correlation coefficients ranging from 0.84 to 0.94[1]. The testing positions were in gravity-minimized positions; however, the participants had various diagnoses, with most having hemiparesis following cerebraovascular accidents. The present findings can also be compared to the results of Cadogan et al. (2011) study[4]. The authors demonstrated fair to excellent intertester reliability for shoulder flexors, abductors, and external rotators (ICC=0.68 to 0.95) in 40 subjects with shoulder pain. The testing positions were in antigravity positions.

Test-retest reliability, by either the same tester or different testers, for the strength measurements was considered excellent in both dominant arms ($ICC_{2,1=}$ 0.83-0.95) and non-dominant arms ($ICC_{2,1=}$ 0.85-0.94). This can be compared to another test-retest reliability study by Meeteren et al. (2002)[17]. They investigated test-retest in isokinetic muscle strength measurements of four shoulder muscles: internal rotators, external rotators, abductors, and adductors in 20 active and not active sports individuals. All measurements were collected at 60°/second (5 repetitions) and respectively 120°/second and 180°/second (10 repetitions). Each group performed two sessions with a 2-week interval. They showed good to excellent test-retest reliability, ICC= 0.69-0.92. However, the authors tested the isokinetic muscle strength in anti-gravity positions versus isometric strength in gravity-minimized positions measured in the current study.

The results regarding test-retest reliability can also be compared to the work of Kolber et al. (2007)[14]. The authors studied test-retest reliability in using the HHD to measure strength of the internal and external rotators of shoulder in 30 asymptomatic subjects. Their findings showed excellent test-retest reliability, ICC= 0.971–0.972. However, all testing positions occurred in anti-gravity positions.

There are several limitations to this study. Small number of participants participated in this study. One of the big limitations is a lack of a gold standard measurement device in this study. It was imperative to compare the use of HHD versus the isokinetic dynamometer as a gold standard to substantiate the findings of this study.

Participants may have been involved in various activities between the two testing sessions and this could not be controlled. Furthermore, participants may have experienced muscle soreness due to change in activity between the testing periods. Also, examiners may not have been competent and experienced in administering the HHD. These factors did not influence the results of the study since the reliability levels were high.

Stability of the HHD is a limitation. The subject's strength can overpower that of the examiner yielding inaccurate data. If the strength of the subject exceeds that of the examiner, the examiner may not maintain a stationary base for the dynamometer[11]. In this study, most of the participants tested probably had less muscle strength than healthy individuals. Thus, stabilization and holding against the patient's maximal effort may have been easier than holding against that of a healthy volunteer.

Further reliability testing that involves more than two examiners, different devices, and additional muscle groups are warranted. The results suggest that the HHD is reliable in measuring shoulder internal rotators, external rotators, middle trapezius and lower trapezius in gravity-minimized position in participants with shoulder dysfunction.

REFERENCES

1- Bohannon, R. and Andrews, A.: Inter-rater reliability of hand-held dynamometer. Physical Therapy, 67: 931-933, 1987.

2- Bohannon, R.W. and Andrews, A.W.: Interrater reliability of hand-held dynamometry. Phys Ther, 67(6): 931-933, 1987.

3- Bohannon, R.W.: Quantitative testing of muscle strength: Issues and practical options for the geriatric population. Top Geriatr Rehabil, 18(2): 1-17, 2002.

4- Cadogan, A., Laslett, M., Hing, W., McNair, P. and Williams, M.: Reliability of a new hand-held dynamometer in measuring shoulder range of motion and strength. Manual therapy, 16(1): 97-101, 2011.

5- Donatelli, R., Ellenbecker, T., Ekedahl, S., Wilkes, J., Kocher, K. and Adam, J.: Assessment of shoulder strength in professional baseball pitchers. Journal of Orthopedic & Sports Physical Therapy, 30(9): 544-551, 2000.

6- Hartmann, A., Knols, R., Murer, K. and de Bruin, E.D.: Reproducibility of an isokinetic strength-testing protocol of the knee and ankle in older adults. Gerontology, 55: 259-268, 2009.

7- Hayes, K., Walton, J.R., Szomor, Z.L. and Murrell, G.A.: Reliability of three methods for assessing shoulder strength. J Shoulder Elbow Surg, 11(2): 33-39, 2002.

8- Hébert, L.J., Maltais, D.B., Lepage, C., Saulnier, J., Crête, M. and Perron, M.: Isometric muscle strength in youth assessed by hand-held dynamometry: a feasibility, reliability, and validity study. Pediatr Phys Ther, 23(3): 289-299, 2011.

9- Kaplan, R.M. and Saccuzzo, D.P.: Psychological Testing: principles, applications, and issues. 7th edition, Wadsworth Publishing, Belomont, California, USA, 2008.

10- Katz-Leurer, M., Rottem, H. and Meyer, S.: Hand-held dynamometry in children with traumatic brain injury: within-session reliability. Pediatr Phys Ther, 20: 259-263, 2008.

11- Kelln, B.M., McKeon, P.O., Gontkof, L.M. and Hertel, J.: Hand-held dynamometry: reliability of lower extremity muscle testing in healthy, physically active, young adults. J Sport Rehabil, 17(2):160-170, 2008.

12- Knols, R.H., Aufdemkampe, G., de Bruin, E.D., Uebelhart, D. and Aaronson, N.K.: Hand-held dynamometry in patients with haematological malignancies: measurement error in the clinical assessment of knee extension strength. BMC Musculoskelet Disord, 10: 31, 2009.

13- Koblbauer, I.F., Lambrecht, Y., van der Hulst, M.L., Neeter, C., Engelbert, R.H., Poolman, R.W. and Scholtes, V.A.: Reliability of maximal isometric knee strength testing with modified hand-held dynamometry in patients awaiting total knee arthroplasty: useful in research and individual patient settings? A reliability study. BMC Musculoskelet Disord. 31(12): 249, 2011.

14- Kolber, M.J., Beekhuizen, K., Cheng, M.S. and Fiebert, I.M.: The reliability of hand-held dynamometry in measuring isometric strength of the shoulder internal and external rotator musculature using a stabilization device. Physiotherapy Theory and Practice, 23(2): 119-124, 2007.

15- Maffiuletti, N.A.: Assessment of hip and knee muscle function in orthopaedic practice and research. J Bone Joint Surg Am, 92(1): 220-229, 2010.

16- Martin, H.J., Yule, V., Syddall, H.E., Dennison, E.M., Cooper, C. and Aihie, S.A.: Is hand-held dynamometry useful for the measurement of quadriceps strength in older people? A comparison with the gold standard Bodex dynamometry. Gerontology, 52: 154-159, 2006.

17- Meeteren, J., Roebroeck, M.E. and Stam, H.J.: Test-retest reliability in isokinetic muscle strength measurements of the shoulder. Journal of Rehabilitative Medicine, 34: 91-95, 2002.

18- O'Shea, S.D., Taylor, N.F. and Paratz, J.D.: Measuring muscle strength for people with chronic obstructive pulmonary disease: retest reliability of hand-held dynamometry. Arch Phys Med Rehabil, 88: 32-36, 2007.

19- Sole, G., Hamrén, J., Milosavljevic, S., Nicholson, H. and Sullivan, S.J.: Test-retest reliability of isokinetic knee extension and flexion. Arch Phys Med Rehabil, 88: 626-631, 2007.

20- Stark, T., Walker, B., Phillips, J.K., Fejer, R. and Beck, R.: Hand-held dynamometry correlation with the gold standard isokinetic dynamometry: a systematic review. PM R, 3(5): 472-479, 2011.

21- Stone, C.A., Nolan, B., Lawlor, P.G. and Kenny, R.A.: Hand-held dynamometry: examiner strength is paramount, even in frail populations. J Rehabil Med, 43(9): 808-811, 2011.

22- Suzuki, M., Yamada, S., Inamura, A., Omori, Y., Kirimoto, H., Sugimura, S. and Miyamoto, M.: Reliability and validity of measurements of knee extension strength obtained from nursing home residents with dementia. Am J Phys Med Rehabil, 88(11): 924-933, 2009.

23- Wadsworth, C., Krishnan, R., Sear, M., Harrold, J. and Nielsen, D.: Intricate reliability of manual muscle testing and hand-held dynametric muscle testing. Physical Therapy, 67: 1342-1347, 1987.

الملخص العربي

دقة استخدام الديناموميتر لقياس قوة عضلات الكتف

أجريت هذه الدراسة لمعرفة دقة استخدام الديناموميتر لقياس قوة عضلات االكتف عند قيام شخصين بالقياس و عند إعادة اختبار القياس بنفس الشخص القائم بالقياس. شارك خمسة وعشرون شخصا (10 رجال و 15 امرأة) يعانون من اختلال وظيفي بمفصل الكتف فى الدراسة . تم اختبار أربعة عضلات للكتف: الدوارات الداخلية، والدوارات الخارجية، العضلة الشبه منحرفة الدنيا و شبه المنحرفة الوسط ي.
وأظهرت نتائج هذه الدراسة على أن الديناموميتر دقيق في قياس قوة المجموعات العضلية في الكتف عند قيام شخصين بالقياس و عند إعادة اختبار القياس بنفس الشخص القائم بالقياس .

الكلمات الدالة : الدقة - الديناموميتر- عضلات الكتف