Portable Hip Clamshell Strength Assessment: Reliability and Validity

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ABSTRACT

Hip abduction and external rotation muscular strength deficits are associated with various musculoskeletal conditions such as balance loss (falls), osteoarthritis, and lower extremity ligament strains. To countermeasure, a clamshell hip resistance exercise is commonly included as a part of preventive or rehabilitative programs. A simple and portable clamshell strength device was developed in attempt to encourage widespread hip strength assessments in clinics.

Objective: Examine test-retest reliability of hip clamshell strength using a portable device and validity with the hip abduction strength using the isokinetic dynamometer.

Methods: A test-retest reliability and validity study design at a sports medicine facility. Twelve young and healthy adults (8M/4F, 27.4yo, 180.1cm, 88.8kg) visited a sports medicine laboratory twice one week apart. Subjects performed maximum voluntary isometric contractions using both a portable clamshell strength device and isokinetic dynamometer. Average peak forces (Newtons) in right and left muscular strength with a clamshell strength device and hip abduction peak torques (Newton-Meters: Nm) with a dynamometer. Reliability and validity was analyzed using the intraclass correlation coefficients (*ICC 3,1*) and Pearson correlation coefficient (*r*), respectively.

Results: Clamshell strength was moderately reliable (*ICC* = 0.593-0.820) and valid (*r* = 0.545-0.584).

Conclusion: The current study found that a portable and inexpensive clamshell strength device was reliable and valid. This result encourages more hip strength testing at point-of-care clinics.

Key terms: dynamometer, clamshell, gluteus medius, power, test-retest, reliability, validity

INTRODUCTION

Physical therapists, chiropractors, and physiatrists often incorporate a wide variety of resistance exercises for hip abductors and external rotators as a part of rehabilitation. The primary hip abductor muscles include the gluteus medius, gluteus minimus, and the tensor fasciae latae; and the primary hip external rotator muscle includes the gluteus maximus which also functions as the primary hip extensor muscle.[1] These hip muscles play an important role in providing balance, joint alignment, and dynamic stability of trunk, pelvis, and lower extremity joints (hip, knee, and ankle). Musculoskeletal modeling has demonstrated that muscular weakness in the hip abductors results in lateral pelvic tilt, increased vertical and lateral ground reaction forces, and increased knee abduction moments during drop vertical jump, which are the primary mechanism of non-contact anterior cruciate ligament (ACL) injury.[2] This contention was supported prospective investigations that found hip abduction and external rotation muscular weakness as a prospective risk factor of non-contact ACL injury and other lower extremity injuries in competitive athletes.[3,4] Furthermore, the lower leg musculature – especially hip abductors, hip extensors, and core muscles – lead to higher incidence of low back pain.[5,6]

Hip abduction strength weakness is associated with poor balance in individuals with chronic ankle instability[7] and predicts prospective inversion ankle sprains in young adults.[8] If not corrected, weak hip abduction muscles and alterations in movement patterns could compromise joint health and contribute to early progression of osteoarthritis in the medial patellofemoral and lateral tibiofemoral joints in older adults.[9] Clinically, hip abduction strength is assessed with an isokinetic dynamometer or a portable hand-held dynamometer (HHD). During HHD testing, subjects are usually in a side-lying position and raise their superior leg against a stationary dynamometer or examiner's hand to record the peak force; and the HHD hip abduction testing has been shown to have good to excellent test-retest reliability (intraclass correlation coefficient: *ICC* = 0.62-0.94) and validity against isokinetic dynamometer (Pearson correlation coefficient: *r* = 0.56-0.92).[10,11]

While it is seemingly simple to train and activate the hip abductors, blindly performing hip abductors for the maximum peak force could lead to hypertrophy of the tensor fasciae latae which is a hip internal rotator secondarily. This hypertrophy of the tensor fasciae latae and atrophy of the gluteus medius was reported in middle-aged adults with hip osteoarthritis.[12,13] Excess hip internal rotation with weaker hip abduction and extension strength was observed in young adults with the patellofemoral pain.[14] In an attempt to minimize the tensor fasciae latae activities and maximize the gluteus medius activities, physical therapists commonly use a hip resistance exercise called "clamshell". This exercise is performed in a side-lying position with the knee flexed at 90 degrees and the hip flexed around 45 degrees. The superior knee is then raised to an 'open' clamshell position while maintaining heel contact. Clamshell exercise has the highest muscle activation ratios of the gluteus medius/maximum over the tensor fascia latae.[15] Similarly, another study reported that the clamshell exercise with or without an elastic band around could the knees activate the gluteal muscles while maintaining lower activation of the tensor fascia latae muscle.[16]

Since performing a clamshell exercise is a novel task isolating the hip abductors and external rotators, clinicians and researchers expressed interests in quantifying the maximum clamshell hip strength. With a simple force transducer and two thigh cuffs (made of Velcro®) attached to each end of the force transducer, we have built a simple contraption to measure the maximum voluntary isometric contraction (MVIC) during a clamshell task. Because it is a novel device with no prior studies, the aim of this study was to establish basic reliability and validity of this clamshell testing device. Clinically, a simple clamshell device can be significant and used to test individuals' ability to perform clamshell MVIC within 5 minutes in attempt to inform surgical or rehabilitation outcomes. To our knowledge, this device is the only one that can quantify the peak force of the gluteus medius without too much involvement of the tensor fasciae latae. It is hypothesized that the clamshell strength device can be moderately reliable ($ICC > 0.6$) and valid ($r > 0.5$) based on the previous hip abduction study.[10,11,17]

METHODS

Participants

A convenient sample of twelve participants (8M/4F) were recruited for the study (average age 27.4 ± 2.0 years, average height 180.1 ± 4.0 cm, and average weight 88.8 ± 23.8 kg). Subjects were included if they were recreationally active a minimum of three times per week for sixty minutes. Subjects were excluded 1) if they had a history of lower extremity musculoskeletal injury within two years, 2) if they were taking any medication or supplements known to affect performance, or 3) if they had a reported medical condition that could affect strength (e.g., acute infection, neurological, or cardiovascular disease). Anthropometric data were measured for each subject (height, weight) prior to testing. At each visit, subjects were asked to perform clamshell and HumacNORM hip abductor MVIC tests. The order of testing methods (clamshell and HumacNORM) and limbs (right and left limb) was randomized.

Study Design

This study was a test-retest reliability and validation study. All subjects reported to the sports medicine research laboratory two times (one week apart) for 30 minutes of strength testing (clamshell and HumacNORM dynamometer testing). The study was approved by the Mayo Clinic Institutional Review Board (IRB 17-001833).

Procedures

Subjects were instructed to warm up on a bicycle for five minutes. For the clamshell isometric strength testing, a custom device was built with Velcro® straps attached to a uniaxial load cell (MLP-300; Transducer Techniques, Temecula, CA; **Figure 1**). The load cell was placed in between the knees of the subjects with their body in a side-lying position with their knees at a 90° angle, but with their feet in line with the longitudinal axis of their body. The Velcro® straps were secured around the thighs proximal to the knee. Subjects were instructed to slowly open the hips in a clamshell motion, engage the load cell, and ramp up force to a maximum effort with the heels connected.

Figure 1. Hip abduction strength testing using HumacNORM isokinetic dynamometer (top) and clamshell strength testing using a clamshell strength device (bottom).

For HumacNORM isometric hip abductor strength testing, the HumacNORM dynamometer (CSMi, Stoughton, MA) was used. Subjects were positioned side-lying on the HumacNORM chair, which was set to a flat position. To limit extraneous movement, restraining straps were secured across the subject's non-testing leg (**Figure 1**). The dynamometer height was raised to align with the hip joint center and the chair was translated to ensure the subject's hip joint center was aligned with the dynamometer arm. For familiarity, subjects completed one practice set at 50% perceived effort. The practice set was followed by a ten-second rest period before the isometric test began. Subjects completed a MVIC for five seconds followed by a twenty-second rest period. Two additional trials were completed. During all tests, the examiner verbally encouraged the subject to give their maximal effort. The setup and testing protocol were then repeated on the contralateral leg.

The peak force during the clamshell MVIC was recorded. The average of three peak forces were used for statistical analysis. The peak torque during the HumacNORM hip abduction strength data was recorded using the HumacNORM software (CSMi, Stoughton, MA), and the average of three torques were used for statistical analysis. The clamshell peak force data for session #1 and session #2 was used to calculate the intraclass correlation coefficients (*ICC 3,1*) to examine test-retest reliability for each limb (right and left). *ICC* values were interpreted as slight (0 to 0.2), fair (0.21 to 0.40), moderate (0.41 to 0.60), substantial (0.61 to 0.80), and almost perfect agreement (0.81 to 1.0) according to Landis and Koch[18]; while Portney and Watkins[19] interpret *ICC* as poor (less than 0.5), moderate (0.5 to 0.75), and good reliability (above 0.75). Both clamshell peak force data and the HumacNORM peak torque data was used to calculate bi-variate Pearson correlation coefficient (*r*) for validation. Significance was set at *P-value* less than 0.05. All statistical analyses were performed with IBM SPSS Statistics (v26; IMB Corp., Armonk, NY).

RESULTS

Descriptive statistics (means and standard deviations: SD) are shown in **Table 1**. Test-retest *ICC* (model: 3,1) for right and left clamshell strength were 0.820 and 0.593, respectively. These *ICC* values were interpreted as good and moderate reliability, respectively. When clamshell strength was compared with HumacNORM isometric hip abduction strength, Pearson correlation coefficients (*r*) were 0.584 and 0.545 for the right and left limb, respectively. These *r* values were statistically significant (*P* = 0.003 and *P* = 0.006), respectively. A scatter plot including all data points (clamshell vs. dynamometer) for both right and left limb on both days is shown in **Figure 2**.

	Clamshell #1 (Newtons)	Clamshell #2 (Newtons)	Test-Retest Reliability	Isometric Hip ABD (Nm)	Validity
	Mean ± SD	Mean ± SD	*ICC* (*95% CI*)	Mean ± SD	*r* (*P-value*)
Right	225.0 ± 57.0	243.5 ± 45.2	0.820 (0.489, 0.945)	112.5 ± 23.9	0.584 (*P* = 0.003)
Left	217.5 ± 56.7	234.4 ± 59.1	0.593 (0.060, 0.863)	105.4 ± 21.5	0.545 (*P* = 0.06)

Table 1. Descriptive statistics on clamshell strength and isometric hip abduction strength testing, test-retest reliability, and validity.

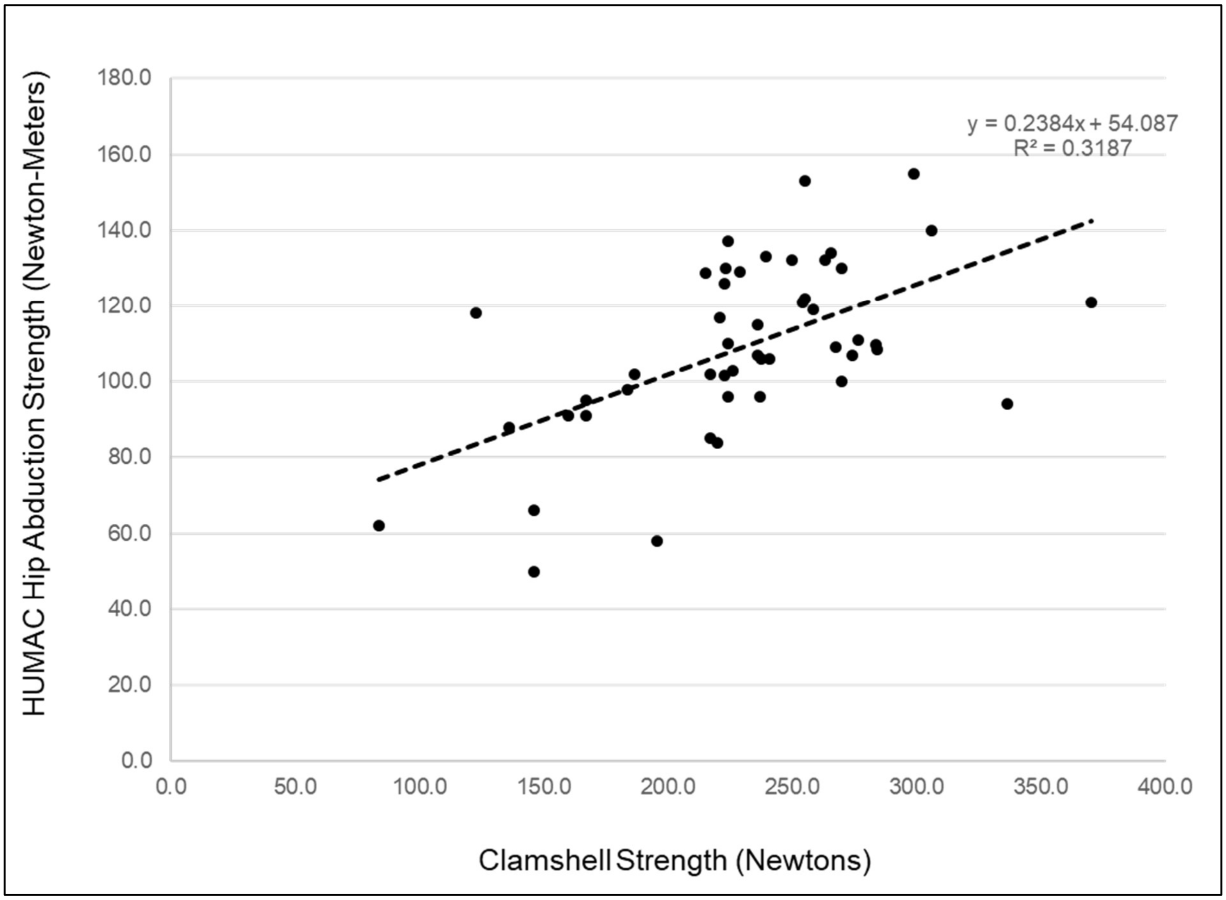

Figure 2. Correlation between clamshell strength and HumacNORM hip abduction strength (both right and left limbs during both visits were combined).

DISCUSSION

This study demonstrated moderate test-retest reliability of the clamshell hip strength and validity with HumacNORM isometric hip abduction strength. Thus, the hypothesis was mostly supported. Stated earlier, a few studies have established test-retest reliability with a simple hand-held dynamometer and concurrent validity with an isokinetic dynamometer machine in young healthy adults.[10,11,17] Test-retest reliability: *ICC* for hip abduction strength with HHD and Pearson correlation coefficient: *r* were 0.90 and 0.56, respectively.[10] Similarly, hip abduction strength by HHD was reliable (*ICC* = 0.88 & 0.90, right & left limb, respectively) and valid (*r* = 0.62 & 0.72, right & left limb, respectively).[11] Another hip abduction HHD reliability and validity study had *ICC* = 0.87-0.95 and *r* = 0.92-0.96.[17] The current reliability values of the clamshell device (*ICC* = 0.593 – 0.820) was slightly less than those studies while the current validity values (*r* = 0.545 – 0.584) were similar to two studies and lower than one study.

Since previous reliability studies had the same subject position and targeted the same hip muscles between hip abduction HHD and isokinetic dynamometer testing, the current study is slightly different during clamshell testing. That could explain slightly lower reliability and validity. In addition, it is interesting to note that the current subjects exhibited better clamshell strength (Visit #1: 221.3 ± 55.7 Newtons, Visit #2: 238.9 ± 51.6 Newtons, paired t-test *P-value*: 0.051) while HumacNORM hip abduction strength values were almost identical between visits (Visit #1: 108.6 ± 23.5 Nm, Visit #2: 109.2 ± 22.4 Nm, paired t-test *P-value*: 0.921). Further research is warranted to determine if a clamshell task is more complex to learn and perform consistently than a hip abduction strength task with the gold standard isokinetic dynamometer machine. More practice trials or visits will likely help to learn and optimize clamshell strength.

The idea of building a simple, low-cost clamshell strength device is essential for building large databases across many clinics as well as for tracking patients or athletes for their progress after interventions or training. Currently, the gold standard isokinetic dynamometer is expensive as well as bulky, making it difficult for small clinics to invest in the dynamometer machine (>$50,000 USD). In addition, aligning the dynamometer and a patient's joint center can be time consuming (especially, when a clinician is not a frequent user), limiting frequent usage at point-of-care. Therefore, HHD provides a simple and inexpensive alternative way to quantify a patient's strength for clinical use. The current clamshell strength device cost was ~$1,800 USD and built by our research members in one hour. Therefore, technically, anyone can make the same clamshell device. This device only measures hip strength (a combination of hip abduction and external rotation muscles) which is uniquely targeting the gluteus medius and maximus and less tensor fasciae latae at the same time,[17,18] instead of testing these muscles separately with the hip abduction, extension, and external rotation testing.

Clinical significance of the hip musculature, the gluteus medius in particular, was mentioned in the introduction and varied from ACL injury[3], loss of balance[7], and ankle sprain injury[8] among young athletes, to osteoarthritis progression[9] and low back pain[5,6] in older individuals. Furthermore, older individuals with a total hip replacement surgery exhibit weaker hip abduction strength. This hip abduction strength is strongly correlated with physical activity score and functional tests.[20,21] Interestingly, even among individuals with a total knee replacement surgery, hip abduction strength plays a critical role in functional tests such as lateral step and tandem gait tests more than other factors (demographics, anthropometric measures, and knee extensor strength).[22] Needless to say, hip strengthening exercises have been introduced in most conditioning programs for athletes or rehabilitation programs post-injuries/-operations. Simple and reliable devices (like the one developed for this study) that provide immediate clamshell strength values would help clinicians and researchers to establish an easy-to-follow clinical guideline for their patients' safe return-to-work/sports/duty. Integration of a simple, reliable, and portable device - such as the hip clamshell strength device presented herein - would provide another objective outcome for both clinicians and researchers to help determine the effectiveness of care (e.g., limitations of activities of daily living, performance, and rehabilitation prescription in the reduction of pain). With the large number of problems associated with deficient hip muscle strength (i.e., ACL injury, ankle instability, lower extremity injury, low back pain, osteoarthritis progression), it would be ideal to collect data on commonly overlooked stabilization and postural lateral hip muscles.

CONCLUSION

The current study investigated a simple and portable hip clamshell strength device and found moderate reliability and validity. Since the clamshell testing can examine individuals' ability to activate their hip abductors and external rotators without excessive activation of the tensor fascia latae muscle, it is clinically significant to monitor the clamshell strength periodically during rehabilitation. The device also provides an inexpensive, yet reliable and valid, alternative to an isokinetic dynamometer.

LIMITATIONS

This study was limited by a relatively small sample size that consequently caused large variability between days and devices. More subjects will likely help improve reliability and validity values. The current study was a pilot study with just one examiner; therefore, inter-rater reliability is largely unknown. However, we are confident that reliability and validity values will be similar to the current results because an examiner only provides verbal encouragement. The clamshell force transducer is located between the knees, and the examiner does not hold or touch the device during testing. This contrasts greatly from the HHD held/pushed by an examiner. In other words, as long as the examiner knows basic subject setup (side-lying with their knee and hip bend and heels connected), the clamshell task is the same.

COMPETING INTERESTS

The authors declare no conflict of interest. The views expressed in this manuscript are those of the authors and do not reflect the official policy of the Department of Army, Department of Defense, or the U.S. Government.

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