ORIGINAL ARTICLE

Muscular strength measurements through hand-held and anchored dynamometry: A study of test-retest and interrater reliability

Christopher Rawdon . *Department of Exercise Science. Mercer University. Macon, GA, United States of America.*
Wayne Shell. *Department of Exercise Science. Mercer University. Macon, GA, United States of America.*
Rachel Le. *Department of Exercise Science. Mercer University. Macon, GA, United States of America.*
Kathryn Mason. *Department of Exercise Science. Mercer University. Macon, GA, United States of America.*

ABSTRACT

Background: Hand-held dynamometry (HHD) offers a cost-effective and accessible method for measuring maximal voluntary contraction (MVC) compared to larger fixed dynamometers. This study aimed to determine if fixing the portable HHD device to a support anchor could improve intra- and inter-rater reliability across different muscle groups. Methods: Twelve healthy adults (ages 18–34) participated in two sessions of isometric MVC testing for ten muscle actions, conducted by two raters under both hand-held and anchored conditions. Interrater and intra-rater reliability were evaluated using intraclass correlation coefficients (ICC). Results: The anchored system demonstrated overall excellent interrater reliability (ICC = 0.935), while the hand-held condition yielded good reliability (ICC = 0.895), falling just below the threshold for excellent. Both methods showed overall excellent intra-rater reliability (HHD ICC = 0.933; Anchor ICC = 0.953). The anchored system yielded excellent reliability for elbow extension & flexion, internal & external rotation of the shoulder, plantarflexion, and neck extension, while moderate reliability was observed for knee assessments. Conclusions: Results support the use of anchoring systems to enhance measurement consistency, especially when using multiple raters. Anchored HHD systems may offer a more stable, repeatable method for muscle strength evaluation, benefiting both muscle strength and muscle injury assessments and research protocols.
Keywords: Sport medicine, Muscle strength assessment, Hand-held dynamometry, Interrater reliability, Anchored dynamometer, Maximal voluntary contraction, Isometric force.

Cite this article as:
Rawdon, C., Shell, W., Le, R., & Mason, K. (2025). Muscular strength measurements through hand-held and anchored dynamometry: A study of test-retest and interrater reliability. *Journal of Human Sport and Exercise, 20*(4), 1309-1321. https://doi.org/10.55860/gzbbh308

Corresponding author. *Department of Exercise Science 1501 Mercer University Dr, Macon, GA 31207, United States of America.*
E-mail: rawdon_cl@mercer.edu
Submitted for publication May 27, 2025.
Accepted for publication August 07, 2025.
Published August 23, 2025.
Journal of Human Sport and Exercise. ISSN 1988-5202.

doi: https://doi.org/10.55860/gzbbh308

INTRODUCTION

Muscle strength serves as a key indicator of injury recovery progress, overall muscular function, and general health status (Eriksrud & Bohannon, 2003; Byram et al., 2010; Hams et al., 2019; Bohannon, 2021). Muscular strength testing can inform sports and rehabilitation professionals about a patient's injury status and their potential independence outside of the clinical space (Eriksrud & Bohannon, 2003; Byram et al., 2010; Hams et al., 2019; Bohannon, 2021). Moreover, recent research has highlighted muscle strength as a potential biomarker for all-cause mortality and cardiovascular disease, even when adjusting for potential confounds (García-Hermoso et al., 2018; Yusuf et al., 2020). This emphasizes the need of accurately assessing muscle strength for athletes. These measures are typically obtained via maximal volitional contractions (MVC) which assesses a muscle or muscle group's maximal voluntary force generation capacity. Although many methods exist for measuring an MVC, such as an isokinetic device or manual muscle testing, hand-held dynamometry (HHD) provides an inexpensive and more accessible (Dollings et al., 2012) alternative for MVC measurements due to its minimal setup, space requirements, and cost.

Previous research underscores the reliability of HHD as an effective tool for obtaining objective measurements of muscular strength across various muscle groups (Johansson & Adolfsson, 2005; Whiteley et al., 2012; Alnahdi et al., 2014; Fieseler et al., 2015; Holt et al., 2016; Conceição et al., 2018; Croteau et al., 2021). However, HHD presents significant challenges that must be addressed to ensure more accurate measurements, such as strength disparities between the rater and the subject and inconsistent placement of the dynamometer (Wikholm & Bohannon, 1991; Bohannon et al., 2012; Thorborg et al., 2013). These factors seem most prevalent and commonly reported when assessing muscles in the lower extremities. Early research by Wikholm and Bohannon (1991) found that muscle groups producing greater isometric force (i.e., knee extensors) had greater variation in measurement compared to weaker muscle groups (i.e., shoulder external rotators). The authors also reported that the magnitude of force measurements varied depending on the strength of the rater or examiner.[15] Thorborg and coworkers (2013) also found a significant between-tester bias in measuring hip strength with HHD suggesting the stronger the subject, the larger the bias. Grootswagers et al. (2022) found that HHD systematically overestimated leg extension and flexion force in older adults compared to torque values obtained by an isokinetic device. Considering these confounds, improving the reliability of HHD is a pressing need for all health professionals as it will increase their confidence in the measures and improve their ability to assess musculoskeletal function and health.

Prior research has also examined externally supported dynamometers as a means to significantly enhance HHD's reliability (Byrne et al., 2020). Recently, Lafayette Instruments has developed a Hand-Held Dynamometer support stand (Model 1066), which anchors the Dynamometer (Model 01165), one of the most widely used HHDs in skeletal muscle research. The anchor is structured so that the HHD is fixated to a metal arm extending from the vertical base that is attached to a platform the tester can stand on. Two handles extend from either side of the base, providing extra leverage for the tester during MVCs which decreases strength bias between the tester and subject. The present research aims to observe the effects of utilizing the support stand anchor on interrater and intra-rater reliability across multiple joints and muscle groups in two separate sessions. The present study design incorporates test-retest assessments of ten distinct isometric muscle actions: knee extension, knee flexion, elbow extension, elbow flexion, internal rotation of the shoulder, external rotation of the shoulder, dorsiflexion, plantarflexion, neck extension, and neck flexion. It was hypothesized that the use of the Model 01166 support stand would improve interrater and intra-rater reliability across the ten muscle actions.

METHODS

Subjects

The subject population for the present study was twelve adults (n = 12), ages 18-34. Subject characteristics by sex are reported in Table 1. All participants within the study needed to satisfy the exclusion criteria: i) individuals less than 18 or older than 34 years old, ii) history of significant body injury (e.g., ligament tears, complete bone fracture, Grade III musculotendon tears), iii) history of medical neurological, or musculoskeletal impairments that could affect force measurements. Any potential subject who listed exclusionary criteria was dismissed from participating in the study. Due to unforeseen scheduling issues, Rater 2 did not collect Day 2 measurements for Subject 1; therefore, this timepoint was omitted from intra- and inter-session analyses.

Table 1. Subject characteristics.

	Males (n = 7)	Females (n = 5)
Age (y)	21.4 ± 4.0	19.4 ± 1.3
Height (cm)	180.0 ± 5.8	169.9 ± 7.6
Mass (kg)	94.1 ± 25.0	79.4 ± 7.7
BMI (kg/ m^2)	28.9 ± 7.0	27.5 ± 1.3

Note. Values are means ± SD. y, years. cm, centimeters. kg, Kilograms. m^2, meters-squared.

Experimental design

Subjects reported to the testing area for the first session, during which they received an introduction and a thorough explanation of the study. The current study was approved by the Institutional Review Board and informed consent was obtained during this time. Additionally, a health history questionnaire was administered to assess the eligibility of the participants for the study. Individuals were excluded if they were under 18 or over 34 years of age, or had a history of significant injury (e.g., ligament tears, fractures, Grade III musculotendinous tears) or medical, neurological, or musculoskeletal conditions affecting torque production.

Following introductory procedures, subjects warmed up for 5 minutes on an elliptical before beginning strength assessments. After warming up, the participants prepared for the strength assessments scheduled for that day. The subjects performed MVCs for each muscle action on a hand-held Dynamometer (Hand-held Dynamometer Model 01165A; Lafayette Instruments, Lafayette, IN, USA) on two separate days within a maximum of seven days (i.e., one week) in-between sessions. There was an average of 3.3 days in-between sessions. Two raters recorded strength measurements under two conditions: one while holding the dynamometer and the other while collecting measurements with the device fixated to the anchor (Model 01166; Lafayette Instruments, Lafayette, IN, USA). Rater 1 is male, and Rater 2 is female. Peak handgrip force for each rater was taken in a series of three attempts with their dominant hand prior to the first subject's data collection with a handgrip dynamometer (Smedley Digital Hand Dynamometer Model 12-0286; Baseline, Fabrication Enterprises Inc, White Plains, NY, USA). Rater 1 had a peak handgrip strength of 58.4 kg and Rater 2 had a peak handgrip strength of 36.6 kg. The raters were trained in hand-held strength testing assessment for approximately 5-6 hours in total over the course of five sessions before data collection began. During hand-held trials, raters were allowed to record the measurements however they were most comfortable, helping minimize error, including using a chair or wall for support. The testing order was a controlled variable and was performed in the order presented below. All assessments were completed on the subject's dominant leg and arm while sitting or lying on an athletic training or treatment table. Once all MVCs for a muscle group and corresponding range of motion were complete on the first condition (i.e., Hand-held vs. Anchored), the subject repeated the assessment under the second condition with the same rater before proceeding to the next muscle group. Once all measurements for all assessments were complete with the first rater, the procedures were repeated with the second rater.

Maximal voluntary contraction strength assessments

The strength of ten different muscle actions was assessed on both testing days. The order of the strength assessments was constant throughout each session and between each subject. During initial intake, subjects provided their upper and lower body dominance (i.e., left-handed and right-footed or right-handed and right-footed). Each strength assessment was performed on the subject's dominant side for the upper and lower extremities. The order of the two conditions (HHD and Anchor) was randomized for each subject; for example, subject one could have performed anchored first, while subject two performed hand-held dynamometry first. Before each MVC trial on both days, subjects completed a practice repetition to introduce the movement. Subjects then performed two recorded MVCs for each condition (Hand-held and Anchored). The dynamometer was tared before each attempt. Each MVC lasted four seconds. Subjects were instructed and vocally encouraged to exert maximum force until told to stop at the end of the four seconds. There was a 90-second rest period between each repetition. A digital clock would countdown periods of rest and effort for the subject. If a mistrial occurred due to errors (i.e., movement of the base or rater during testing; deviation of joint angle during test; force reading inconsistency; subject pain) the trial was redone after the subject rested to ensure accurate measurement. Data from mistrials were excluded from analysis to maintain consistency and reliability.

Knee extension

Subjects sat upright on the edge of the testing table with both hands resting on their thighs or the side of the table, ensuring consistency in hand placement throughout the assessment. Using a hand-held goniometer (EZ Read Jamar Goniometer, Sammons Preston), the rater positioned their dominant leg in 90° knee flexion with both their hip and ankle joints at 90°. For both conditions, the rater positioned the dynamometer ~ 2 cm above the talus bone on the anterior side of the dominant leg. During HHD attempts, the rater was positioned in a chair against the wall, directly in front of the subject on the table. During anchored trials, the dynamometer was attached to the arm of the anchor, placed adjacent to the dominant leg, and adjusted in height to account for individual differences in anthropometrics. The rater supported the anchor by standing in a split stance and braced to resist each contraction.

Knee flexion

Subjects sat upright on the edge of the testing table with their hands resting either on their thighs or the sides of the table, ensuring consistency in hand placement throughout the assessment. The rater positioned the dynamometer ~ 2 cm above the talus bone on the posterior side of the dominant leg. For HHD trials, the rater sat in front of the subject, resisting the subject pulling their leg. During anchored trials, the dynamometer was attached to the arm of the anchor and placed behind the dominant leg. The rater supported the anchor in a split stance and braced to resist each contraction.

Elbow flexion

Subjects sat upright on the edge of the testing table with their non-dominant hand resting on their thigh while their dominant arm rested in 90° elbow flexion with the forearm in supination. The subject was instructed to pin a hand towel against their ribcage on their dominant side using their upper arm to ensure that it stayed fixated at their side during the assessment. The rater stood adjacent to the subject and rested the dynamometer proximal to the radial styloid process on the subject's radial surface of their forearm. For the HHD condition, the rater resisted the movement downward. During the anchor condition, the rater stood on top of the anchor platform to prevent it from sliding or tipping over.

Elbow extension

Subjects lay supine with their head near the end of the testing table. Their non-dominant hand rested at their side, while the dominant arm was positioned in 90° shoulder flexion and 90° elbow flexion, with the forearm in neutral supination. The rater stood adjacent to the subject and positioned the dynamometer proximally to the ulnar styloid process on the ulnar surface of the forearm. For the HHD condition, the rater resisted the movement downward. During the anchor condition, the rater stood on top of the anchor platform to prevent it from sliding or tipping over.

Internal rotation of the shoulder

Subjects lay supine with their head near the end of the testing table. Their non-dominant hand gripped the side of the table to prevent sliding, while the dominant arm was positioned at 45° of shoulder abduction and 90° of elbow flexion. The dynamometer was placed on the anterior forearm proximal to the ulnar styloid, with the forearm in neutral supination. For the HHD condition, the rater resisted the movement by pulling against the arm of the subject. During the anchor condition, the anchor was positioned adjacent to the dominant side, and the rater stood on top of the anchor platform to prevent it from sliding or tipping over.

External rotation of the shoulder

Subjects lay supine with their head near the end of the testing table. Their non-dominant hand gripped the side of the table to prevent sliding, while the dominant arm was positioned at 45° of shoulder abduction and 90° of elbow flexion. The dynamometer was placed on the posterior forearm proximal to the ulnar styloid, with the forearm in neutral supination. For the HHD condition, the rater resisted the movement by pulling against the arm of the subject. During the anchor condition, the anchor was positioned adjacent to the dominant side, and the rater stood on top of the anchor platform to prevent it from sliding or tipping over.

Dorsiflexion

Subjects lay supine with their hips and knees extended and their ankle joint positioned at 90°. The dynamometer was placed over the metatarsal heads on the dorsum of the dominant foot. In the HHD condition, the rater was seated at the end of the testing table in a chair against the wall, with arms fully extended to resist movement during measurements. During the anchor condition, the raters supported the anchor in a split stance and braced to resist each contraction.

Plantarflexion

Subjects lay supine with their hips and knees extended and their ankle joint positioned at 90°. The dynamometer was placed over the metatarsal heads on the plantar surface of the dominant foot. In the HHD condition, the rater was seated at the end of the testing table in a chair against the wall, with arms fully extended to resist movement during measurements. During the anchor condition, the raters supported the anchor in a split stance and braced to resist each contraction.

Neck extension

Subjects lay prone on the testing table, with arms in a comfortable position by their sides and the head hanging off the front edge of the table. The neck rested in a neutral hang position while the dynamometer was placed on the back of the subject's head (crown). For the HHD condition, the rater resisted the movement downward. During the anchor condition, the rater stood on top of the anchor platform, which was positioned in the same manner as the rater in the HHD condition, to prevent it from sliding or tipping over.

Neck flexion

Subjects lay supine on the testing table, with arms in a comfortable position by their sides and the head resting near the edge of the table. For comfort, a bolster was placed under the posterior side of each subject's neck. The dynamometer was placed on the subject's forehead. For the HHD condition, the rater resisted the movement downward. During the anchor condition, the rater stood on top of the anchor platform, which was positioned in the same manner as the rater in the HHD condition, to prevent it from sliding or tipping over.

Data analysis and statistics

Test-retest data was analysed using the intraclass correlation coefficient (ICC) analysis. ICC serves as a measure of repeatability that evaluates both the degree of correlation and agreement between measurements (Koo & Li, 2016). ICC values below 0.5 are considered to have poor reliability, between 0.5 and 0.75 are considered moderate reliability, 0.75 and 0.9 are considered good reliability, and greater than 0.90 is considered excellent reliability based on a 95% confidence interval (Koo & Li, 2016). A Two-way mixed model with absolute agreement was used to calculated interrater and intra-rater ICCs. Statistical analysis was conducted using SPSS (IBM) Version 29 and Excel (Microsoft Office 2021).

RESULTS

Table 2. Mean isometric MVC force.

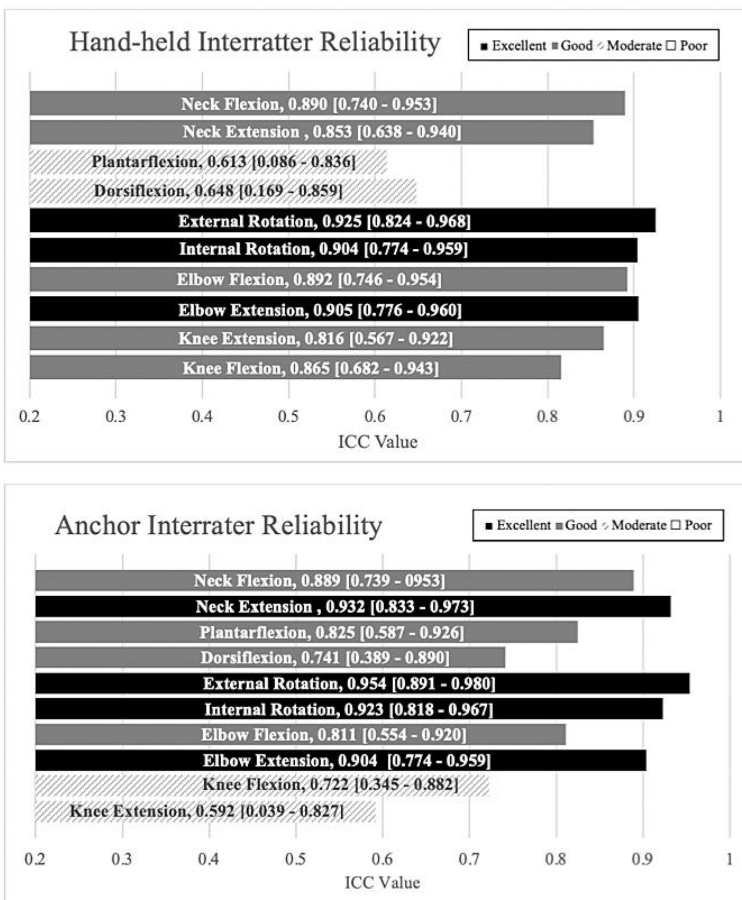
Muscle action	Rater	HHD day 1	HHD day 2	Anchor day 1	Anchor day 2
	1	415.8 ± 103.4	404.3 ± 104.6	313.9 ± 68.4	309.1 ± 58.7
KE	2	360.2 ± 93.5	318.9 ± 87.2	322.2 ± 69.2	296.3 ± 66.1
	Total	388.0 ± 100.5	363.5 ± 104.1	318.0 ± 67.4	303.0 ± 61.2
	1	179.63 ± 73.2	208.8 ± 57.8	109.6 ± 34.8	128.2 ± 31.3
KF	2	211.0 ± 75.3	226.8 ± 78.5	139.8 ± 37.2	152.5 ± 46.1
	Total	195.3 ± 74.4	217.4 ± 67.5	124.7 ± 38.5	139.8 ± 40.1
	1	225.3 ± 77.1	215.2 ± 77.3	236.6 ± 82.6	214.8 ± 75.0
EF	2	244.3 ± 89.1	249.8 ± 101.1	209.4 ± 65.3	228.4 ± 86.2
	Total	234.8 ± 82.1	231.7 ± 89.1	223.0 ± 74.1	221.3 ± 79.0
	1	167.3 ± 79.5	171.7 ± 85.1	171.9 ± 76.4	166.1 ± 77.4
EE	2	182.3 ± 86.9	190.6 ± 92.7	164.0 ± 54.4	170.5 ± 74.0
	Total	174.8 ± 81.8	180.7 ± 87.3	168.0 ± 65.0	168.2 ± 74.1
	1	168.5 ± 70.2	163.8 ± 59.5	165.4 ± 64.39	147.7 ± 53.4
IR	2	180.0 ± 54.7	178.0 ± 70.5	151.5 ± 44.5	148.5 ± 58.1
	Total	174.3 ± 61.9	170.6 ± 63.9	158.5 ± 54.9	148.0 ± 54.4
	1	143.8 ± 57.0	141.9 ± 45.8	131.7 ± 53.7	129.1 ± 40.5
ER	2	144.4 ± 54.8	151.0 ± 51.5	136 ± 51.9	134.2 ± 52.5
	Total	144.1 ± 54.7	146.3 ± 47.7	133.8 ± 51.7	131.5 ± 45.6
	1	195.6 ± 63.8	197.7 ± 48.0	164.8 ± 30.6	161.8 ± 30.6
DF	2	214.9 ± 83.8	204.4 ± 68.7	171.5 ± 40.6	165.0 ± 27.8
	Total	205.3 ± 73.5	200.9 ± 57.5	168.2 ± 35.4	163.3 ± 28.7
	1	347.3 ± 68.4	347.8 ± 82.8	336.8 ± 83.3	334.0 ± 73.2
PF	2	313.3 ± 97.5	302.4 ± 102.9	315.8 ± 62.3	327.1 ± 61.6
	Total	330.3 ± 84.2	326.0 ± 93.7	326.3 ± 72.8	330.7 ± 66.4
	1	183.2 ± 88.9	170.8 ± 51.7	196.8 ± 89.6	188.8 ± 67.9
NE	2	206.6 ± 74.3	199.6 ± 85.8	200.1 ± 71.4	188.8 ± 77.2
	Total	194.9 ± 80.8	184.5 ± 69.8	198.5 ± 79.1	188.8 ± 70.6
	1	112.7 ± 45.5	111.1 ± 36.9	134.3 ± 53.2	135.0 ± 55.1
NF	2	145.1 ± 59.5	152.9 ± 64.7	124.3 ± 37.1	142.6 ± 52.7
	Total	128.9 ± 54.4	131.1 ± 55.1	129.3 ± 45.2	138.7 ± 52.9

Note. Mean force values (±SD) in Newtons for each muscle action measured by both raters across two testing days using hand-held dynamometry (HHD) and anchored methods. KE = Knee Extension, KF = Knee Flexion, EF = Elbow Flexion, EE = Elbow Extension, IR = Internal Rotation, ER = External Rotation, DF = Dorsiflexion, PF = Plantarflexion, NE = Neck Extension, NF = Neck Flexion.

Reliability analysis

Force values for each muscle group, measured by both raters across both days using HHD and anchored methods, are reported in Table 2.

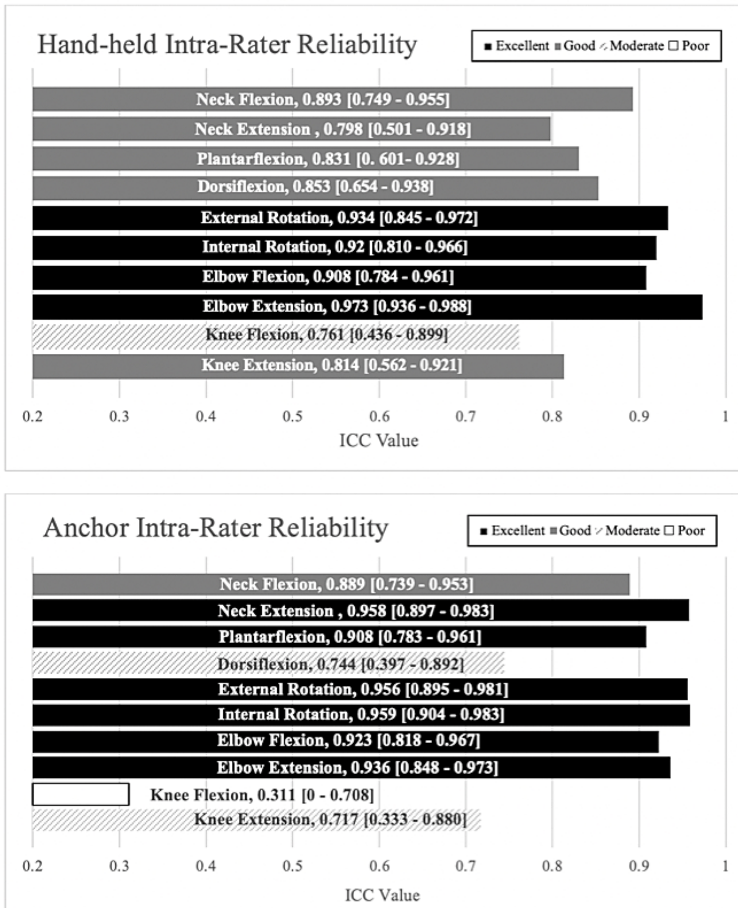
The total interrater reliability for hand-held dynamometry (HHD) was good (ICC = 0.895, 95% CI = 0.864 – 0.919), while the anchored method showed excellent reliability (ICC = 0.935, 95% CI = 0.915 – 0.950). Total intra-rater reliability was excellent for HHD (ICC = 0.933, 95% CI = 0.913 – 0.949) and anchored (ICC = 0.953, 95% CI = 0.940 – 0.964). Interrater and intra-rater reliability, as measured by Intraclass Correlation Coefficients (ICCs), are presented visually in Figures 1 and 2, respectively, for both HHD and anchored conditions across all muscle actions tested. Interrater reliability with HHD ranged from moderate to excellent (ICC = 0.613 to 0.925). Excellent reliability was observed for internal & external rotation of the shoulder as well as elbow extension. Good reliability was observed for knee flexion, knee extension, elbow flexion, neck extension, and neck flexion. Moderate reliability was observed for plantarflexion and dorsiflexion. With the anchored method, interrater reliability ranged from moderate to excellent (ICC = 0.592 to 0.931). Excellent reliability was observed for elbow extension, internal & external rotation of the shoulder, and neck extension. Good reliability was observed for elbow flexion, plantar flexion, and neck flexion. Moderate reliability was observed for knee extension, knee flexion, and dorsiflexion.



Note. Intraclass Correlation Coefficients (ICCs) are shown for each muscle action test. The dashed lines represent thresholds for poor (<0.5), moderate (0.5-0.75), good (0.75-0.9), and excellent (>0.9) reliability.

Figure 1. Interrater reliability of muscle strength measurements using (A) hand-held dynamometry (HHD) and (B) anchored methods.

Intra-rater ICCs ranged from moderate to excellent (0.761 to 0.973) for day-to-day reliability with HHD. Excellent reliability was observed for elbow extension, elbow flexion, internal rotation of the shoulder, and external rotation of the shoulder. Good reliability was observed for knee extension, dorsiflexion, plantar flexion, neck extension, and neck flexion. Moderate reliability was observed for knee flexion. Intra-rater ICCs ranged from poor to excellent (0.311 to 0.959) with the anchored method. Excellent reliability was observed for elbow extension, elbow flexion, internal rotation of the shoulder, external rotation of the shoulder, plantar flexion, and neck extension. Good reliability was observed for neck flexion. Moderate reliability was observed for knee extension and dorsiflexion. Poor reliability was observed for knee flexion.



Note. Infraclass Correlation Coefficients (ICCs) are shown for each muscle action tested. The dashed lines represent thresholds for poor (<0.5), moderate (0.5-0.75), good (0.75-0.9), and excellent (>0.9) reliability.

Figure 2. Intra-rater reliability of muscle strength measurements using (A) hand-held dynamometry (HHD) and (B) anchored methods.

DISCUSSION

Both methods exhibited excellent intra-rater reliability (ICC > 0.9) across all muscle actions, supporting previous findings that individual testers can obtain consistent results under controlled conditions (Whiteley et al., 2012; Byrne et al., 2020). However, the anchored method demonstrated superior interrater reliability (ICC = 0.935) than the hand-held dynamometer (HHD) method (ICC = 0.895). This finding coincides with prior studies highlighting the importance of external fixation for consistent measurements (Aerts et al., 2025;

Beshay et al., 2011). It is worth noting that the hand-held approach also performed well, nearing the threshold for excellent reliability (ICC > 0.9). For coaches, trainers, researchers, and clinicians, using an anchored system could enhance confidence in muscle strength assessments, particularly in cases where multiple testers are involved or when working with individuals capable of producing high force compared to the tester (Wikholm & Bohannon, 1991; Bohannon et al., 2012; Thorborg et al., 2013).

Notably, elbow extension, internal rotation, and external rotation exhibited excellent interrater reliability (ICCs > 0.9) with the anchored system, paralleling findings from Beshay and coauthors in 2011, which also saw improvements in shoulder strength measurements with external fixation of a dynamometer. Using a stable anchor minimized variability stemming from tester strength and positioning, a recurring limitation of HHD in previous studies (Wikholm & Bohannon, 1991; Bohannon et al., 2012; Thorborg et al., 2013; Grootswagers et al., 2022). Plantarflexion yielded moderate interrater reliability when using HHD (ICC = 0.613). Previous research has shown a wide range of reliability across populations when assessing plantarflexion with rankings from poor (Katoh & Yamasaki, 2009; Marmon et al., 2013) to moderate (Mentiplay et al., 2015) to good (Mentiplay et al., 2015; Hartmann et al., 2009) to excellent (Hartmann et al., 2009; Davis et al., 2017). Our current findings demonstrated that the anchored system improved reliability substantially (ICC = 0.825 interrater reliability, ICC = 0.908 intra-rater reliability), surpassing benchmarks established in previous studies. The use of an anchored system in these settings could help prevent underestimating or overestimating strength of the plantarflexor group, leading to better-targeted interventions for patients recovering from injuries such as Achilles tendon ruptures or for athletes undergoing performance assessments.

Anchored method also demonstrated notable improvements in reliability for neck strength measurements compared to hand-held dynamometry. Neck extension achieved excellent ranking for both intrarater & interrater reliability (ICC > 0.90) with the anchored method, compared to the good ranking from the hand-held method (ICC < 0.90). The anchored system also had borderline excellent intra-rater and interrater reliability (ICCs = 0.889) for the neck flexion assessment. These findings align with prior research assessing the reliability of neck strength measurements with hand-held dynamometry (Shahidi et al., 2012; Cibulka et al., 2017). By reducing variability through stabilization, the anchored system offers a clinically meaningful advantage for evaluating neck strength, particularly in contexts such as cervical spine, assessment, rehabilitation and ergonomics. The results overall emphasize the critical role of external stabilization in gathering more reliable measurements of force production, especially from stronger muscle groups where confounds from raters can have a more significant influence on results.

Knee flexion and extension presented many challenges in the anchored condition. Interrater reliability in this condition ranged from moderate to good (ICC = 0.625 for knee flexion, ICC = 0.711 for knee extension). These results contradict the higher reliability found in studies like Kelln et al. (2008), where standardized positioning and belt stabilization improved measurements. We believe part of these findings stem from the testing environment which had tiled floors which reduced friction and caused a higher prevalence of mistrials and additional repetitions through movement of the stand. Additionally, we made the choice to test both knee extension and flexion at a 90° knee joint angle to prioritize efficiency of transition between knee extension and knee flexion. This decision may have compromised reliability by putting the hamstring group (i.e., knee flexors) in a shortened position when the knee joint angle is at 90° of flexion. This limitation is established in the length-tension relationship of skeletal muscle fibres were less isometric tension will be produced by fibres in a shortened position (Gordon et al., 1966). Addressing these limitations by using non-slip surfaces for testing and optimizing anchor placement or testing angles could improve reliability further, giving clinicians more confidence in their assessments and enabling personalized rehabilitation programs.

Limitations

The small sample size (n = 12) may limit the generalizability of the findings, especially among diverse populations. Additionally, the testing environment and protocol constraints may have introduced variability. Mistrials were more common when high force was being applied in the sagittal plane (e.g., knee extension) likely due to a lack of friction between the metal base of the anchor and the tile flooring. A different surface could likely limit eliminate anchor movement during trials. Future research should evaluate larger cohorts and incorporate standardized environmental conditions.

CONCLUSION

Overall, this study demonstrates the potential reliability improvements achievable with an anchored dynamometer system compared to hand-held methods, highlighting key improvements to recording maximal volitional contractions for muscle force production. The findings positively contribute to previous research, underscoring the cruciality of stabilization in achieving consistent and accurate strength assessments, especially in larger or stronger muscle groups capable of producing greater force. Using a stable anchor as an attachment point for HHDs can minimize variability resulting from disparities between tester strength, positioning, and possibly training. Notably, these findings emphasize the use of an anchored system for performance, clinical and research applications, especially concerning robust upper limb and complex lower limb muscle actions. A more reliable method for assessing muscle strength can give professionals and researchers from various fields greater confidence in their ability to develop valid procedures. Additionally, this approach may reduce the time needed to conduct these assessments, potentially decreasing the number of errors caused by individual differences among testers. Continued exploration of methodological refinements will further enhance its utility and reliability, possibly through addressing some of the limitations.

AUTHOR CONTRIBUTIONS

Chris Rawdon: Conceptualization, study design, data collection, statistical analysis, interpretation of results, literature review, manuscript drafting/editing, and correspondence. Wayne Shell: Study design, data collection, statistical analysis, interpretation of results, literature review, manuscript drafting/editing, and correspondence. Rachel Le: Statistical analysis, interpretation of results, literature review, manuscript drafting/editing, and correspondence. Kathryn Mason: Study design, data collection, statistical analysis, interpretation of results, literature review, manuscript drafting/editing, and correspondence.

SUPPORTING AGENCIES

No funding agencies were reported by the authors.

DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

ETHICAL APPROVAL AND INFORMED CONSENT

All procedures were approved by the Mercer University Institutional Review Board. Informed consent was obtained from all participants prior to participation.

DATA AVAILABILITY STATEMENT

The datasets generated and/or analysed during the current study are available from the corresponding author upon reasonable request.

ACKNOWLEDGMENTS

The authors would like to thank Lafayette Instruments for donating the dynamometer support stand used in this study. Lafayette Instruments had no role in the preparation, conduct, or authorship of this research.

REFERENCES

Aerts, F., Sheets, H., Anderson, C., Bussie, N., Hoskins, R., Maninga, A., & Novak, E. (2025). Reliability and agreement of hand-held dynamometry using three standard rater test positions. International Journal of Sports Physical Therapy, 20(2), 243. https://doi.org/10.26603/001c.128286

Alnahdi, A. H., Zeni, J. A., & Snyder-Mackler, L. (2014). Hip abductor strength reliability and association with physical function after unilateral total knee arthroplasty: A cross-sectional study. Physical Therapy, 94(8), 1154-1162. https://doi.org/10.2522/ptj.20130335

Beshay, N., Lam, P. H., & Murrell, G. A. (2011). Assessing the reliability of shoulder strength measurement: Hand-held versus fixed dynamometry. Shoulder & Elbow, 3(4), 244-251. https://doi.org/10.1111/j.1758-5740.2011.00137.x

Bohannon, R. W., Kindig, J., Sabo, G., Duni, A. E., & Cram, P. (2012). Isometric knee extension force measured using a hand-held dynamometer with and without belt-stabilization. Physiotherapy Theory and Practice, 28(7), 562-568. https://doi.org/10.3109/09593985.2011.640385

Bohannon, R. W. (2021). Characterization of muscle strength using the strength domain of the stroke impact scale: An integrative review. Isokinetics and Exercise Science, 29(3), 219-231. https://doi.org/10.3233/IES-210101

Byram, I. R., Bushnell, B. D., Dugger, K., Charron, K., Harrell, F. E., & Noonan, T. J. (2010). Preseason shoulder strength measurements in professional baseball pitchers: Identifying players at risk for injury. American Journal of Sports Medicine, 38(7), 1375-1382. https://doi.org/10.1177/0363546509360404

Byrne, A., Lodge, C., & Wallace, J. (2020). Intrarater test-retest reliability of hip abduction, internal rotation, and external rotation strength measurements in a healthy cohort using a hand-held dynamometer and a portable stabilization device: A pilot study. Archives of Rehabilitation Research and Clinical Translation, 2(2), 100050. https://doi.org/10.1016/j.arrct.2020.100050

Cibulka, M. T., Herren, J., Kilian, A., Smith, S., Mahmutovic, F., & Dolles, C. (2017). The reliability of assessing sternocleidomastoid muscle length and strength in adults with and without mild neck pain. Physiotherapy Theory and Practice, 33(4), 323-330. https://doi.org/10.1080/09593985.2017.1302539

Conceição, A., Parraca, J., Marinho, D., Costa, M., Louro, H., Silva, A., et al. (2018). Assessment of isometric strength of the shoulder rotators in swimmers using a hand-held dynamometer: A reliability study. Acta of Bioengineering and Biomechanics, 20(4), 119-127.

Croteau, F., Robbins, S. M., & Pearsall, D. (2021). Hand-held shoulder strength measures correlate with isokinetic dynamometry in elite water polo players. Journal of Sport Rehabilitation, 30(8), 1233-1238. https://doi.org/10.1123/jsr.2020-0277

Davis, P. R., McKay, M. J., Baldwin, J. N., Burns, J., Pareyson, D., & Rose, K. J. (2017). Repeatability, consistency, and accuracy of hand-held dynamometry with and without fixation for measuring ankle plantarflexion strength in healthy adolescents and adults. Muscle & Nerve, 56(5), 896-900. https://doi.org/10.1002/mus.25576

Dollings, H., Sandford, F., O'Conaire, E., & Lewis, J. S. (2012). Shoulder strength testing: The intra- and inter-tester reliability of routine clinical tests, using the PowerTrack™ II Commander. Shoulder & Elbow, 4(2), 131-140. https://doi.org/10.1111/j.1758-5740.2011.00162.x

Eriksrud, O., & Bohannon, R. W. (2003). Relationship of knee extension force to independence in sit-to-stand performance in patients receiving acute rehabilitation. Physical Therapy, 83(6), 544-551. https://doi.org/10.1093/ptj/83.6.544

Fieseler, G., Molitor, T., Irlenbusch, L., Delank, K. S., Laudner, K. G., Hermassi, S., et al. (2015). Intrarater reliability of goniometry and hand-held dynamometry for shoulder and elbow examinations in female team handball athletes and asymptomatic volunteers. Archives of Orthopaedic and Trauma Surgery, 135(12), 1719-1726. https://doi.org/10.1007/s00402-015-2331-6

García-Hermoso, A., Cavero-Redondo, I., Ramírez-Vélez, R., Ruiz, J. R., Ortega, F. B., Lee, D. C., et al. (2018). Muscular strength as a predictor of all-cause mortality in an apparently healthy population: A systematic review and meta-analysis of data from approximately 2 million men and women. Archives of Physical Medicine and Rehabilitation, 99(10), 2100-2113. https://doi.org/10.1016/j.apmr.2018.01.008

Gordon, A. M., Huxley, A. F., & Julian, F. J. (1966). The variation in isometric tension with sarcomere length in vertebrate muscle fibres. Journal of Physiology, 184(1), 170-192. https://doi.org/10.1113/jphysiol.1966.sp007909

Grootswagers, P., Vaes, A. M. M., Hangelbroek, R., Tieland, M., van Loon, L. J. C., & de Groot, L. C. P. G. M. (2022). Relative validity and reliability of isometric lower extremity strength assessment in older adults by using a hand-held dynamometer. Sports Health, 14(6), 899-905. https://doi.org/10.1177/19417381211063847

Hams, A. H., Evans, K., Adams, R., Waddington, G., & Witchalls, J. (2019). Shoulder internal and external rotation strength and prediction of subsequent injury in water-polo players. Scandinavian Journal of Medicine & Science in Sports, 29(9), 1414-1420. https://doi.org/10.1111/sms.13459

Hartmann, A., Knols, R., Murer, K., & De Bruin, E. D. (2009). Reproducibility of an isokinetic strength-testing protocol of the knee and ankle in older adults. Gerontology, 55(3), 259-268. https://doi.org/10.1159/000172832

Holt, K. L., Raper, D. P., Boettcher, C. E., Waddington, G. S., & Drew, M. K. (2016). Hand-held dynamometry strength measures for internal and external rotation demonstrate superior reliability, lower minimal detectable change and higher correlation to isokinetic dynamometry than externally-fixed dynamometry of the shoulder. Physical Therapy in Sport, 21, 75-81. https://doi.org/10.1016/j.ptsp.2016.07.001

Johansson, K. M., & Adolfsson, L. E. (2005). Intraobserver and interobserver reliability for the strength test in the Constant-Murley shoulder assessment. Journal of Shoulder and Elbow Surgery, 14(3), 273-278. https://doi.org/10.1016/j.jse.2004.08.001

Kelln, B. M., McKeon, P. O., Gontkof, L. M., & Hertel, J. (2008). Hand-held dynamometry: Reliability of lower extremity muscle testing in healthy, physically active, young adults. Journal of Sport Rehabilitation, 17(2), 160-170. https://doi.org/10.1123/jsr.17.2.160

Koo, T. K., & Li, M. Y. (2016). A guideline of selecting and reporting intraclass correlation coefficients for reliability research. Journal of Chiropractic Medicine, 15(2), 155-163. https://doi.org/10.1016/j.jcm.2016.02.012

Katoh, M., & Yamasaki, H. (2009). Comparison of reliability of isometric leg muscle strength measurements made using a hand-held dynamometer with and without a restraining belt. Journal of Physical Therapy Science, 21(1), 37-42. https://doi.org/10.1589/jpts.21.37

Marmon, A. R., Pozzi, F., & Alnahdi, A. H. (2013). The validity of plantarflexor strength measures obtained through hand-held dynamometry measurements of force. International Journal of Sports Physical Therapy, 8(6), 820-827.

Mentiplay, B. F., Perraton, L. G., Bower, K. J., Adair, B., Pua, Y. H., Williams, G. P., McGaw, R., & Clark, R. A. (2015). Assessment of lower limb muscle strength and power using hand-held and fixed dynamometry: A reliability and validity study. PLoS ONE, 10(10), e0140822. https://doi.org/10.1371/journal.pone.0140822

Shahidi, B., Johnson, C. L., Curran-Everett, D., & Maluf, K. S. (2012). Reliability and group differences in quantitative cervicothoracic measures among individuals with and without chronic neck pain. BMC Musculoskeletal Disorders, 13, 1. https://doi.org/10.1186/1471-2474-13-215

Thorborg, K., Bandholm, T., Schick, M., Jensen, J., & Hölmich, P. (2013). Hip strength assessment using hand-held dynamometry is subject to intertester bias when testers are of different sex and strength. Scandinavian Journal of Medicine & Science in Sports, 23(4), 487-493. https://doi.org/10.1111/j.1600-0838.2011.01405.x

Whiteley, R., Jacobsen, P., Prior, S., Skazalski, C., Otten, R., & Johnson, A. (2012). Correlation of isokinetic and novel hand-held dynamometry measures of knee flexion and extension strength testing. Journal of Science and Medicine in Sport, 15(5), 444-450. https://doi.org/10.1016/j.jsams.2012.01.003

Wikholm, J. B., & Bohannon, R. W. (1991). Hand-held dynamometer measurements: Tester strength makes a difference. Journal of Orthopaedic & Sports Physical Therapy, 13(4), 191-198. https://doi.org/10.2519/jospt.1991.13.4.191

Yusuf, S., Joseph, P., Rangarajan, S., Islam, S., Mente, A., Hystad, P., et al. (2020). Modifiable risk factors, cardiovascular disease, and mortality in 155,722 individuals from 21 high-, middle-, and low-income countries. The Lancet, 395(10226), 795-808. https://doi.org/10.1016/S0140-6736(19)32008-2