

Original Article

Reliability and Correlations Among Handgrip Strength Measurements and Muscle Power in Older Women

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Abstract

Objectives: The reliability of handgrip strength measurements and their relationship with muscle power in older adults is not well understood. This study aimed to determine the reliability and correlations between handgrip strength measurements and muscle power in older women. **Methods:** Twenty older healthy women (67.8 ± 5.8 years) participated in two separate testing sessions. During each session, handgrip contractions were performed to evaluate strength, specifically measuring peak force and rate of force development (RFD) across various time intervals. Muscle power was assessed by measuring sit-to-stand peak power and seated medicine ball throw distance. **Results:** Handgrip strength measurements, sit-to-stand peak power, and seated medicine ball throw distance demonstrated good test-retest reliability. The intraclass correlation coefficients were between 0.930 and 0.978. The coefficients of variation were between 2.7 and 8.0%. There were significant correlations between handgrip strength measurements and both sit-to-stand peak power ($r = 0.485-0.533$, $P = 0.015-0.030$) and seated medicine ball throw distance ($r = 0.457-0.634$, $P = 0.003-0.043$). **Conclusions:** Our study showed good reliability for handgrip strength measurements, sit-to-stand peak power, and seated medicine ball throw distance in older women. The significant correlations we observed suggest that handgrip peak force and RFD may be important variables associated with one's muscle power.

Keywords: Clinimetrics, Maximal Force, Medicine Ball, Rate of Force Development, Sit-to-stand

Introduction

Handgrip strength measurements, such as peak force and rate of force development (RFD), are effective parameters at characterizing the strength capacities of numerous muscle groups in the upper and lower extremities^{1,2}. These measurements are valuable for assessing athletic performance³, predicting functional impairments⁴, and monitoring changes in neuromuscular function resulting from training or fatigue⁵. Handgrip peak force and RFD are usually derived from a maximal contraction of the

dominant hand⁶. Handgrip peak force is a measure of maximal strength, whereas handgrip RFD is a measure of rapid strength⁷. Both measures have been employed as a diagnostic tool for sarcopenia – the age-associated loss of muscle mass, function, and strength – a condition frequently observed in older adults^{8,9}. Handgrip strength has also been used as an index of muscular function, bone mineral density, physical performance outcomes, chronic diseases, quality of life, and mortality^{8,10}.

Most research on handgrip strength focuses solely on measuring peak force^{2,11,12}, with considerably fewer studies examining handgrip RFD. RFD measurements play an important role in fast and forceful muscle actions¹³ and are significantly related to performance during explosive-type activities⁹. Previous investigations have emphasized the importance of measuring RFD at different time intervals when assessing handgrip rapid strength^{9,13}. This includes early (100 ms), late (200 ms), and maximum (peak) RFD phases⁷. Borges et al.¹⁴ showed that handgrip RFD at 200 ms (RFD200) was significantly correlated with mobility in older adults. Moreover, Palmer⁴ found significant correlations in older women between vertical jump performance and

Ty B. Palmer co-invented the Dynamo Torque Analyzer. Alexandra L. Khartabil has nothing to disclose.

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handgrip strength characteristics, with slightly stronger correlations for RFD than peak force. Collectively, these findings suggest that handgrip strength, and in particular RFD, may be an effective variable at predicting explosive performance outcomes in older individuals.

Reliability is frequently assessed by researchers to confirm the repeatability of a given measurement¹⁵. Research has revealed the reliability of handgrip peak force and RFD measurements in young, college-aged adults^{7,16,17}. Few investigations have examined the reliability of these measurements in older adults. Most studies involving older adults have shown good reliability for handgrip peak force^{11,18}. But, the reliability of handgrip RFD has yielded mixed findings, with some researchers indicating good reliability⁶ and other researchers showing poorer reliability¹. Such discrepancies likely stem from methodological differences in calculating handgrip RFD across studies, including variations in the number of trials used.

The sex of the participants may also be an important factor to consider in relation to handgrip RFD¹⁹. Jenkins et al.¹ found poor test-retest reliability for handgrip RFD in older men. The reliability of handgrip RFD in older women has not been well established. Furthermore, it remains unclear whether handgrip peak force and RFD are associated with performance during sit-to-stand and seated medicine ball throw tests. These tests are often used in research and clinical settings to assess the power performance capacities of older adults^{20,21}. Given the utility of the sit-to-stand and seated medicine ball throw as valid assessments of muscle power^{22,23}, further research is needed to examine the correlations between these tests and handgrip peak force and RFD. Investigating such correlations may help determine the efficacy of handgrip strength measurements as predictors of power-related performances in older adults. Therefore, the primary aim of this investigation was to evaluate the reliability of handgrip strength characteristics, sit-to-stand power, and seated medicine ball throw distance in older women. A secondary aim was to determine the correlations between handgrip strength measurements and sit-to-stand power and seated medicine ball throw distance. Based on the results reported by previous studies^{7,20,21,24,25}, we hypothesized that each variable in our investigation would be highly reliable. We also hypothesized that the handgrip strength measurements would be positively correlated with sit-to-stand power and seated medicine ball throw distance.

Materials and Methods

Subjects

We conducted a power analysis for our study. The analysis indicated that a sample size of at least 19 participants was required to achieve a statistical power of 0.80 at an alpha level of 0.05²⁶. Thus, 20 older women (mean \pm standard deviation [SD]; age = 67.8 \pm 5.8 years; height = 164.7 \pm 6.9 cm; body mass = 67.9 \pm 9.7 kg) were recruited to participate

in the present study. The participants were recruited from a community-based health and wellness facility, where all testing was also conducted. Inclusion criteria consisted of participants who were healthy and between the ages of 60 and 80 years. All participants were free of any neuromuscular disorders or musculoskeletal injuries affecting the upper or lower extremities. Participants were considered recreationally trained based on their self-reported volume of physical activity (8.6 \pm 7.4 h·wk⁻¹). Each participant completed a custom-designed health history questionnaire.

Experimental Design

This study employed a test-retest reliability design to assess the consistency of handgrip strength variables, sit-to-stand power, and seated medicine ball throw distance across sessions. Each participant reported for testing on two different occasions, separated by 1-3 days at approximately the same time of day (\pm 2 hours). For each testing session, participants completed five sit-to-stands, three seated medicine ball throws, and three handgrip maximal voluntary contraction (MVC) trials with their dominant hand. Participants identified their dominant hand as the one they typically use to hold a pencil²⁷. This "pencil method" is a quick and simple procedure, but it has limitations and may not reflect true hand dominance. All data collection procedures were conducted by a single researcher (TBP).

Sit-to-Stand Power Test

Sit-to-stand power was assessed using a Tendo Weightlifting Analyzer (Tendo Sports Machines; Trencin, Slovak Republic). This device has been shown to be a valid instrument for measuring sit-to-stand power in older adults²². The Tendo device was affixed to the left side of a belt secured to each subject's waist. The Kevlar string of the Tendo device was aligned with the sagittal plane when standing. For each assessment, participants sat on a chair (43-cm height) with their arms crossed over their chest, their torso bent slightly forward, and their feet positioned shoulder-width apart on the floor. Participants were instructed to rise from the chair to a fully upright position and return to a seated position five times as quickly as possible without stopping. The participant's mass was entered into the Tendo device prior to testing. The device then calculated and displayed estimated peak power output in Watts (W) following each repetition. All participants performed one practice trial followed by five repetitions of the sit-to-stand test. The average peak power value of the five repetitions was utilized for further analysis.

Seated Medicine Ball Throw

The seated medicine ball throw was performed to estimate upper body power using methods similar to those described previously²³. During the test, participants were

seated in a chair with their torso upright and feet flat on the floor. A 5-meter distance was marked in front of them on the floor using a tape measure. All throws were conducted bilaterally using a 2.7-kg medicine ball. To account for differences in arm length, participants held the medicine ball in their hands with their arms extended away from their chest and were instructed to drop the ball straight down on the tape measure. The point where the ball's nearest edge hit the tape measure served as the zero mark. Participants started each throw with the ball positioned at their chest. The ball was held with both shoulders abducted and elbows flexed. Each participant performed three trials of the medicine ball throw with one minute of recovery between each trial. For all trials, participants were instructed to throw the ball as far as possible at an approximate angle of 45° above the horizontal plane (precise release angles could not be verified), using a motion similar to a basketball chest pass. The spot where the front end of the ball hit the floor was marked and recorded with the tape measure. Test scores were reported as the average horizontal distance of the three throws.

Handgrip Contractions

Handgrip contractions were performed using the dominant hand and measured with a Dynamo Torque Analyzer (Dynamo, Version 1.0; Texas Tech University, Lubbock, TX, USA) (Figure 1)¹³. The procedures for these contractions have been reported elsewhere^{7,13}. In brief, participants sat in a chair with their shoulder adducted, elbow flexed at 90°, and forearm and wrist held in a neutral position²⁸. For each MVC, participants squeezed the handles of the Dynamo “as hard and fast as possible” for 3-4 s while receiving standardized, strong verbal encouragement throughout the effort. Participants completed three handgrip MVCs with one minute of rest between each trial. After each trial, the Dynamo automatically calculated and displayed handgrip strength measurements of peak force, peak RFD, and RFD at time intervals of 0-100 (RFD100) and 0-200 (RFD200) ms from contraction onset (Figure 2). The average of the three trials was used for subsequent analysis and the contraction onset for the Dynamo was set at 5 Newtons (N).

Statistical Analysis

Paired samples *t*-tests were conducted to assess potential systematic differences between testing sessions 1 and 2 for sit-to-stand peak power, seated medicine ball throw distance, and handgrip strength variables (peak force, peak RFD, RFD100, and RFD200). *P* values and Cohen's *d* effect sizes were determined for each test. Reliability statistics were computed to evaluate the consistency of each variable across sessions. These statistics included the intraclass correlation coefficient (ICC, model 2.k, where “k” indicates the average across trials), standard error of measurement (SEM), minimal difference (MD) needed to be considered

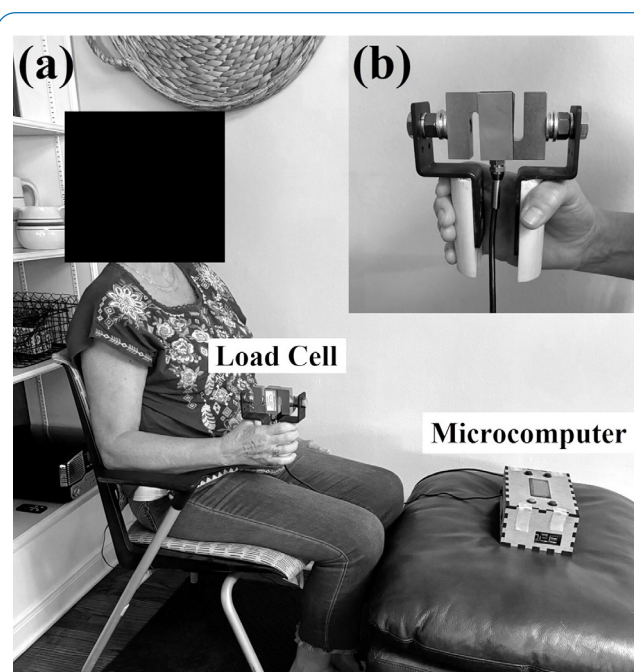


Figure 1. (a) A participant performing a handgrip maximal voluntary contraction using the Dynamo. The Dynamo consists of two functional components: a load cell and a microcomputer. The load cell was equipped with two semi-cylindrical handles for gripping. (b) An enlarged picture of the handles attached to the load cell is provided.

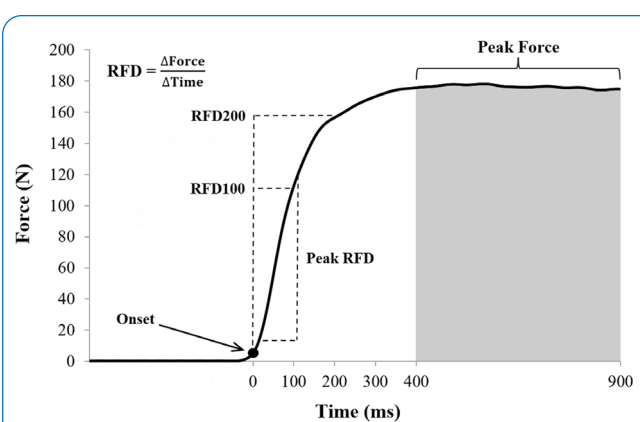


Figure 2. Example of a processed force signal derived from the Dynamo during a handgrip maximal voluntary contraction. The force signal produced during the contraction was used to measure handgrip peak force and rate of force development (RFD) characteristics. Peak force was calculated as the highest mean 500 ms epoch. RFD was calculated as the linear slope of the force signal ($\Delta force/\Delta time$) at time intervals of 0-100 (RFD100) and 0-200 (RFD200) ms from onset. Peak RFD was calculated as the highest slope value for any 100 ms epoch that occurred over the initial 200 ms of the force signal.

Table 1. Mean \pm standard deviation (SD) and reliability statistics between sessions for handgrip strength variables, sit-to-stand peak power, and seated medicine ball throw distance.

Variable	Mean \pm SD		P	ICC _{2,k} (95% CI)	SEM	SEM% (95% CI)	MD	MD% (95% CI)	CV (95% CI)
	Session 1	Session 2							
Handgrip									
Peak Force (N)	160 \pm 27	160 \pm 28	0.966	0.978 (0.9-1.0)	5.98	3.7 (2.8-5.5)	16.6	10.4 (7.9-15)	2.7 (1.6-3.8)
Peak RFD (N·s ⁻¹)	984 \pm 191	1004 \pm 180	0.307	0.939 (0.9-1.0)	62.69	6.3 (4.8-9.2)	173.8	17.5 (13-26)	5.0 (3.0-7.0)
RFD100 (N·s ⁻¹)	977 \pm 190	1000 \pm 178	0.281	0.931 (0.8-1.0)	65.46	6.6 (5.0-9.7)	181.4	18.4 (14-27)	5.2 (3.1-7.3)
RFD200 (N·s ⁻¹)	649 \pm 121	664 \pm 111	0.194	0.950 (0.9-1.0)	34.41	5.2 (4.0-7.7)	95.4	14.5 (11-21)	4.3 (2.5-6.1)
Peak Power (W)	612 \pm 174	650 \pm 194	0.052	0.930 (0.8-1.0)	58.63	9.3 (7.1-14)	162.5	25.7 (20-38)	8.0 (5.5-11)
Throw Distance (m)	2.4 \pm 0.4	2.5 \pm 0.4	0.085	0.969 (0.9-1.0)	0.09	3.6 (2.8-5.3)	0.2	10.0 (7.9-15)	3.3 (2.3-4.3)

P = type I error rate for the paired samples *t*-test between sessions 1 and 2. ICC_{2,k} = intraclass correlation coefficient, model 2,k. SEM = standard error of measurement, expressed as an absolute value and as a percentage of the grand mean. MD = minimal difference to be considered real, expressed as an absolute value and as a percentage of the grand mean. CV = coefficient of variation. CI = confidence interval. RFD = rate of force development.

real, and coefficient of variation (CV). The methods for calculating these statistics have been described in detail elsewhere^{29,30}. The SEM and MD were reported both as absolute values and percentages of the grand mean.

Data normality was assessed using quantile-quantile (Q-Q) plots, along with the Kolmogorov-Smirnov and Shapiro-Wilk Tests. Outliers were defined as values exceeding 2.2 times the interquartile range above the third quartile or below the first quartile¹³. Descriptive statistics for each variable were reported as mean \pm SD. Pearson Correlation Coefficients (*r*) from data averaged across both sessions were calculated to examine the relationships between the handgrip strength variables and sit-to-stand peak power and seated medicine ball throw distance. Ninety-five percent confidence intervals were reported for the ICC, SEM%, MD%, CV, and *r* values. Calculations for the ICC, SEM, MD, and CV were conducted using a custom-designed spreadsheet in Microsoft Excel (Microsoft Corp., Redmond, WA, USA). All other statistical analyses were performed using SPSS software (version 29; SPSS Inc., Chicago, IL, USA). Given the exploratory nature of our study, we opted not to use the Holm-Bonferroni (or other) correction to control the family-wise error rate. An alpha level of $P \leq 0.050$ was considered statistically significant for all analyses.

Results

No outliers were identified, and all data were confirmed to be normally distributed. Table 1 presents the reliability results across sessions for each variable in our study. There were no systematic differences ($P = 0.052$ - 0.966 , $d = 0.010$ - 0.463) between sessions for any of the variables. Reliability analysis revealed that handgrip strength variables, sit-to-stand peak power, and seated medicine ball throw distance were highly consistent between sessions, with ICCs ranging between 0.930 and 0.978 and CV values between 2.7 and 8.0%.

There were significant correlations between sit-to-stand peak power and handgrip peak force ($r = 0.485$, 95% CI = 0.054-0.764, $P = 0.030$), peak RFD ($r = 0.498$, 95% CI = 0.071-0.771, $P = 0.026$), RFD100 ($r = 0.495$, 95% CI = 0.067-0.769, $P = 0.027$), and RFD200 ($r = 0.533$, 95% CI = 0.118-0.789, $P = 0.015$). There were also significant correlations between seated medicine ball throw distance and handgrip peak force ($r = 0.634$, 95% CI = 0.266-0.841, $P = 0.003$), peak RFD ($r = 0.470$, 95% CI = 0.035-0.755, $P = 0.037$), RFD100 ($r = 0.457$, 95% CI = 0.018-0.748, $P = 0.043$), and RFD200 ($r = 0.605$, 95% CI = 0.222-0.826, $P = 0.005$). The scatterplots for these correlations are shown in Figures 3 and 4.

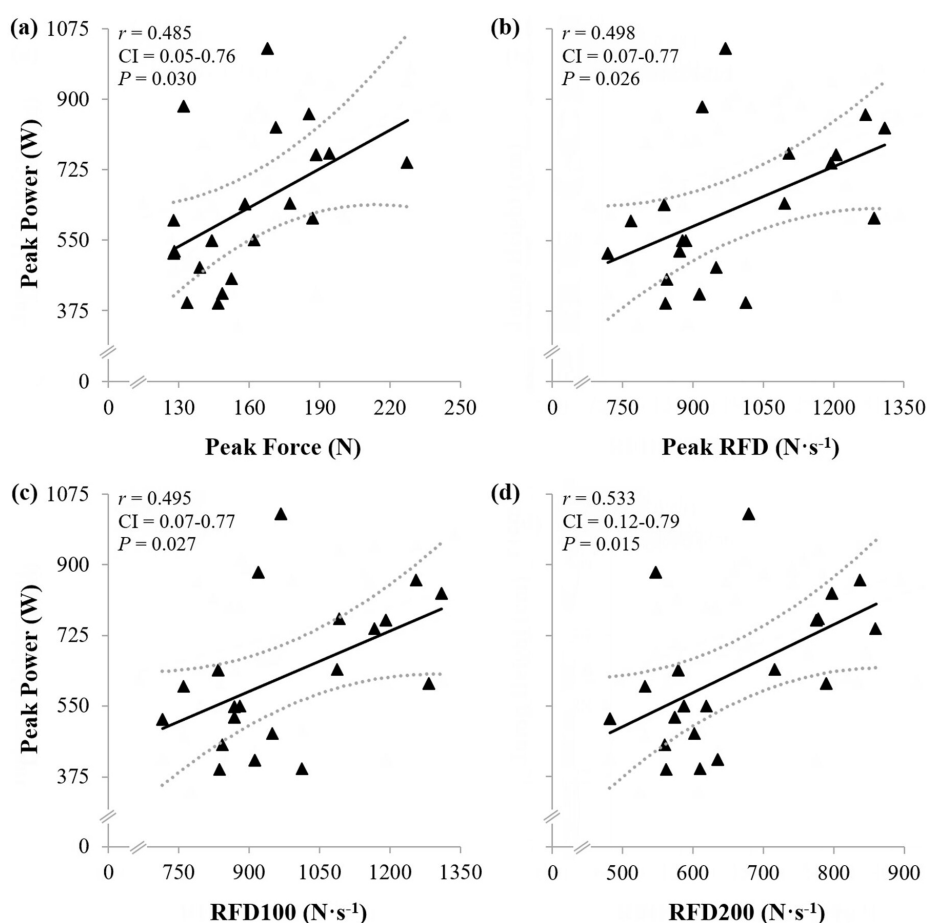


Figure 3. Correlations between sit-to-stand peak power and handgrip a) peak force, b) peak RFD, c) RFD100, and d) RFD200. Individual data points are presented as well as the linear regression line (solid line) with 95% confidence intervals surrounding it (dotted lines, for illustration purposes only). Each graph includes the Pearson r , 95% CI, and P value. CI = confidence interval. RFD = rate of force development.

Discussion

We aimed to evaluate the reliability of handgrip strength measurements, sit-to-stand peak power, and seated medicine ball throw distance in older women. As a general rule, ICC values greater than 0.90 and CV values less than 10% indicate good reliability³¹. We found good reliability for each variable in our study, with ICCs of 0.930-0.978 and CV values of 2.7-8.0% (Table 1).

The ICC and CV values for handgrip peak force in our study were 0.978 and 2.7%, respectively (Table 1). Previous studies in older adults have also reported good reliability for handgrip peak force (ICC = 0.941-0.981, CV = 5.2-7.6%)^{11,18}. However, previous studies have reported inconsistent findings regarding the reliability of handgrip RFD. Specifically, Uygur et al.⁶ demonstrated good reliability for handgrip RFD (ICC = 0.930, CV =

7.6%), whereas Jenkins et al.¹ reported poorer reliability for this variable (ICC = 0.670, CV = 42.8%). Our findings, which revealed good reliability (ICC \geq 0.931, CV \leq 5.2%, Table 1), may differ from that of Jenkins et al.¹ because of discrepancies in the number of trials used to calculate RFD. The participants in the present study and those in the study by Jenkins et al.¹ performed three handgrip MVC trials during each testing session. Jenkins et al.¹ appears to have calculated RFD from the best trial instead of calculating it from the average of all three trials. It has been recommended that investigators collect multiple MVC trials and use the average of some or all MVCs for further data analysis to ensure strength variables, including RFD, are accurately obtained^{32,33}. Although further research is needed to compare RFD characteristics derived from varying numbers of trials, the use of averaged MVCs—as implemented in our investigation, could produce

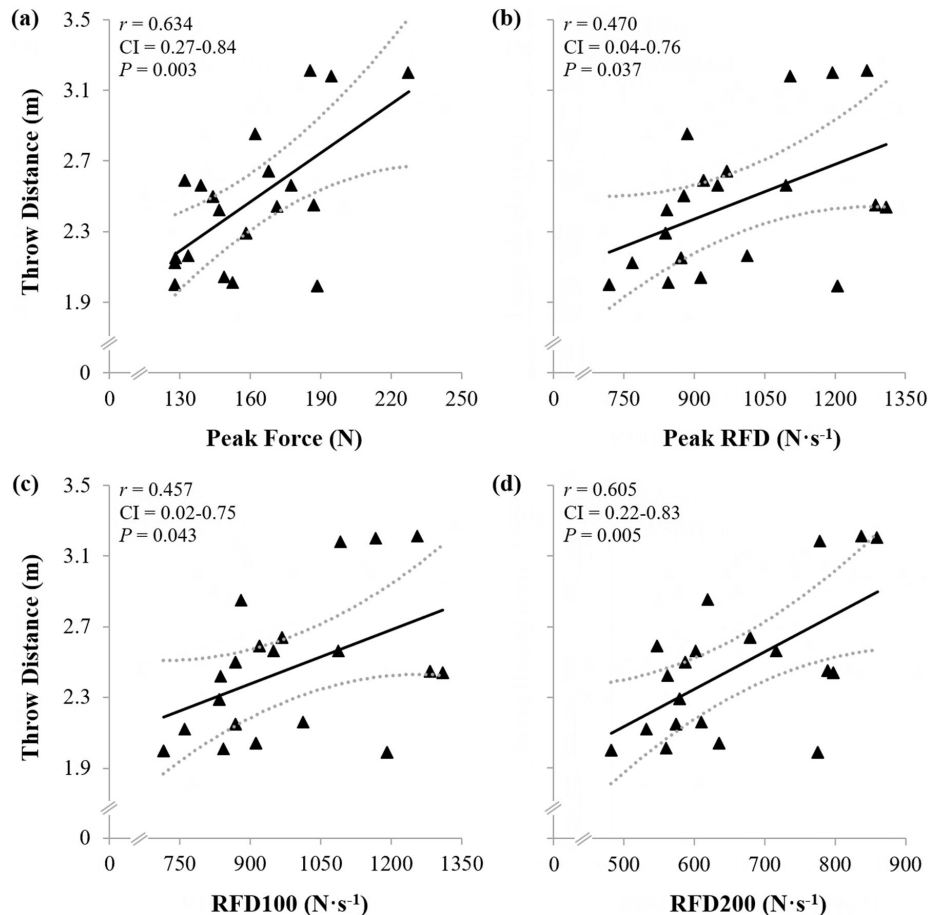


Figure 4. Correlations between seated medicine ball throw distance and handgrip a) peak force, b) peak RFD, c) RFD100, and d) RFD200. Individual data points are presented as well as the linear regression line (solid line) with 95% confidence intervals surrounding it (dotted lines, for illustration purposes only). Each graph includes the Pearson r , 95% CI, and P value. CI = confidence interval. RFD = rate of force development.

RFD variables that are both highly accurate and more consistent.

One of the reliability statistics reported in our investigation was the MD. The MD could be particularly valuable for practitioners seeking to establish if differences in handgrip strength characteristics are clinically meaningful⁷. Sisneros et al.⁹ reported that a group of older women, similar to those in the present study, had significantly lower handgrip RFD200 values than a group of young, college-aged women. The mean percent difference in handgrip RFD200 between these age groups was 15.0%. This value exceeded our MD of 14.5% (Table 1), suggesting a clinically meaningful difference that surpasses the margin of measurement error. While this represents only a single example, the MD values reported in this study may assist future researchers and practitioners in interpreting the clinical significance of differences in handgrip strength as a result of age, health status, and/or acute physical impairment.

Results from our study showed ICC and CV values of 0.930 and 8.0% for sit-to-stand peak power and 0.969 and 3.3% for seated medicine ball throw distance, respectively (Table 1). Similarly, previous studies in older adults have reported ICCs of 0.910-0.980 and CV or SEM% values of 2.5-9.9% for these same variables^{20,21,34}. Taken together, these findings provide support that sit-to-stand peak power and seated medicine ball throw distance are reliable measures for assessing the power performance capacities of older individuals.

The secondary aim of this study was to ascertain if handgrip strength measurements correlated with power-related performances during sit-to-stand and seated medicine ball throw tests. Handgrip strength has been used as an important index of whole-body strength^{1,35}, and thus, may be associated with upper- and lower-body performances. Previous studies have reported significant correlations between handgrip peak force and sit-to-stand

peak power and seated medicine ball thrown distance in middle-aged and older adults^{24,25}. In our investigation, handgrip peak force was significantly associated with sit-to-stand peak power and seated medicine ball throw distance in older women (Figures 3 and 4). These findings support the notion that handgrip strength and upper- and lower-body power performances are related to each other.

A novel aspect of the present study was the assessment of handgrip RFD. We found significant positive correlations between handgrip RFD measurements (i.e., peak RFD, RFD100, RFD200) and both sit-to-stand peak power and seated medicine ball throw distance (Figures 3 and 4). These correlations were akin to those observed between handgrip peak force and the same performance metrics. Together, these findings underscore the importance of both maximal and rapid strength, suggesting that handgrip peak force and RFD may serve as effective variables for estimating power-related performances. The capacity of these variables to estimate muscle power could have important implications. Specifically, the seated medicine ball throw and sit-to-stand tests are prominent assessments of upper- and lower-body power, respectively^{20,21}. These tests have been shown to be useful measures; however, they may be too difficult to perform for some older individuals, especially those with strength or mobility issues^{36,37}. Also, these tests could carry a potential risk due to participants dropping the medicine ball on their foot or losing their balance when rising from a chair^{38,39}. In contrast, handgrip strength variables are easy, safe, and practical measures of performance. They can be obtained from a seated position and have been used as a surrogate marker for multiple health outcomes in many older adults, including those with poor strength and mobility^{14,40}. These measurements are associated with muscle power and may therefore serve as a preferable alternative to medicine ball throws or sit-to-stand tests for certain populations, including healthy older women.

One limitation of this study was the relatively small sample size. A post-hoc sensitivity analysis indicated that, with $n = 20$, the minimum detectable correlation coefficient at 80% power and an alpha level of 0.05 was approximately $r = 0.50$. Our observed correlations ranged from $r = 0.46$ to 0.63, meaning that some fell below the threshold for adequate power. However, given the exploratory nature of this study, our goal was to identify potential relationships between variables that could inform future research. While we observed statistically significant correlations between handgrip strength and power-related performance measures, these findings should be interpreted with caution and confirmed in studies with larger sample sizes. Another limitation is the exclusive focus on healthy older women. While this can be considered a strength—since the results are not confounded by orthopedic limitations or neuromuscular disorders—we acknowledge that our findings may not be generalizable to other populations. The researcher, Ty B. Palmer (TBP), operated the Dynamo device during all testing sessions. Because TBP was solely responsible for data collection, assessor blinding to session

measurements was not feasible, which may introduce some potential for bias. However, this approach ensured consistent administration of the testing protocol across all participants and sessions, which may have contributed to the strong reliability observed in our study.

In summary, we found good ICCs and CVs for each variable in our investigation. We also observed positive correlations between handgrip strength measurements and both sit-to-stand peak power and seated medicine ball throw distance. These correlations suggest that handgrip peak force and RFD could be useful variables at estimating the upper- and lower-body muscle power capacities of older women. Given the reliability and prognostic value of such variables, clinicians and other practitioners may want to use handgrip strength measurements in their current test battery. These measurements may provide practitioners with an attractive evaluation tool for estimating the power performance capacities of older women in both laboratory and field-based settings. Further research is needed to assess whether handgrip strength measurements correlate with power-related performances in other populations, including older men and individuals with health conditions or disabilities.

Ethics approval

This study was approved by the Texas Tech University Institutional Review Board for human subject research (IRB #2023-315) and conducted in accordance with the Declaration of Helsinki (1964) and its later amendments.

Consent to participate

Written informed consent was obtained from all participants.

Authors' contributions

Alexandra L. Khartabil analyzed the data and wrote the manuscript. Ty B. Palmer revised the manuscript and collected the data. Both authors read and approved the final version of the manuscript.

Acknowledgements

Some of the information/results in this study were presented in preliminary form at the Texas Chapter of the American College of Sports Medicine Conference, 2025.

Ty B. Palmer, co-inventor of the Dynamo Torque Analyzer, calibrated the device and verified its proper functioning prior to and throughout all data collection sessions.

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