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Original Article

Can handgrip strength measurements predict postural balance performance in older women?

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Abstract

Objectives: The link between handgrip strength and postural balance in older adults is not well understood. This study aimed to examine the correlations between postural balance performance and handgrip peak force and rate of force development (RFD) measurements in older women. **Methods**: Twenty older women (67 ± 5 years) participated in this study. Handgrip contractions were used to assess peak force, peak RFD, and RFD at 0-100 (RFD100) and 0-200 (RFD200) ms. Postural balance was evaluated using a commercially designed balance testing device, which provides a measurement of static stability based on the sway index. **Results**: There were significant correlations between sway index and handgrip peak force (r = -0.497, P = 0.026), peak RFD (r = -0.552, P = 0.012), RFD100 (r = -0.539, P = 0.014), and RFD200 (r = -0.499, P = 0.025). Stepwise multiple regression analysis indicated that handgrip peak RFD was the single best predictor of sway index (R^2 = 0.305). The other variables, including peak force, did not add any unique variance to the stepwise prediction model. **Conclusion**: These findings suggest that handgrip strength, and in particular peak RFD, may be an effective parameter at predicting postural balance performance in older women.

Keywords: Contraction, Falls Risk, Peak Force, Rate of Force Development, Sway Index

Introduction

Age-related decreases in postural balance performance are commonly reported in older adults[1]. Decreases in postural balance have been associated with a higher incidence of falls and fall-related injuries[2], which may lead to an elevated risk of future disability and mortality. Postural sway measurements are often used to evaluate balance performance and can be obtained from devices like force platforms[3] and computerized balance testing systems[4,5]. Although these devices have been reported to be reliable tools[6,7], they are expensive and may not be readily available in clinical settings. Thus, the prospect of identifying physiological measurements from a less expensive device that can successfully predict postural sway may be advantageous in the testing and evaluation of balance performance in older populations.

Handgrip strength measurements, such as peak force and rate of force development (RFD), are typically assessed from the force signal produced during a maximal voluntary contraction (MVC) with the dominant hand[8] and do not require large or expensive equipment[3]. These measurements have been shown to be significantly associated with the strength capacities of the lower-body musculature[8,9]. Because lower-body strength is critical to postural balance[10], handgrip peak force and RFD may be related to the sway values produced during quiet standing. Previous studies investigating the correlation between handgrip peak force and postural balance performance in older adults have reported conflicting results, with some research reporting a significant correlation[11] and other research demonstrating no correlation between these variables[3,12]. Such discrepancies are likely due to the different handgrip testing devices used in each study. Moreover, because peak force takes greater than 300 ms to be achieved[13], it may not be the best measurement at characterizing the explosive actions required for balance-related tasks. When a disruption in balance occurs, rapid muscle actions and quick response times of less than 150 ms

Ty B. Palmer co-invented the Dynamo Torque Analyzer. The remaining authors declare no conflict of interest.

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are required to regain balance and maintain stability[14]. Rapid strength characteristics, which include handgrip RFD, have functional significance in fast and forceful muscle actions[15] and thus, may be better measurements than peak force at explaining the variance associated with postural balance and other physical performance parameters. Borges et al.[16] showed that handgrip RFD assessed over a short time period (200 ms) was a better measurement than peak force at predicting physical performance in older adults. However, since the performance data used in this study was limited to mobility, it remains unclear whether handgrip RFD is a better measurement than peak force at predicting postural sway.

Few studies have examined the importance of handgrip RFD as it relates to postural balance. Trajkov et al.[5] found predominantly non-significant correlations between handgrip peak RFD and postural balance performance in older adults. Although these findings do not support the capacity of handgrip RFD as a predictor of postural balance, it should be noted that Trajkov et al.[5] used a handgrip device that recorded force at a sampling frequency of 500 Hz. Research suggests that the force signal from a strength assessment device should be sampled at a high frequency of at least 1000 Hz to acquire accurate measurements of RFD[17]. If recording force data from a handgrip device at 1000 Hz improves the overall accuracy of RFD, then such measurements may correlate better with postural balance; however, further research is needed to test this hypothesis.

The Jamar dynamometer is a widely accepted device for measuring handgrip strength[18]. This device is easy to use[19]; however, due to its curved shaped handle, it has been criticized by previous research as being incapable of assessing the forces exerted with the fingertips during a contraction[20]. Also, the Jamar dynamometer only measures handgrip peak force[18]; it cannot measure handgrip RFD. Other devices, such as handheld strain gauges and force transducers, are able to calculate handgrip RFD characteristics[5,16]. However, such calculation requires extensive offline analysis with data processing software. To address these limitations, a novel strength testing device was developed called the Dynamo Torque Analyzer (Dynamo). The Dynamo consists of a load cell and a microcomputer. Previous studies have used this device to assess maximal and rapid torque production of the lower-body musculature[15,21]. Our laboratory has recently modified the Dynamo by attaching semi-cylindrical handles at either end of the load cell. With this modification, the Dynamo can now be used to assess handgrip peak force and RFD. Unlike previous handgrip devices, the Dynamo automatically calculates and displays peak force and multiple RFD measurements (i.e., peak RFD and RFD at 0-100 [RFD100] and 0-200 [RFD200] ms from contraction onset) immediately after a contraction. Consequently, it may be an attractive tool for evaluating handgrip strength in older adults. Moreover, it is important to note that previous studies investigating correlations between handgrip strength and balance-related tasks have only examined young and older men[8,22]. Additional research investigating handgrip strength measurements and balance performance capacities in older women is needed. Thus, the purpose of the present study was to examine the correlations between postural balance performance and handgrip peak force and RFD characteristics in older women.

Materials and methods

Participants

Before data collection, an a priori power analysis was performed for a correlational design. Using G*Power software (version 3.1.9.2; Heinrich Heine University, Düsseldorf, Germany) and effect sizes from relevant research[11], it was determined that 20 participants were needed to achieve a statistical power of 0.80 at an alpha level of 0.05. Thus, 20 older women (mean ± standard deviation [SD]; age = 67 ± 5 years; height = 164 ± 6 cm; body mass = 68 ± 11 kg) were recruited to participate in the present study. The participants were recruited from and tested at a community-based health and wellness facility. None of the participants reported any current or ongoing neuromuscular diseases or musculoskeletal injuries specific to the upper and lower extremities. Participants were considered recreationally-trained based on their self-reported levels of physical activity (5 ± 4 h•wk^{-1}). This study was approved by the university's institutional review board for human subject's research, and each participant signed and completed an informed consent document and health history questionnaire.

Experimental Design

The present study used a correlational research design to investigate the relationships between handgrip strength measurements and postural balance performance in older women. Each participant reported for testing on two different occasions, separated by 2-3 days. During the first visit, participants were familiarized with the testing procedures by performing several postural balance and handgrip MVC assessment trials. During the second visit, participants completed two postural balance assessments followed by three handgrip MVCs with the dominant hand. Hand dominance was self-reported prior to testing as the preferred hand for holding a pencil[23]. Of the 20 participants in our study, 18 were right-hand dominant.

Postural Balance Assessments

Postural balance assessments were performed using a BioSway Balance System (Biodex Medical Systems, Inc, Shirley, NY, USA), which provides a measurement of static stability based on the sway index, determined as the postural sway from the center point of the platform on which the participant stood. For all testing, participants removed their footwear and stood on the platform of the balance system with feet shoulder width apart and hands positioned on the hips. For each assessment, a custom protocol was used, in which participants were instructed to look "straight ahead" and stand "as still as possible" for 20 s on the platform

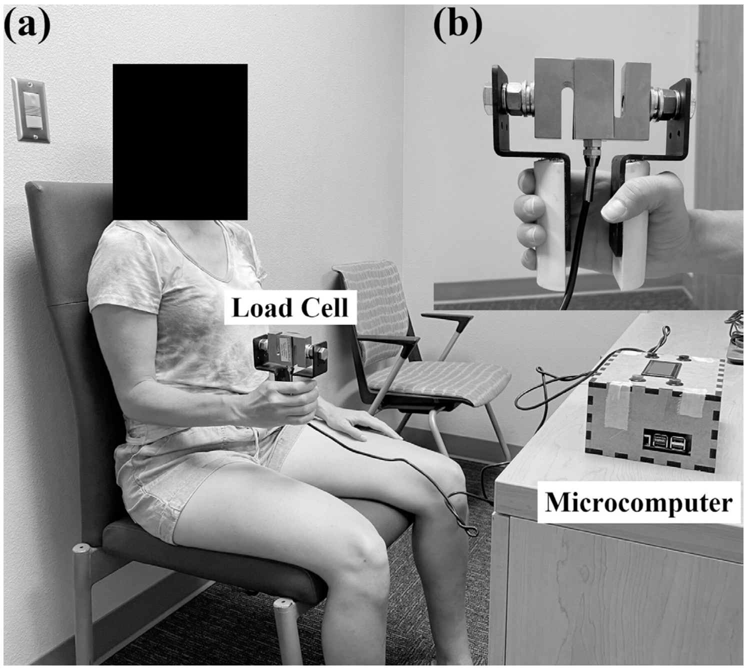

Figure 1. (a) A participant performing a handgrip maximal voluntary contraction using the Dynamo. The Dynamo consists of two functional components: a load cell and a microcomputer. The load cell was equipped with two semi-cylindrical handles for gripping. (b) An enlarged picture of the handles attached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

surface, which was kept locked in a static stability position[4]. Calculation of the sway index involved recording the position of each participant's foot using the coordinates on the platform's grid and entering it into the balance system computer, and subsequently deriving the sway index value which was calculated and displayed by the computer at the conclusion of each assessment. Two balance assessments were performed with 10 s of rest between trials, and the lower sway index value (i.e., lower value indicates greater stability) of the two trials was used for subsequent analysis[6].

Handgrip Contractions

Handgrip contractions were performed with the dominant hand using a Dynamo Torque Analyzer (Figure 1). The Dynamo consisted of a microcomputer and a load cell that was equipped with two semi-cylindrical handles for gripping. These handles were attached at either end of the load cell and positioned approximately 4.8 cm apart in accordance with the procedures described by Barbosa et al.[19]. For all testing, participants sat in a chair with their shoulder adducted, elbow flexed at 90°, and forearm and wrist held in a neutral position[24]. Following three submaximal (warm-up) handgrip muscle actions, participants completed three handgrip MVCs with one minute of recovery between each trial. For all MVCs, participants were instructed to squeeze the handles of the load cell "as hard and fast as possible" for a total of 3-4 s,

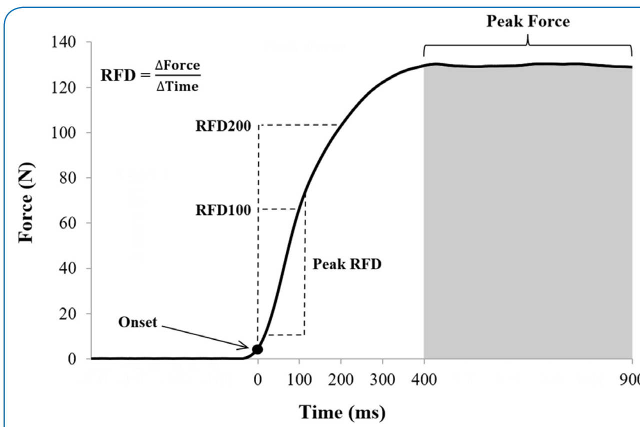

Figure 2. Example of a processed force signal derived from the Dynamo during a handgrip maximal voluntary contraction. The force signal produced during the contraction was used to measure handgrip peak force and rate of force development (RFD) characteristics. Peak force was calculated as the highest mean 500 ms epoch. RFD was calculated as the linear slope of the force signal (Δforce/Δtime) 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, SD, 95% confidence interval (CI), and range for each variable in the study.

Variable	Mean	SD	95% CI	Range
Handgrip				
Peak Force (N)	158.75	27.24	146.00-171.50	122.56-210.43
Peak RFD (N•s^{-1})	926.06	191.18	836.58-1015.53	639.00-1251.41
RFD100 (N•s^{-1})	893.84	214.92	793.25-994.42	514.75-1228.62
RFD200 (N•s^{-1})	630.72	125.80	571.85-689.60	473.32-865.93
Sway Index	0.24	0.05	0.21-0.27	0.15-0.35

RFD = rate of force development

Table 2. Stepwise multiple regression analysis for the prediction of sway index.

Model	*B*	SE_B	*β*
Constant	0.3864	0.0533	-0.552*
Handgrip Peak RFD	-0.0002	0.0001	

*B = unstandardized beta; SE_B = standard error for the unstandardized beta; β = standardized beta; RFD = rate of force development. *R^2 = 0.305, P = 0.012.*

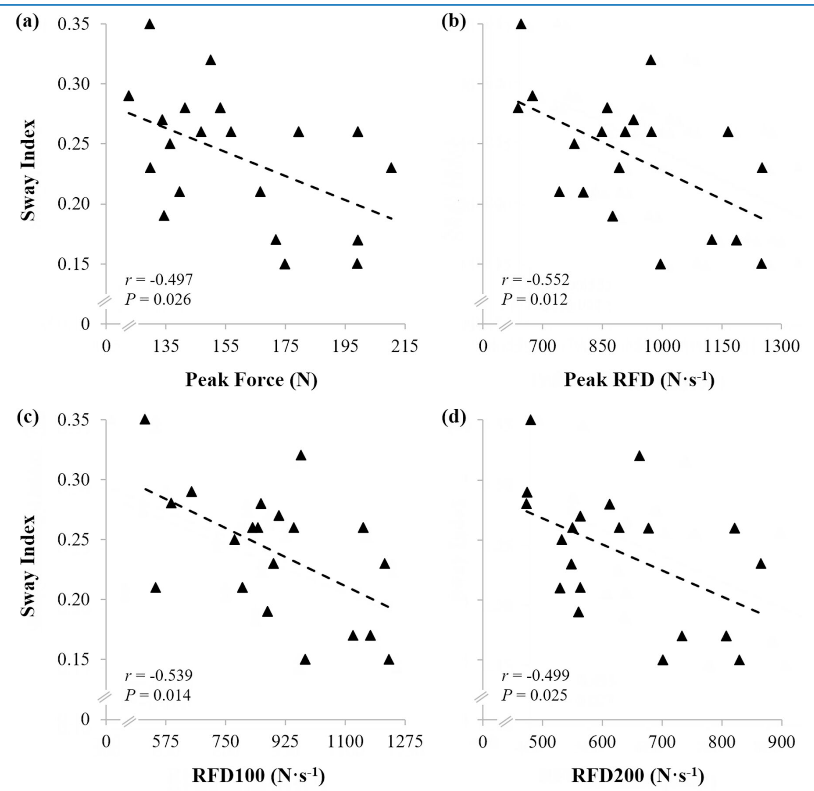

Figure 3. Relationships between sway index and handgrip (a) peak force, (b) peak RFD, (c) RFD100, and (d) RFD200. RFD = rate of force development.

and strong verbal encouragement was given throughout the duration of the contraction[8].

For the MVC assessments, the Dynamo's microcomputer was programmed by the primary investigator to record force from the load cell in Newtons (N). During each MVC, the scaled force signal from the load cell was sampled, interpolated to 1000 Hz, and processed automatically by the Dynamo. The force signal was low-pass filtered with a zero-phase lag, fourth-order Butterworth filter at a cutoff frequency of 10 Hz[25]. At the start of each MVC, participants applied a light steady baseline force to the handles of the load cell. This baseline force was subtracted from the signal so that the new baseline force value was 0 N[26]. All subsequent analyses were conducted on the filtered and baseline-corrected force signal.

Peak force was calculated as the highest mean 500 ms epoch (Figure 2). RFD100 and RFD200 were calculated as the linear slope of the force signal at time intervals of 0-100 and 0-200 ms from contraction onset, respectively (Figure 2). 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 (Figure 2). The contraction onset for the Dynamo was set at 5 N[27]. Peak force, peak RFD, RFD100, and RFD200 were calculated and displayed by the Dynamo at the conclusion of each MVC. Of the three MVCs performed, the MVC with the highest peak RFD value was selected for analysis[25].

Statistical Analyses

We inspected data for normality using the Shapiro-Wilk test. Outliers were defined as values that exceeded 2.2 times the interquartile range away from the first and third quartiles[28]. Pearson correlation coefficients (*r*) were calculated to examine the relationships between sway index and handgrip peak force and RFD variables. Multiple regression analysis (stepwise model) was used to determine which variables were the best predictors of sway index. All statistical analyses were conducted using SPSS software (Version 26, IBM Corp, Armonk, NY), and an alpha level of $P \leq 0.050$ was used to determine statistical significance.

Results

No outliers were identified, and all data were confirmed as being normally distributed. Table 1 shows the mean, SD, confidence interval, and range for each variable in the study. There were significant negative correlations between sway index and handgrip peak force ($r = -0.497$, $P = 0.026$), peak RFD ($r = -0.552$, $P = 0.012$), RFD100 ($r = -0.539$, $P = 0.014$), and RFD200 ($r = -0.499$, $P = 0.025$) (Figure 3). For the multiple regression analysis, handgrip peak force, peak RFD, RFD100, and RFD200 were entered as predictor variables into the stepwise model. The model revealed that handgrip peak RFD was the single best predictor of sway index ($R^2 = 0.305$, $P = 0.012$, Table 2), with the other variables explaining no further unique variance.

Discussion

Handgrip strength has been shown to be an effective parameter at characterizing the force production capabilities of numerous muscle groups, including those of the lower extremities[9]. Because lower extremity force production is critical to postural stability[10], handgrip strength measurements may be related to the sway index values produced during quiet standing. A lower index value indicates less postural sway and therefore, better balance. In this study, handgrip peak force and RFD variables were negatively correlated with sway index values in older women (Figure 3). Although correlations cannot determine cause-and-effect relationships, these findings suggest that greater handgrip strength is associated with better postural stability. Previous research has reported similar findings, showing significant correlations in older adults between handgrip peak force and postural balance performance[11]. In contrast, other studies investigating older adults have reported no correlations between these variables[3,12]. The discrepancies between these findings and those reported by the present study may be due to differences in testing procedures, the physical activity levels of the participants, and/or the device used to assess handgrip strength. The present study assessed handgrip strength using the Dynamo, which consisted of a load cell and a microcomputer, whereas the previous studies evaluated handgrip strength using a Jamar dynamometer[3,12]. The Jamar dynamometer uses a handle with a curved-shaped surface at the grip center[18]. Although this handle is easy to grasp, it has been criticized by previous research as being incapable of assessing the forces exerted with the fingertips during a contraction[20]. This limitation may lead to an underestimation of force production that could attenuate the correlation between handgrip strength and postural balance performance. Alternatively, the Dynamo device in the present study used a load cell with two semi-cylindrical handles for gripping. Cylindrical handles can account for the forces exerted by the fingertips[18,20], which may improve the overall assessment of handgrip strength and its relationship with postural sway.

Most studies evaluating handgrip strength only measure peak force[9,12,23]. A novel aspect of the present study was the assessment of handgrip RFD. We found significant negative correlations between sway index and handgrip peak RFD, RFD100, and RFD200. Moreover, multiple regression analysis indicated that handgrip peak RFD was the single best predictor of sway index ($R^2 = 0.305$, Table 2). The other variables, including peak force, did not add any unique variance to the stepwise prediction model. Collectively, these findings highlight the importance of rapid strength and suggest that handgrip peak RFD may be a better variable than peak force at predicting postural balance performance in older adults. Previous authors investigating balance as a function of age have reported substantial decreases in the postural stability of older individuals[1]. During normal standing, an older person may experience a disruption in balance due to age-related impairments in their sensory[29], nervous[2], and/or musculoskeletal[30] systems. When a disruption in balance occurs, rapid muscle actions and quick response times of less than 150 ms are required to regain balance and maintain stability[14]. Because the time required to achieve peak force is typically greater than 300 ms[13], rapid strength characteristics (0-200 ms) may be more functionally relevant than peak force for balance-related tasks in older adults. Thus, the possibility of greater functional relevance between rapid strength and postural balance performance may explain why a larger portion of the variance in sway index could be accounted for in the present study by handgrip peak RFD.

A recent study by Trajkov et al.[5] found predominantly non-significant correlations between handgrip peak RFD and postural balance parameters in older adults, which is inconsistent with the present findings. However, unlike the present study which obtained RFD values from the Dynamo, these authors measured peak RFD from a sliding device with a built-in strain gauge[5]. Moreover, the sliding device used by the previous authors[5] recorded force at a sampling frequency of 500 Hz instead of 1000 or 2000 Hz which represents the sampling frequencies of choice for most handgrip MVC assessments[8,16,31]. According to Maffiuletti et al.[17], the force signal from a strength assessment device should be sampled at a high frequency of at least 1000 Hz to acquire accurate measurements of RFD. Although future studies are needed to compare RFD characteristics derived from force signals sampled at different frequencies, it is possible that recording force data from a handgrip device at 1000 Hz, which was the sampling frequency used by the Dynamo in the present study, may yield RFD values that are more closely associated with postural balance and other physical performance parameters.

The Jamar dynamometer can measure handgrip peak force[18], but it cannot measure RFD. Other devices, such as handheld strain gauges and force transducers, are able to calculate handgrip RFD characteristics[5,16]. However, to calculate RFD with these devices, offline analysis of the force signal using data processing software is required. Because analyzing the force signal offline can be a time-consuming task, this method of RFD calculation may not be feasible in certain research or clinical situations where rapid data analysis is required for immediate RFD results[21]. In contrast, the Dynamo device used in our study automatically calculates and displays multiple RFD parameters immediately after a contraction. To our knowledge, the Dynamo is the first device capable of calculating and displaying real-time measurements of RFD. The present findings provide support that handgrip RFD measurements from the Dynamo may be particularly useful at predicting postural balance performance in older women. Given the potential importance of rapid strength to balance-related tasks, clinicians and other practitioners may want to consider using Dynamo measurements of handgrip RFD in their current test battery. These measurements may provide practitioners with an additional evaluation tool to help in identifying individuals with poor postural balance. Because loss of balance is known to be a major cause of falls during physical activity[32], Dynamo handgrip RFD measurements may also have important and promising implications for the assessment and prediction of falls risk in older adults.

In summary, this investigation showed significant correlations between sway index and handgrip peak force, peak RFD, RFD100, and RFD200 (Figure 3). These findings provide support that handgrip strength measurements are related to the sway values produced during quiet standing. In this study, multiple regression analysis indicated that handgrip peak RFD was the single best predictor of sway index (Table 2). The other variables, including peak force, did not add any unique variance to the stepwise prediction model. Taken together, these findings highlight the importance of rapid strength and suggest that handgrip peak RFD may be a better parameter than peak force at explaining the variance associated with postural balance in older adults. A unique feature of the present study was the Dynamo. The ability of the Dynamo to provide real-time measurements of handgrip RFD that are associated with postural sway may make it an attractive evaluation tool for purposes of predicting the balance performance capacities of older adults in both laboratory and field-based settings.

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