

## Short Communication

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# Evaluating Additional Aspects of Muscle Function with a Digital Handgrip Dynamometer and Accelerometer for Cognitive Functioning in Older Adults: A Pilot Study

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Accepted 11 November 2020

**Abstract.** Handgrip dynamometers are used to assess handgrip strength (HGS), and low HGS is linked to poor cognitive function. Although HGS is a reliable measure of muscle function, it is only measuring maximal grip force. Other aspects of muscle function such as force control, fatigability, and steadiness are unaccounted for in current HGS protocols. This pilot study sought to determine the role of maximal HGS, submaximal HGS force control, HGS fatigability, and HGS neuromuscular steadiness on cognitive function in older adults. Our findings indicate that these additional HGS measurements could factor into detecting poorer cognitive functioning, while also evolving HGS protocols.

**Keywords:** Aging, geriatrics, geriatric assessment, mental status and dementia tests, muscle strength, muscle weakness, nervous system diseases

## INTRODUCTION

Handgrip dynamometers are used as part of a convenient procedure for characterizing strength capacity [1, 2]. Declines in handgrip strength (HGS) have

been shown to be associated with cognitive impairment [3, 4]. Although HGS is a clinically-viable screening tool for health conditions related to poor muscle function, HGS has undergone scrutiny for being a proxy assessment of overall strength [5]. For example, the prognostic value of HGS is limited because it is only measuring a maximal grip force task on a single hand [6]. Thus, there is a growing recognition to evolve HGS testing methodologies [6, 7]. New assessments of muscle function that maintain the

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feasibility of HGS, but also diversify measurements should be identified for improving the predictive utility of dynamometers.

Measures of HGS are characterized as a maximal isometric grip force task [8]. Muscle function, however, includes other aspects such as fatigability, force control, and neuromuscular steadiness [9, 10]. Therefore, being that HGS is only measuring maximal force, other critical components of muscle function are overlooked. Examining additional characteristics of muscle function, as part of HGS assessments, will not only help to maintain feasibility in HGS measurements, but also provide novel insights into improving the prognostic value of handgrip dynamometers for geriatric health conditions such as cognitive impairment. This pilot study sought to determine the role of maximal HGS, submaximal HGS force control, HGS fatigability, and HGS neuromuscular steadiness on cognitive function in older adults.

## MATERIALS AND METHODS

### *Participants*

The study took place in the internal medicine unit at a clinic in Fargo, ND. Participants were recruited through flyers, word-of-mouth, and physician referrals. Individuals had to be aged  $\geq 65$ -years, read and speak the English language (for consent purposes), complete HGS testing on either hand without severe pain in the hands, arthritis, or a surgical procedure, and not be living with a severe cognitive impairment. Of the 20 persons that completed a pre-consent screening questionnaire, 5 were unable to continue in the study because they did not meet study criteria, and 2 did not engage in data collections before study closure due to the COVID-19 pandemic. The remaining 13 participants completed a descriptive questionnaire after providing written informed consent to participate in the study. Protocols were approved by the Sanford Health Institutional Review Board (STUDY00001816).

### *Cognitive function*

The Montreal Cognitive Assessment (MoCA) evaluated cognitive functioning [11]. Briefly, the MoCA is a well-validated screening tool for distinguishing normal cognition from cognitive impairment [11]. A trained interviewer administered the MoCA. Scores ranged from 0–30 and those with scores  $\leq 25$  were considered as having a cognitive impairment [12].

### *Handgrip strength measurements*

All HGS measurements were ascertained with a Biopac handgrip dynamometer and Student Lab software (Biopac; Goleta, CA). HGS data were collected using four different protocols: maximal HGS, radial and ulnar digit strength, submaximal HGS control, and HGS fatigue (details are described in each subsection below). Trained interviewers explained all HGS protocols and participants completed a practice trial. The hand in which HGS testing started was randomized. For all trials, participants were seated with their shoulders adducted and neutrally rotated, elbow flexed at 90-degrees, and forearm in a neutral position. Two trials for each HGS test were collected on each hand with verbal encouragement from interviewers and at least 30-seconds of rest between trials. Time stamps were also recorded for the beginning and end of each trial because data were collected digitally with the dynamometer.

### *Maximal handgrip strength*

Participants squeezed the dynamometer with maximal effort before releasing the contractions. The single highest HGS value on either hand was included in the analyses.

### *Radial and ulnar digit strength*

A maximal HGS test was performed on the radial (digits 2 and 3) and ulnar digits (digits 4 and 5). Specifically, participants squeezed the dynamometer with only the radial and ulnar digits at maximal effort before releasing the contractions. The order in which the radial or ulnar digits squeezed the dynamometer was randomized.

### *Submaximal control*

A 25% submaximal value was calculated from the maximum HGS recorded for each hand. Participants were asked to squeeze the dynamometer and maintain the 25% submaximal target grip force, as steady as possible, for 10-seconds. Each participant was allowed to watch the computer screen wherein data were being digitally recorded for helping them maintain the 25% submaximal target as they squeezed the dynamometer. The coefficient of variation was determined over the middle 8-second time period [13]. The best performing submaximal HGS control value was included in the analyses.

Table 1  
Descriptive characteristics of the participants

Variables	Overall (n = 13)	Cognitively Intact (n = 9)	Cognitive Impairment (n = 4)
Age (y)	70.9 ± 4.0	69.6 ± 2.3	73.7 ± 5.8
Female (n (%))	7 (53.9)	5 (55.6)	2 (50.0)
Non-Hispanic White (n (%))	13 (100)	9 (100)	4 (100)
Married (n (%))	10 (76.9)	8 (88.9)	2 (50.0)
Completed graduate degree (n (%))	4 (30.8)	3 (33.3)	1 (25.0)
Retired (n (%))	9 (69.2)	7 (77.8)	2 (50.0)
Standing height (cm)	171.0 ± 10.4	170.3 ± 9.4	172.5 ± 14.3
Body mass (kg)	81.1 ± 21.0	75.2 ± 17.8	94.3 ± 24.0
Body mass index (kg/m <sup>2</sup> )	27.4 ± 4.8	25.7 ± 4.1	31.4 ± 4.4
Self-reported diabetes diagnosis (n (%))	2 (15.4)	0 (0.0)	2 (50.0)
Self-reported diagnosed additional morbidities (n (%))	10 (76.9)	7 (77.8)	3 (75.0)
Montreal Cognitive Assessment Score	26.3 ± 2.2	27.6 ± 1.2	23.5 ± 0.5

Additional morbidities included hypertension, cancer (excluding minor skin cancers), lung disease, heart condition, stroke, psychiatric problems, or arthritis.

Table 2  
Differences in handgrip strength measurements by cognitive functioning status

Variables	Cognitively Intact (n = 9)	Cognitive Impairment (n = 4)	p	Cohen's d
Maximal Handgrip Strength (kg)	22.2 ± 4.8	23.7 ± 12.6	0.75	0.17
Submaximal handgrip strength force control (CV)	21.1 ± 4.2	23.6 ± 4.2	0.36	0.49
Handgrip strength fatigue (fatigability index)	16.9 ± 8.2	15.1 ± 4.2	0.68	0.22
Maximal handgrip strength steadiness (VM)	3.6 ± 5.1	16.1 ± 23.2	0.36	0.77
Ulnar digits grip steadiness (VM)	7.3 ± 8.1	22.6 ± 25.5	0.31	0.80
Radial digits grip steadiness (VM)	4.3 ± 4.6	17.0 ± 29.3	0.45	0.66
Handgrip strength fatigue steadiness (VM)	0.46 ± 0.60	0.52 ± 0.56	0.87	0.08

Results are presented as mean ± standard deviation where indicated. No VM was detected for submaximal handgrip strength force control steadiness. Cognitively Intact, Montreal Cognitive Assessment ≥26; Cognitive Impairment, Montreal Cognitive Assessment <26. CV, coefficient of variation; VM, vector magnitude.

Table 3  
Correlations between each handgrip strength measurement and cognitive functioning

Variables	Montreal Cognitive Assessment Score	
	r	p
Maximal handgrip strength	-0.03	0.91
Submaximal handgrip strength force control	-0.32	0.27
Handgrip strength fatigue	0.22	0.46
Maximal handgrip strength steadiness	-0.40	0.16
Ulnar digits grip steadiness	-0.39	0.17
Radial digits grip steadiness	-0.26	0.37
Handgrip strength fatigue steadiness	-0.28	0.33

The r-value represents the correlation coefficient. No vector magnitude was detected for submaximal handgrip strength force control steadiness.

### Fatigability

Participants squeezed the dynamometer at maximal effort for as long as possible. Grip force was collected beginning when the dynamometer was first squeezed until the participant voluntarily released their grip on the dynamometer. A corresponding grip force curve was created from the collected data and HGS fatigue was determined from the fatigability index equation [14]. The lowest fatigability index, which represents lower fatigue, on either hand was included in the analyses.

### Neuromuscular steadiness

An ActiGraph GT3X-BT accelerometer (ActiGraph; Pensacola, FL) was attached to the top of the dynamometer for measuring neuromuscular hand steadiness during all HGS tests. ActiLife software (ActiGraph) was used to initialize the accelerometer at 60 Hz and process accelerometer data. Data were stored in 1-second epochs. The specific beginning and end times of every HGS measurement were recorded to coincide with the time stamps from each HGS measure. Vector magnitude was averaged for

the duration of each HGS measurement included in the analyses.

### Statistical analysis

All analyses were conducted with SAS 9.4 software (SAS Institute; Cary, NC). Independent *t*-tests analyzed differences in the following HGS measurements for those who were cognitively intact and impaired: maximal HGS, submaximal HGS force control, HGS fatigue, and steadiness during maximal HGS, ulnar digit strength, radial digit strength, submaximal force control and HGS fatigue. Cohen's *d* (adjusted for smaller sample sizes) determined the effect sizes between the HGS measurements for the cognitively intact and impaired groups [15]. Pearson correlations evaluated the relationships between the HGS measurements and MoCA scores. As a supplementary analysis, Mann-Whitney U tests also analyzed differences in the HGS measurements for those who were cognitively intact and impaired. Ulnar and radial digit strength were not analyzed. An alpha level of 0.05 was used for all analyses.

## RESULTS

The descriptive characteristics of the participants are shown in Table 1. Overall, the 13 participants were aged  $70.9 \pm 4.0$  years, and 4 participants (30.8%) were considered as having a cognitive impairment. Table 2 reveals the differences for each HGS measurement by cognitive functioning status, and Cohen's *d* values. Although there were no statistically significant differences for the HGS measures between cognitive functioning groups, those with a cognitive impairment generally had poorer mean scores on nearly all HGS measurements. Table 3 presents correlations for the HGS measurements and MoCA scores. There was a non-significant moderate negative correlation for HGS steadiness ( $r = -0.40$ ), ulnar digit steadiness ( $r = -0.39$ ), and submaximal HGS force control ( $r = -0.32$ ) on MoCA scores. Supplementary Table 1 shows additional differences for each HGS measurement by cognitive functioning status.

## DISCUSSION

This pilot study found that a signal may exist for some of the additional HGS measurements and cognitive functioning. Although low HGS has been shown to be associated with cognitive impairment [3, 4], other aspects of muscle function may also factor

into cognitive functioning. As adults age, the cognitive demand for completing motor tasks increases [16]. Hand dexterity, which is partially mediated by the nervous system, is an essential determinant for grip-related tasks [17]. Reduced hand steadiness is also associated with decreased strength in aging adults [17], and unsteadiness during muscle contractions is associated with aspects such as fatigue [18]. While our findings revealed a non-significant weak-to-moderate correlation for the HGS measurements and MoCA scores, these findings align with those from another similar investigation that revealed such HGS measurements could be categorized as maximal strength, contractile steadiness, and functional strength, thereby supporting the use of a summary index or battery with the HGS measurements [19]. This rationale may help to explain our findings which showed a signal, albeit not statistically significant, existed for some of the additional HGS measurements we evaluated and cognitive functioning.

Some limitations should be noted. Data collections for our study were halted due to the COVID-19 pandemic. Thus, our sample size was lower than projected and may have factored into the null results. There was no vector magnitude for submaximal HGS force control steadiness because the measure was not vigorous enough to generate involuntary tremoring during HGS muscle contractions. Although the MoCA is a well-validated assessment of cognitive functioning [11], more detailed examinations of cognitive function may have provided additional insights into the role of the HGS measurements on cognitive status.

### Conclusions

This pilot study showed that a signal may exist for the additional HGS measurements and cognitive functioning in older adults. More research could be warranted to better determine if submaximal HGS force control, fatigability, steadiness, and other relevant characteristics of muscle function, independently or together with maximal HGS, improves the predictive utility of physical measurements with handgrip dynamometers for health conditions such as cognitive impairment, relative to maximal HGS alone.

## ACKNOWLEDGMENTS

Support for this project was provided by the Sanford Health-North Dakota State University

Collaborative Research Seed Grant Program wherein RM was the PI. LK and SJM are co-first authors.

## CONFLICT OF INTEREST

The authors have no conflict of interest to report.

## SUPPLEMENTARY MATERIAL

The supplementary material is available in the electronic version of this article: <https://dx.doi.org/10.3233/ADR200225>.

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