HHS Public Access

Author manuscript

Adv Biol (Weinh). Author manuscript; available in PMC 2025 October 01.

Published in final edited form as:

Adv Biol (Weinh). 2024 October ; 8(10): e2400068. doi:10.1002/adbi.202400068.

Relationship of Handgrip Strength and Asymmetry with Walking Ability in Older Adults with Excess Adiposity

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Abstract

Sarcopenia is characterized by low muscle mass and impaired strength and physical function. When coexisting with excess adiposity, it is termed sarcopenic obesity (SO). Handgrip strength (HGS) is used in the diagnosis of sarcopenia as it is a predictor of disability and mortality. Asymmetry in HGS, particularly ≥10% strength differences between hands, may indicate neuromuscular dysfunction observable prior to declines in maximal strength are detected. HGS asymmetry could be incorporated to identify those at risk of physical limitations and SO. This study compared HGS values and asymmetry in older adults with excess adiposity and evaluated their relationships with physical function. Baseline data from two previous pilot weight loss studies in 85 older adults with body mass index values ≥30 kg/m^2 were included with measures of body composition, walking speed, and chair stand ability. Sixty-three participants met the criteria for SO. HGS correlated to gait speed (r=0.22), distance walked (r=0.40), chair stand time for 5 repetitions (r=0.42) and during 30 s (r=0.31). HGS asymmetry was only correlated to gait speed (r=0.31) and there were no differences in physical function between those with and without asymmetry. Maximal HGS tests should continue to be used to screen for functional decline and disability.

Graphical Abstract

This study evaluates the relationships of handgrip strength (HGS) and asymmetry with physical function in older adults with sarcopenic obesity. It highlights the ability of HGS to identify functional limitations better than asymmetry but provides interesting insight into the possibility of combining strength and asymmetry measurements to further evaluate older adults with the greatest risks and provide early interventions.

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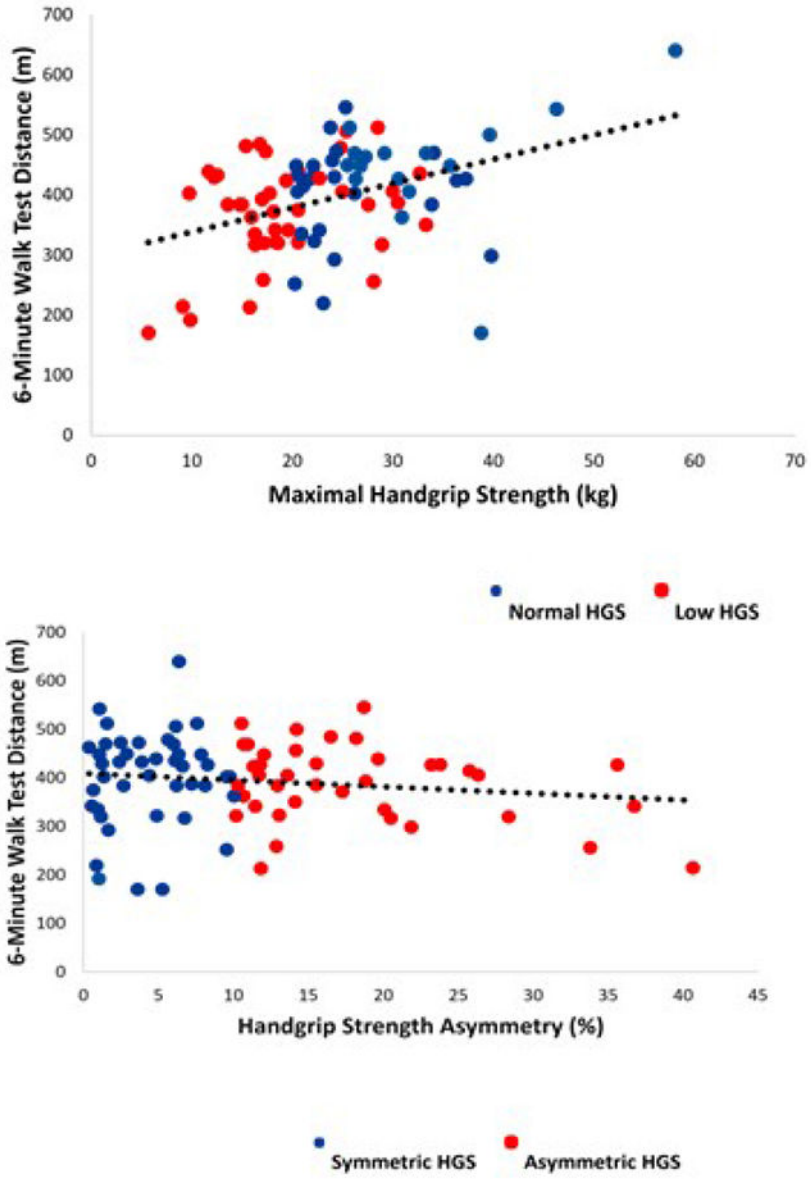
Conflicts of Interest Disclosure

The authors have no conflicts of interest to report.

Ethics Approval Statement

The Dartmouth-Hitchcock and University of North Carolina Institutional Review Boards approved the conduct of this study and all participants provided informed consent. The trials were registered on clinicaltrials.gov (NCT#03104205 and NCT#03104192).



INTRODUCTION

Aging is associated with changes in body composition favoring the deposition of adipose tissue and reductions in muscle mass leading to reductions in physical function and strength [1], [2]. These changes are collectively known as sarcopenia and are associated with disability, falls, hospitalizations, decreased quality of life, and increased mortality [3]. Sarcopenia can be exacerbated when excess adiposity, or obesity, is present [4] [5]. Sarcopenic obesity (SO), can have a synergistic effect in older adults leading to functional declines and greater risks of comorbidities, disability and loss of independence than either sarcopenia or obesity alone [5], [6], [7]. Older adults with excess adiposity are unique as they are regarded to be at a lower risk of sarcopenia due to having greater muscle mass and strength due to enhanced mechanical loading experienced in daily activities [1], however,

those diagnosed with SO possess high levels of intramuscular fat contributing to heightened muscle mass, but interfering with contractile function and force production, thereby limiting specific force [1].

While there are no existing universal diagnostic criteria for SO, the European Society for Clinical Nutrition and Metabolism (ESPEN) and the European Association for the Study of Obesity (EASO) currently advocate for a screening, diagnosis, and staging plan for the assessment of SO using parameters of altered skeletal muscle and body composition [5]. The skeletal muscle parameters include handgrip strength (HGS) or chair stand tests; common clinical assessments that have been shown to predict overall physical function. For example, time to complete five repetitions of the sit-to-stand test is also indicative of lower body strength [8] and times greater than 15 s suggest impaired skeletal muscle function placing older adults at risk of recurrent falls [9] and disability [10]. Low HGS is an indicator of skeletal muscle dysfunction that may represent the onset of disability before declines in physical performance, such as gait speed or distance one can walk, are observed [11].

HGS is typically measured in the right and left hands and the highest strength value of one hand is considered the maximum HGS [12]. It is agreed upon by multiple professional groups that HGS is an important variable in the identification of individuals with sarcopenia and SO [5], [13], [14], however, recent work suggests that the difference in HGS between hands, referred to as asymmetry, may indicate neuromuscular dysfunction prior to detectable decrements in maximal HGS [15]. This could then be a stronger diagnostic tool than maximal HGS [16]. HGS asymmetry is generally quantified as being greater than a 10% difference in HGS between hands, and has been associated with slow gait speed and poor balance [17], risk of falls and fractures [11], and disability [16]. However, this measurement is not part of the current screening tools for sarcopenia and SO and its relation to physical function in these older adults with low muscle mass and weakness is unknown.

Given that both maximal HGS and HGS asymmetry have been shown to be associated with declines in physical function [11], [17], it is important to explore how older adults, particularly those with excess adiposity and SO, are classified according to these measurements and how they differ in physical function and body composition. Therefore, the purpose of this study was to compare maximal HGS and asymmetry values in older adults with excess adiposity and to evaluate their relationships with physical function. It was hypothesized that HGS would be a stronger predictor of physical function than HGS asymmetry.

METHODS

Study Design

This study was a secondary analysis of two single-arm pilot studies consisting of diet and exercise interventions conducted from 2018-2020 [18], [19]. Older adults aged 65 years and older with a body mass index (BMI)≥30 kg/m^2 were recruited from a rural community in New Hampshire via posters, tear-off cards, and presentations from primary care clinics. The studies were approved by the institutional review boards of Dartmouth-Hitchcock

and the University of North Carolina at Chapel Hill, and the trials were registered at clinicaltrials.gov (NCT03104192 and NCT 03104205).

Participants

Selection criteria were reviewed by a research assistant through an electronic medical record review. Inclusion criteria consisted of English-speaking, community-dwelling participants, age ≥65 years with a BMI≥30kg/m^2. Participants were excluded if they had cognitive impairment, uncontrolled psychiatric illness; a history of bariatric surgery, life-threatening illness or receiving palliative/hospice services; participated in a previous weight-loss program; on medications promoting obesity (steroids, anti-psychotics); or had advanced cardiac, renal or liver dysfunction. Additional exclusion criteria consisted of weight-loss ≥5% in the past six months and a Callahan cognitive screen of <3 [20] . Data from 85 subjects were used in this study.

Measurements

Upon inclusion into the study, participants had their weight (A+D digital scale, Ann Arbor, MI) and height (Seca 216, Hamburg, Germany) measured and BMI was calculated. Waist circumference was measured at the level of the iliac crest and hip circumference was measured at the widest part of the buttocks. Waist-hip ratio was calculated.

Percent fat mass and skeletal muscle mass (SMM) were assessed using the Seca 514 mBCA 8-point bioelectrical impedance analyzer (Hamburg, Germany) according to the manufacturer's recommendations. Waist circumference was inputted into the machine and physical activity level across five levels was inputted based on the self-report of the participants. SMM was quantified as the sum of the segmental skeletal muscle mass of the right and left arms and legs and torso and was normalized to body mass (SMM/Weight) based on the recommendations from ESPEN and EASO [5].

The Function component of the Late-Life Function and Disability Instrument (LLFDI) was used to measure the self-reported functional status of participants ability to perform 32 daily activities across three dimensions: upper extremity, basic lower extremity, and advanced lower extremity. The questions are asked to determine the difficulty one has doing activities without the help of someone else and without the use of assistive devices. The rating scale ranges from 1 to 5 with the higher scores representing less difficulty performing the activities. The overall function raw score was the sum of the scores of the 32 items. Raw scores for the function domain were transformed to scaled scores ranging from 1 to 100, where higher numbers denoted higher levels of function [21] .

A trained research assistant assessed grip strength, gait speed, 6-minute walk tests, and chair stand tests. A digital Jamar hand dynamometer plus (Chicago, IL) was used to measure handgrip strength (HGS). The strength of each hand was then measured in alternating sequence three times with the arm extended at 90° and laid on a flat surface. Participants squeezed the device as tightly as possible for 15 seconds. Maximal HGS for each hand was used in the analysis and the dominant hand was determined to be the stronger hand. Grip strength has been shown to relate to upper and lower extremity strength, and can predict mobility disability (test-retest reliability, r=0.95 in healthy older adults) [22] .

Chair stand tests using a straight-backed chair without arms, with a seat pan height of 45 cm were utilized to assess lower body strength. Since data from two studies were compiled, participants completed either the 30 s chair stand test (n=33) or the sit-to-stand test (n=52). In the 30-s chair stand test, participants folded their arms across their chest and rose to a standing position and sat back down. This was repeated as many times as possible in 30 seconds and the number of repetitions completed was recorded. The test-retest reliability and validity against a leg strength test demonstrated intra-class correlations (ICC) of 0.88 and 0.75, respectively [23]. The sit-to-stand test was performed using the same chair. Participants folded their arms, rose to a standing position, and sat back down completing 5 repetitions as quickly as possible and the time to complete the 5 repetitions was recorded. The reliability and validity against a functional mobility test demonstrated intraclass correlations of 0.99 and 0.64, respectively [24]. In both tests, participants were not permitted to use their hands.

Gait speed was timed over a 5m walkway with 1.67 meters on either side of the timed markings to provide acceleration and deceleration phases. There were two meters on either side of the timed walkway. Participants were asked to walk at their usual walking pace. The research assistant timed using a stopwatch. The fastest time of three trials was recorded.

The six-minute walk test (6MWT) was conducted in accordance with the American Thoracic Society [25] to evaluate aerobic function. This test took place in a 70-foot-long corridor that was marked with cones every 10 feet. Participants were instructed to walk back and forth in the hallway with the goal to walk as far as possible for 6 minutes without running or jogging. If needed, they could rest standing up, but were instructed to resume walking as soon as possible. Distance walk during the 6MWT was recorded.

Screening and Diagnosis of Sarcopenic Obesity

Participants were initially screened for SO based on BMI values ≥30kg/m^2 and then were classified as SO based on skeletal muscle function (HGS, 30 s chair stand test, or 5 times sit-to-stand test) and body composition (% fat mass or SMM/W) according to ESPEN and EASO [5]. We used the following cut-off values for classifying participants as having SO not based on skeletal muscle function: HGS<35 and <20 kg for males and females, respectively, or below normative values across 5 years age ranges for the 30 s sit-to-stand test [26], or ≥17 s for the 5 times sit-to-stand test. Bioelectrical impedance defined percent fat mass cut-offs were >38% for females and >27% for males, and SMM/Weight were <37% for males and <28% for females to further classify SO based on body composition. To be classified as SO, participants had to possess values below the cut-off values in any tests of skeletal muscle function and either % fat mass or SMM/Weight [5].

Classification of Low Handgrip Strength and Asymmetry

Males were categorized as low HGS if <35 kg and normal HGS if ≥35kg. Females were categorized as low HGS if <20 kg and normal HGS if ≥20 kg [27]. Asymmetry was calculated as ((weaker HGS value – stronger HGS value)/stronger HGS value)*100% and those with asymmetry values >10% were categorized as asymmetric and those with values ≤10% were categorized as symmetric [28].

Statistical Analysis

Data was analyzed using IBM SPSS Statistics for Windows, Version 27.0 (Armonk, NY). Significance was set at $P<0.05$. Descriptive statistics (means ± standard deviation) were calculated on the whole sample, by biological sex, by HGS classification, and by asymmetry classification. The primary outcome variables assessed were gait speed and distance walked on the 6MWT, but exploratory analyses were performed on the time and repetitions from the chair stand tests since not all participants completed each test. Two-way analysis of variance (ANOVA) tests were performed to compare physical function between males and females based on HGS and asymmetry classifications. Significant interactions and main effects were followed up with one-way ANOVAs or independent t-tests to compare mean differences. Effect sizes using Cohen's *d* were determined and interpreted based on benchmarks from Cohen [29]: small (d = 0.20), medium (d = 0.50), and large (d = 0.80). Correlation analysis was performed to determine the relationship between gait speed and distance walked and HGS maximal values and magnitude of asymmetry while controlling for age, sex, and BMI. Minimal clinically important differences (MCID) were determined for the outcome variables among HGS and asymmetry classifications. The MCID for handgrip strength is 5 kg [22], 30 m for 6MWT [30], 0.10 to 0.20 $m{\cdot}s^{-1}$ in gait speed [31], 2.3 s in the 5-repetition sit-to-stand test [32], and 2 repetitions in the 30-s chair stand test [33].

RESULTS

Participants

All participants in the study met the body composition criteria to be diagnosed with SO as 100% of the sample had BMI ≥30kg/m^2, % body fat values ≥43% and ≥27%, and SMM/Weight values <28% and <37% for females and males, respectively. Forty-four females and nine males (62% of the sample) had waist-to-hip ratios above 0.88 and 1.02, respectively. Sixty-three participants (74% of the sample) met at least one of the criteria for low skeletal muscle function and therefore met the criteria to being classified as having SO (Table 1). Thirty-six of those participants with SO (7 males and 29 females) had low HGS, 29 (9 males and 20 females) fell below the cut-point for the 30 s chair stand test, and one female fell below the cut-point in the 5 times sit-to-stand test. Eleven females and two males (15% of the sample) fell below the cut-points in both HGS and one of the chair stand tests.

Males and females differed in anthropometric measurements of height, weight, waist-to-hip ratio, percent body fat and SMM/Weight and males had stronger grip strengths than females. They did not differ in the tests of physical function, although males self-reported higher upper extremity function and advanced lower extremity function (Table 1).

Classifications According to HGS and HGS Asymmetry

Forty-five participants had dominant HGS of the right arm (right=24.6±9.4; left=20.6±8.6 kg, $P=0.05$, $d=0.43$) and 40 participants were dominant in the left (right=21.8±8.5; left=23.3±9.3 kg, $P=0.44$, $d=0.17$). Fifty-one percent (n=43) of the sample were classified as having normal HGS and they did not differ in the magnitude of asymmetry between right and left dominant hands (Table 2). Forty-nine percent (n=42) of the sample were classified as having asymmetric HGS (Table 3). Overall, 24 participants (28%) did not have low HGS

or HGS asymmetry, 38 (45%) were classified as either low HGS or asymmetric, and 23 (27%) were classified as both low HGS and having HGS asymmetry.

Physical Function in Normal and Low HGS

There was no significant interaction between sex and HGS category for gait speed (P=0.18) and the main effect of sex was also not significant (P=0.77). There was a significant main effect for HGS category (P=0.05) as participants with normal HGS walked on average 0.15 $m{\cdot}s^{-1}$ faster than those with low HGS (P=0.03, d=0.65) which is within the range of a MCID for gait speed (Table 2). There was no significant interaction between sex and HGS category for distance walked in the 6MWT (P=0.47). The main effect of sex (P=0.11) and HGS category (P=0.08) for distance walked in the 6MWT were not statistically significant. Despite this, participants with normal HGS walked on average 43 meters farther than those with low HGS which exceeds the MCID. There were no differences between the HGS groups in self-reported physical function (Table 2). The low HGS group also demonstrated slower times on the 5-repetition sit-to-stand test (P=0.004, d=1.09) and less repetitions on the 30 s sit-to-stand test (P=0.04, d=0.59) for the low HGS group. Both differences exceeded the MCID (Table 2).

Physical Function in Symmetric and Asymmetric HGS

There was no significant interaction between sex and HGS asymmetry for gait speed (P=0.80) and the main effects of sex and HGS asymmetry category were also not significant (P=0.85 and P=0.21, respectively). The differences between the groups did not meet the MCID (Table 3). There was no significant interaction between sex and HGS asymmetry for distance walked in the 6MWT (P=0.29). The main effect of sex (P=0.17) and HGS asymmetry category (P=0.27) for distance walked in the 6MWT were not statistically significant and the difference of 12 meters did not reach the threshold of a MCID. There were no differences between the HGS asymmetry groups in self-reported physical function (Table 3). There were also no differences between asymmetry groups in the 5-repetition sit-to-stand test (P=0.93, d=0.03) and the 30 s sit-to-stand test (P=0.90, d=0.03) and these differences did not meet the MCID (Table 3).

Individuals who possessed both normal HGS and symmetric HGS had significantly faster gait speeds (1.22± 0.19 $m{\cdot}s^{-1}$; P=0.002) than those classified with both low HGS and HGS asymmetry (1.01± 0.26 $m{\cdot}s^{-1}$) and either low HGS or HGS asymmetry (1.02± 0.23 $m{\cdot}s^{-1}$). There were no differences in any other physical function variables (Table 4). Maximal HGS of the left and right arms were similar in those classified as no weakness or asymmetry and either weakness or asymmetry, but the combination group had the lowest strength values (Table 4).

Relationships Between Physical Function and HGS and HGS asymmetry

HGS was significantly correlated with gait speed (r=0.23, P=0.04, Figure 1A), distance walked in the 6MWT (r=0.40, P<0.001, Figure 1B), 5-repetition sit-to-stand (r=−0.30, P=0.04), and 30 s sit-to-stand (r=0.46, P<0.001). HGS asymmetry values was only correlated with gait speed (r=−0.29 (P<0.01, Figure 2A), but not distance walked in the

6MWT (r=−0.16, *P*=0.17, Figure 2B), 5-repetition sit-to-stand (r=−0.21, *P*=0.27), and 30 s sit-to-stand (r=−0.03, *P*=0.82).

DISCUSSION

This study found that maximal HGS in older adults with excess adiposity was related to physical function assessed via gait speed, distance walked, and ability to rise from a chair while HGS asymmetry was only significantly correlated to gait speed. Further, clinically meaningful differences in physical function were apparent when individuals were dichotomized into normal and low HGS based on the diagnosis criteria for SO, but none were evident when participants were divided into HGS symmetric and asymmetric groups.

Using the 10% threshold in asymmetry linked to sarcopenia, gait abnormalities, poor health, multimorbidity, and mortality [11], [15], [17], [28], [34], we did not find any differences in habitual gait speed, distance walked in 6-minutes, or ability to rise from a chair in older adults with excess adiposity with and without HGS asymmetry. Abdalla et al. [12] found that older adults (sarcopenia status was not reported) with greater HGS asymmetry had progressively slower habitual gait speeds and based on this, proposed sex-specific cut points for HGS asymmetry of 17.7% and 11.4% for males and females, respectively. When we applied the categorization based on the results of Abdalla et al. [12] to our sample, there were fewer older adults presenting with HGS asymmetry (39% vs 49%) than with the 10% cut point as expected, but there were still no differences in physical function between those with HGS asymmetry and symmetry. Pratt et al. [15] investigated HGS asymmetry in individuals with sarcopenia and found that those with HGS asymmetry had lower skeletal muscle mass and HGS strength values than those without asymmetry. They advocate for the use of HGS asymmetry, possibly at a cut point of 12.4%, as an additional tool to use in the diagnosis of sarcopenia as they determined a 2.67 greater odds for sarcopenia with HGS asymmetry compared to 1.83 and 1.79 greater odds for HGS weakness and low skeletal muscle mass, respectively [15]. Interestingly, the results of our study do not fully support these findings as maximal HGS, SMM/Weight, and all measures of physical function did not differ according to HGS asymmetry categorization in older adults with excess adiposity, perhaps because our participants already met a criterion for low skeletal muscle mass and low HGS. Therefore, the use of HGS asymmetry measurements alone to identify those at risk of physical function limitations in older adults with excess adiposity does not appear to be beneficial and therefore challenges the utility of asymmetry classifications in older adults with SO.

While HGS asymmetry alone was not associated with poor physical function, individuals that possessed both HGS weakness and asymmetry exhibited the slowest gait speed and trended, albeit insignificantly, towards more adverse anthropometric measures (Table 4) compared to those with no weakness and no asymmetry, as well as those with either HGS weakness or HGS asymmetry. This finding is in agreement with Collins et al. [16] who proposed that including measures of HGS asymmetry with maximal HGS concurrently, may improve identification of individuals with physical function limitations. Inclusion of HGS asymmetry should be feasible and convenient since the screenings already include measures of maximal HGS of each hand.

HGS asymmetry has been studied within large cohorts. but there is a paucity of research in individuals with excess adiposity and those that meet the diagnostic criteria of SO. The physiological mechanisms related to HGS asymmetry are not well known, but could arise from disuse of the non-dominant limb and the age-related changes in muscle mass and neural and motor system dysfunction that ensue [16]. Loss of muscle mass alone may not be enough to explain weakness in older adults, especially those with excess adiposity, as it may be more related to low muscle quality due to the infiltration of intramuscular adipose tissue [1]. Intramuscular adipose tissue has a direct, negative impact on muscle contraction [35] as it impedes neuromuscular activation [36] and central activation [37], and is markedly pro-inflammatory [38], and reduces force production. Further, HGS asymmetry may indicate neuromuscular denervation, as greater concentrations of neural cell adhesion molecule (NCAM) in individuals with asymmetry have been found [15].This too can lead to contractile impairments and decrements in force production. Based on the results of our study, it is plausible that HGS asymmetry may not be sensitive enough to detect these neuromuscular changes arising from the alterations in muscle composition in those with excess adiposity and SO. Since our data reveals that individuals with both HGS weakness and asymmetry appear to be trending towards poorer physical function and body composition, future research should work to establish the combined effect of HGS and asymmetry in screening individuals with SO as that may then aid in the implementation of more rigorous interventions to combat losses of physical function. Future research studies should also evaluate the physiological mechanisms related to muscle weakness and asymmetry in older adults with SO.

The evaluations of sex as a biological variable in human physiology is an essential topic [39] that was included in the present study. Despite our study including predominately females, the breakdown of participants classified as having low HGS and HGS asymmetry by sex were rather similar, while a greater percentage of females (88%) than males (64%) met the criteria for SO. As expected, males exhibited lower body fat and higher muscle mass values and had a stronger HGS than females, but the magnitude of asymmetry did not differ. Males and females also did not differ in measured physical function. Liu et al. [40], did not report sex differences in the longitudinal association of HGS and multimorbidity risk, but they did find that HGS asymmetry was more associated with the risk of multimorbidity in females only. They attributed these sex differences to females possibly relying more on central control to mediate force production compared to men and suggested that HGS asymmetry may be a useful measurement in women [40]. While our study did not indicate a propensity for more females to experience greater asymmetry levels than males, sex as a biological variable should be integrated into future studies.

This study is not without limitations. First, this study is a compilation of baseline data from two pilot studies evaluating the effects of weight loss interventions in older adults who were primarily Caucasian with excess adiposity and the sample size is smaller and less diverse than previous HGS studies that utilized epidemiological data. Additionally, the inconsistent chair stand tests employed in the study lack statistical power and limit the conclusions we can draw. Despite these weaknesses, our study provides evidence of clinical meaningful differences between individuals with low and normal HGS and suggests that HGS asymmetry alone may not be strongly associated with physical function. Future studies

should follow-up with larger and more diverse samples and evaluate strength and asymmetry before and after interventions to improve strength, body composition and physical function.

In conclusion, the measurement and classification of HGS in older adults with excess adiposity results in differences in body composition and skeletal muscle function that may identify those at risk of mobility limitations while the classification according HGS asymmetry did not. The combination of maximal HGS and HGS asymmetry provides preliminary evidence that simultaneous use may further delineate those at risk and possibly lead to early interventions. Therefore, it is recommended that maximal HGS tests continue to be used as a screening tool for functional decline and disability in older adults and the additional measure of HGS asymmetry used supplementary should be assessed.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

ACKNOWLEDGEMENTS

Dr. Batsis' research reported in this publication was supported in part by the National Institute on Aging under Award Number K23AG051681. Support was also provided by the Dartmouth Health Promotion and Disease Prevention Research Center supported by Cooperative Agreement Number U48DP005018 from the Centers for Disease Control and Prevention, the Dartmouth Clinical and Translational Science Institute, under award number UL1TR001086, and the NC Translational and Clinical Sciences (NC TraCS) Institute, which is supported by the National Center for Advancing Translational Sciences (NCATS), National Institutes of Health, through Grant Award Number UL1TR002489. Dr. Batsis also owns equity in SynchroHealth LLC.

Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author.

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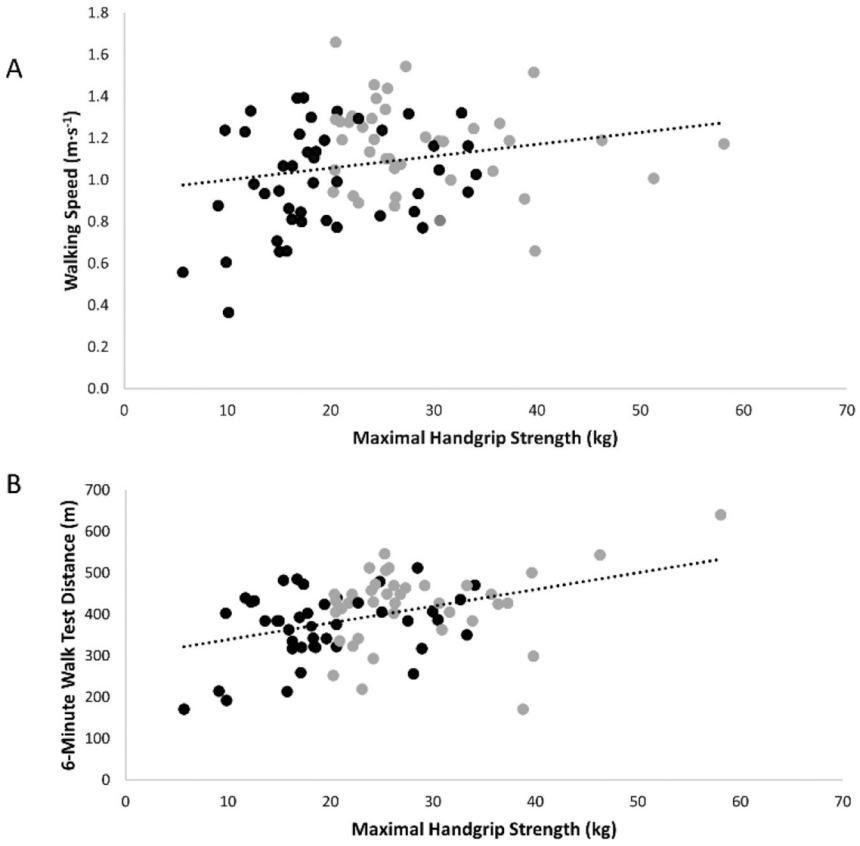

Figure 1:

Relationship between maximal handgrip strength (HGS) and (A) walking speed (r=0.22, *P*=0.05) and (B) distance walked in the 6-Minute Walk Test (r=0.40, *P*<0.001). Black circles represent those classified with low HGS (males <35 kg and females <20 kg) and gray circles represent normal HGS.

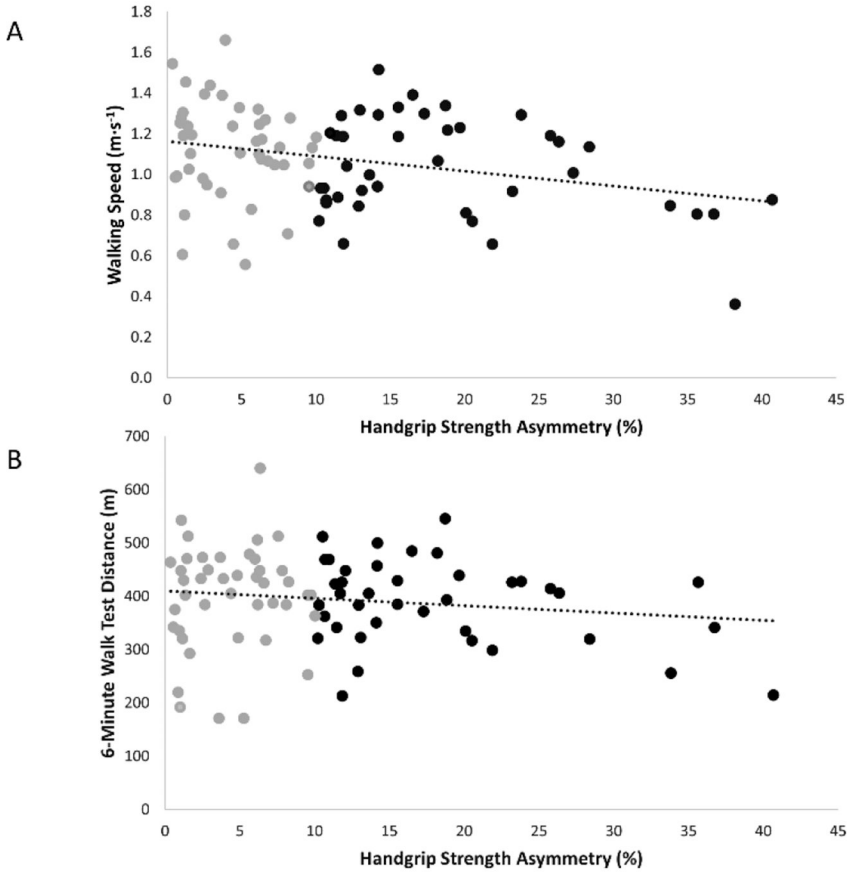

Figure 2:

Relationship between handgrip strength (HGS) asymmetry and (A) walking speed (r=0.31, *P*<0.01) and (B) distance walked in the 6-Minute Walk Test (r=0.17, *P*=0.13). Black circles represent those classified with HGS asymmetry (>10%) and gray circles represent symmetric HGS.

Table 1:

Prevalence of sarcopenic obesity, handgrip weakness, and asymmetry and means of anthropometric and physical function measures in males and females.

	Females		Males		Total	
	n	%	n	%	n	%
Sarcopenic Obesity Status						
Meets all criteria	49	88	14	64	63	74
Does not meet skeletal muscle function criteria	14	22	8	36	22	26
Handgrip Strength Status						
Low	29	46	13	59	42	49
Normal	34	54	9	41	43	51
Handgrip Asymmetry Status						
Asymmetric	30	47	12	55	42	49
Symmetric	33	53	10	45	43	51
	Mean ± SD		**Mean ± SD**		**Mean ± SD**	
Anthropometrics						
Age (years)	72.7 ± 4.4		73.8 ± 5.3		73.0 ± 4.6	
Height (m)*	1.60 ± 0.06		1.76 ± 0.07		1.64 ± 0.10	
Weight (kg)*	94.8 ± 15.6		111.3 ± 17.6		99.1 ± 17.6	
Body Mass Index (kg/m^2)	37.2 ± 5.6		36.0 ± 4.7		36.9 ± 5.4	
Waist to Hip ratio*	0.89 ± 0.06		1.00 ± 0.07		0.92 ± 0.08	
Percent Body Fat (%)*	51.0 ± 3.8		38.7 ± 4.6		47.8 ± 6.7	
Skeletal Muscle Mass/Weight (%)*	22.2 ± 3.7		29.3 ± 1.8		24.0 ± 4.6	
Physical Function						
Gait Speed (m·s^{-1})	1.08 ± 0.26		1.08 ± 0.21		1.08 ± 0.24	
6-Minute Walk Test Distance (m)	387 ± 84		417 ± 102		395 ± 89	
5x Sit-to-Stand (s) (n=33)	10.4 ± 3.1		9.3 ± 3.2		10.2 ± 3.1	
30-s Chair Stand (reps) (n=52)	13.0 ± 4.2		13.4 ± 5.2		13.1 ± 4.5	
Grip Strength						
Right Arm (kg)*	19.3 ± 6.2		32.4 ± 9.7		22.7 ± 9.2	
Left Arm (kg)*	19.0 ± 5.9		32.7 ± 8.0		22.5 ± 8.8	
Asymmetry (%)	11.1 ± 9.9		12.6 ± 9.2		11.5 ± 9.7	
Overall Function	58.9 ± 7.9		62.8 ± 9.3		59.9 ± 8.4	
Upper Extremity*	76.5 ± 12.1		84.2 ± 14.1		78.5 ± 13.0	
Basic Lower Extremity	72.3 ± 12.9		74.8 ± 13.6		72.9 ± 13.1	
Advanced Lower Extremity*	46.9 ± 13.0		53.7 ± 13.5		48.6 ± 13.4	

Table 2:

Prevalence of dominant hand and means of anthropometric and physical function measures in older adults with normal and low handgrip strength.

	Normal HGS	**Low HGS**	
Total n(%)	43 (51%)	42 (49%)	
Right hand dominant n(%)	26 (60%)	19 (45%)	
Left hand dominant n(%)	17 (40%)	23 (55%)	
	Mean ± SD	**Mean ± SD**	**Effect Size *d***
Anthropometrics			
Age (years)	73.1 ± 5.0	72.8 ± 4.3	0.08
Height (m)	1.65 ± 9.1	1.63 ± 9.8	0.18
Weight (kg)	97.8 ± 16.4	100.3 ± 18.8	0.14
Body Mass Index (kg/m^2)	36.0 ± 4.6	37.8 ± 6.0	0.34
Waist to Hip ratio	0.91 ± 0.07	0.93 ± 0.08	0.29
Percent Body Fat (%)	47.1 ± 6.2	48.6 ± 7.2	0.23
Skeletal Muscle Mass/Weight (%)	24.7 ± 5.0	23.3 ± 4.1	0.30
Measured Physical Function			
Gait Speed (m·s^{-1}) *	1.15 ± 0.22	1.00 ± 0.25	0.65
6-Minute Walk Test Distance (m)	416 ± 89	373 ± 85	0.50
Sit-to-Stand (s) (n=33) *	8.60 ± 2.63	11.75 ± 4.20	1.09
30-s Chair Stand (reps) (n=52) *	14.3 ± 4.4	12.8 ± 4.2	0.59
Grip Strength			
Right Arm (kg) *	27.5 ± 8.5	17.8 ± 7.1	1.23
Left Arm (kg) *	26.5 ± 8.2	18.5 ± 7.6	1.01
Asymmetry (%)	9.6 ± 8.0	13.4 ± 10.9	0.39
Self-Reported Overall Function	60.9 ± 8.4	58.8 ± 8.4	0.25
Upper Extremity	80.4 ± 12.9	76.6 ± 13.0	0.29
Basic Lower Extremity	75.5 ± 14.3	70.2 ± 11.3	0.41
Advanced Lower Extremity	50.1 ± 12.2	47.2 ± 14.5	0.22

HGS: Handgrip strength, *d*=Cohen's *d* effect size

All values represented as mean ± standard deviation (SD) or counts (%).

* Significant difference between normal and low HGS (P<0.05)

Table 3:

Prevalence of dominant hand and means of anthropometric and physical function measures in older adults with symmetric and asymmetric handgrip strength.

	Symmetric HGS	Asymmetric HGS	
Total n(%)	43(51%)	42(49%)	
Right hand dominant n(%)	23(53%)	22(52%)	
Left hand dominant n(%)	20(47%)	20(48%)	
	Mean ± SD	**Mean ± SD**	**Effect Size *d***
Anthropometrics			
Age (years)	73.1 ± 5.0	72.9 ± 4.3	0.05
Height (m)	1.63 ± 9.6	1.65 ± 9.3	0.18
Weight (kg)	97.3 ± 17.7	100.9 ± 17.4	0.20
BMI ($kg \cdot m^2$)	36.6 ± 5.7	37.2 ± 5.1	0.11
Waist to Hip ratio	0.91 ± 0.08	0.93 ± 0.07	0.17
Percent Body Fat (%)	48.1 ± 6.9	47.5 ± 6.7	0.09
Skeletal Muscle Mass/Weight (%)	24.0 ± 5.1	24.1 ± 4.0	0.03
Measured Physical Function			
Gait Speed ($m \cdot s^{-1}$)	1.12 ± 0.24	1.03 ± 0.24	0.34
6-Minute Walk Test Distance (m)	400 ± 99	388 ± 78	0.13
Sit-to-Stand (s) (n=33)	10.25 ± 2.97	10.25 ± 2.97	0.03
30-s Chair Stand (reps) (n=52)	13.2 ± 5.5	13.0 ± 3.2	0.04
Grip Strength			
Right Arm (kg)	23.4 ± 9.5	22.0 ± 9.1	0.15
Left Arm (kg)	23.3 ± 9.5	21.7 ± 8.1	0.17
Asymmetry (%) *	4.3 ± 2.9	18.9 ± 8.5	1.74
Self-Reported Overall Function	60.2 ± 8.9	59.6 ± 8.0	0.07
Upper Extremity	78.6 ± 13.3	78.4 ± 12.9	<0.01
Basic Lower Extremity	73.6 ± 14.1	72.3 ± 12.1	0.01
Advanced Lower Extremity	49.5 ± 12.8	47.8 ± 14.0	0.13

HGS: Handgrip strength, *d*=Cohen's *d* effect size

All values represented as mean ± standard deviation (SD) or counts (%).

*Significant difference between symmetric and asymmetric HGS ($P<0.05$)

Table 4:

Prevalence and means of anthropometric and physical function measures in older adults with combinations of handgrip strength weakness and asymmetry.

	No Weakness or Asymmetry Mean ± SD	Either Weakness or Asymmetry Mean ± SD	Both Weakness and Asymmetry Mean ± SD
Total n(%)	24(28%)	38(45%)	23(27%)
Anthropometrics			
Age (years)	73.0 ± 5.5	73.2 ± 4.3	72.5 ± 4.3
Height (m)	1.63 ± 9.2	1.64 ± 9.7	1.63 ± 9.7
Weight (kg)	96.1 ± 18.4	99.5 ± 15.4	101.6 ± 20.3
BMI ($kg \cdot m^2$)	35.7 ± 4.8	37.0 ± 5.6	37.9 ± 5.5
Waist to Hip ratio	0.90 ± 0.08	0.92 ± 0.07	0.93 ± 0.08
Percent Body Fat (%)	47.0 ± 6.2	48.3 ± 7.0	47.8 ± 6.7
Skeletal Muscle Mass/Weight (%)	25.0 ± 5.7	23.5 ± 4.2	23.8 ± 3.9
Measured Physical Function			
Gait Speed ($m \cdot s^{-1}$) *	1.22 ± 0.19[a]	1.03 ± 0.23[b]	1.01 ± 0.26[b]
6-Minute Walk Test Distance (m)	418 ± 105	395 ± 79	369 ± 83
Sit-to-Stand (s) (n=33)	9.01 ± 2.90	10.07 ± 3.06	11.34 ± 3.24
30-s Chair Stand (reps) (n=52)	14.4 ± 5.6	13.1 ± 4.3	11.7 ± 2.1
Grip Strength			
Right Arm (kg) *	26.9 ± 8.8[a]	23.6 ± 9.5[a]	16.8 ± 5.9[b]
Left Arm (kg) *	26.7 ± 9.3[a]	22.6 ± 8.2[a]	18.1 ± 7.3[b]
Asymmetry (%) *	4.3 ± 3.1[a]	10.4 ± 8.1[b]	20.9 ± 9.2[c]
Self-Reported Overall Function	61.3 ± 9.7	59.6 ± 8.3	58.9 ± 8.2
Upper Extremity	80.0 ± 12.4	78.8 ± 14.1	76.5 ± 12.1
Basic Lower Extremity	77.0 ± 15.6	71.4 ± 11.8	71.1 ± 11.8
Advanced Lower Extremity	50.6 ± 12.8	48.8 ± 12.3	46.4 ± 15.8

All values represented as mean ± standard deviation (SD) or counts (%).

* Significant difference between groups ($P<0.05$). Means with different letters demonstrate significantl difference.