




# Does skeletal muscle morphology or functional performance better explain variance in fast gait speed in older adults?

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## Abstract

**Background** Fast gait speed is being increasingly recognized as an important clinical tool in older adults. However, the underlying muscular and functional contributors to fast gait speed performance remain poorly understood.

**Aim** We sought to determine predictors of fast gait speed in older adults. We hypothesized that lower-extremity skeletal muscle size and quality would be strong predictors.

**Methods** Ninety community-dwelling older adults (33 men, 57 women; mean  $\pm$  SD age =  $74 \pm 6$  years) participated. B-mode ultrasonography was used to capture images of the vastus lateralis, rectus femoris, and gastrocnemius in the transverse plane. Each participant performed 30-second chair stand, heel-rise, functional reach, and grip strength tests. Fast gait speed was measured using the NIH Toolbox 4-Meter Walk Test. ImageJ software was used to quantify cross-sectional area (CSA), subcutaneous tissue thickness, and echo intensity. Two separate stepwise regression analyses were performed, one using muscle morphology variables as independent variables, and another including the functional outcomes.

**Results** The ultrasound variables exhibited weak-to-moderate correlations with fast gait speed ( $|r|$  range = 0.168–0.416). The initial regression analysis indicated that the combination of medial gastrocnemius CSA and subcutaneous tissue thickness explained 22.8% of the variance in fast gait speed. The secondary analysis indicated that 30-second chair stand, heel-rise, and grip strength performance explained 45.5% of the variance.

**Conclusion** While medial gastrocnemius morphology is important, measures of upper and lower-extremity muscle function are better predictors of fast gait speed. These results highlight a dissociation between skeletal muscle morphology and fast gait speed.

**Keywords** Ultrasound · Echo intensity · Muscle quality · Fast gait speed · Functional tests

## Introduction

In the absence of progressive exercise programming, many older adults experience declines in physical function [1]. The inability to perform activities of daily living and the loss of independence due to these impairments have been associated with depression [2], anxiety [3], and all-cause mortality [4]. As such, public health officials and researchers are increasingly recognizing the need for assessment tools that can be used to quickly identify older adults who may be

at an increased risk of musculoskeletal injury and in need of preventative interventions. One simple solution may be the measurement of comfortable gait speed. Classic work by Winter et al. [5] demonstrated that older adults alter their gait mechanics to allow for more stability and safety. Such changes include a smaller step length, increased double limb support time, decreased power when pushing off, and a flat-foot landing as compared to a traditional heel strike [5]. Gait speed also predicts multiple adverse outcomes, such as disability, cognitive impairment, falls, and mortality [6]. For these reasons, measurement of comfortable gait speed in clinical settings has been strongly recommended by experts, with 0.8 m/s being designated as an important cut-point for deciding when intervention is necessary [6].

In addition to comfortable gait speed, some investigators have examined the potential clinical utility of fast gait

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speed. Although studies are limited, evidence suggests that fast gait speed performance is linked to the neuromuscular system's ability to produce force rapidly, which may be mediated by parameters such as voluntary activation, corticospinal excitability/inhibition, and/or motor unit firing rates [7–9]. For example, Clark et al. [10] reported significant differences in the rate of muscle activation for the gastrocnemius in older adults with slow versus fast 10-m gait speed. It should be noted, however, that attempts to explain additional variance in fast gait speed have produced varying results, perhaps in part due to investigators utilizing dissimilar independent variables. Clark et al. [11] reported that the combination of age, muscle and fat mass variables, and the rate of electromyographic rise accounted for ~72% and ~44% of the variance in fast gait speed for men and women, respectively. Mantel et al. [12] was able to explain more than 80% of the variance in fast gait speed utilizing a variety of tests focused on both balance and strength. More recently, Stock et al. [13] reported that both peak torque and the rate of torque development during a maximal isometric squat test explained ~25% of the variance in fast gait speed in older adults. Interestingly, relative to other measures, assessments of muscle mass have not been useful in predicting fast gait speed [11, 13], providing support for a mechanistic dissociation between skeletal muscle morphology and lower-extremity function [14, 15].

Within the last decade there has been a substantial increase in the number of investigators using B-mode ultrasonography to assess skeletal muscle morphology in older adults [16, 17]. Though these topics can also be studied using MRI and CT, the cost and portability of B-mode ultrasonography make its use a realistic option for many investigators wishing to conduct research in the community. While measurements of adiposity and skeletal muscle size [e.g., muscle thickness and cross-sectional area (CSA)] have long been common, the scientific community has recently shown widespread interest in using echo intensity (EI) as a measurement of muscle quality [18, 19]. The theoretical basis of EI is derived from the notion that skeletal muscle tissue and non-contractile tissues differ in the amplitude of sound of the returning signal [18]. Specifically, skeletal muscle presents as very dark, whereas adipose and fibrous tissue appear much lighter [20]. As such, EI is an ultrasound-derived measure that computes the mean gray value of a given region of interest, or the amount of returning echoes per a given area. While EI has been shown to be sensitive to exercise training adaptations [21], concentric-only muscle actions [22], and disuse immobilization [23], many reports in the literature have suggested that EI is associated with various aspects of muscle function in the older adult

population [24–26]. Given the apparent weak association between fast gait speed and muscle mass in older adults [11, 13], limited literature with small sample sizes concerning such a relationship with EI is thus far encouraging [27, 28].

There is compelling evidence to suggest that declines in lower-extremity muscle function during older adulthood are not synonymous with declines in muscle mass. Longitudinal data from 1,880 older participating in the Health, Aging, and Body Composition Study demonstrated that annualized rates of leg strength decline (3.4% in white men, 4.1% in black men, 2.6% in white women, and 3.0% in black women) were roughly three times greater than the rates of loss of leg lean mass (~1% per year) [29]. Equally fascinating, data from a subset of the participants showed that maintaining or gaining muscle mass did not prevent longitudinal declines in muscle strength [29]. Given these findings, Clark and Manini [14] proposed that the age-related loss of muscle mass (sarcopenia) and voluntary muscle strength (dynapenia) are different concepts. As a result, researchers from a variety of disciplines have performed studies in older adults to parse out these differences [30, 31].

The purpose of the present study was to use a comprehensive battery of skeletal muscle and functional tests to predict fast gait speed performance in older adults. Our primary hypothesis was that EI, but not necessarily CSA, would be a strong predictor of fast gait speed. Given the importance of plantarflexion power in the gait cycle [32], we speculated that morphology of the gastrocnemius would be the strongest predictor of fast gait speed. In an attempt to explain further variance, a secondary aim was to determine if other functional assessments which are commonly utilized in the older adult population predicted fast gait speed performance.

## Materials and methods

### Study design

This study utilized a cross-sectional design in adults  $\geq 60$  years of age. Data collection occurred during the spring of 2019. All participants were recruited from the Learning Institute for Elders group, a 501(c)3 organization in partnership with and hosted by the University of Central Florida. All testing occurred at the University of Central Florida School of Kinesiology and Physical Therapy's Neuromuscular Plasticity Laboratory and the Innovative Mobility Initiative Lab during a single, 90-min visit. The personnel involved in data collection and analysis remained consistent across all participants, with each investigator performing a specific task. The tests were performed in the order in which they have been described below.

## Participants

Ninety older adults (33 men, mean  $\pm$  SD age =  $76 \pm 6$  years, mass =  $85.4 \pm 17.0$  kg, height =  $178.0 \pm 7.2$  cm; 57 women, mean  $\pm$  SD age =  $75 \pm 6$  years, mass =  $65.8 \pm 11.0$  kg, height =  $162.2 \pm 5.7$  cm) participated in this study. Major inclusion criteria included age  $\geq 60$  years and having the ability to walk at least 20 feet without an assistive device. Major exclusion criteria included having any significant cognitive deficits, the inability to follow directions during assessment, and neurological, neuromuscular, or musculoskeletal disorders that could impair the ability to perform any of the functional performance tests. All participants were made aware of the study procedures prior to enrollment and consented to participate. The University of Central Florida's Institutional Review Board approved of this study (ID # IRB00001138).

## B-mode ultrasonography image acquisition

The B-mode ultrasonography image acquisition and analysis performed in this study was largely based off the work of Young et al. [18]. All images were captured with a portable B-mode imaging device (GE Logiq *e* BT12, GE Healthcare, Milwaukee, WI, USA) and a multi-frequency linear-array probe (12 L-RS, 5–13 MHz, 38.4-mm field of view, GE Healthcare, Milwaukee, WI, USA). The panoramic function (LogiqView, GE Healthcare, Milwaukee, WI, USA) was used to obtain images of the dominant (based on kicking preference) vastus lateralis (VL), rectus femoris (RF), medial gastrocnemius (MG) and lateral gastrocnemius (LG) in the transverse plane. For all participants, imaging of the VL and RF was performed first, followed by the MG and LG. All imaging was performed with the participants resting on a padded treatment table. Specifically, VL and RF imaging was performed with the participants in the supine position, whereas MG and LG assessments were performed in the prone position, both with pillow support provided as needed. As recent evidence has demonstrated no significant effect of supine duration on measures of muscle morphology [33], the participants did not rest for a prolonged period before data collection. The VL and RF images were taken at a location corresponding to 50% of the distance between the greater trochanter and superior patella. It is important to note that this measurement site represents 50% of the entire length of the VL, but not the RF. All gastrocnemius images were taken at a location corresponding to the largest circumference of the lower leg [34], which was measured prior to assessment. For both locations, a high-density foam pad was secured around the limb with an adjustable strap to ensure a stable probe movement in the transverse plane. Ultrasound settings (Frequency: 10 MHz, Gain: 55 dB, Dynamic Range: 72) were kept consistent across participants. The default

image depth used for the RF and VL was 5.0 cm, whereas 4.0 cm was used for the MG and LG. For participants with limbs too large to capture the entire muscle, image depth was increased to the smallest increment necessary such that the deep border was clear during analysis. A generous amount of water-soluble transmission gel (Aquasonic 100 ultrasound transmission gel, Parker Laboratories, Inc., Fairfield, NJ, USA) was applied to the skin such that it immersed the probe surface during testing to enhance acoustic coupling. Three images of each muscle were taken, and the means of the three values for each variable have been reported (Fig. 1).

## B-mode ultrasonography image analysis

The ultrasound images were digitized and examined with ImageJ software (version 1.51, National Institutes of Health, Bethesda, MD, USA) after the study. The polygon function was used to outline the border of each muscle. Care was taken to ensure that fascia along the borders of each muscle was not included in the analyses. Anatomical CSA was calculated for each muscle ( $\text{cm}^2$ ). EI was assessed by computer-aided gray-scale analysis using the histogram function. The raw EI values were determined as the corresponding index of muscle quality ranging between 0 and 255 arbitrary units [A.U. (black = 0; white = 255)]. Subcutaneous adipose tissue thickness (SCAT) was quantified with ImageJ's straight-line function as the distance between the skin-muscle interface and the superior border of each muscle's aponeurosis at three locations (left, center, right) [35]. The EI values were then

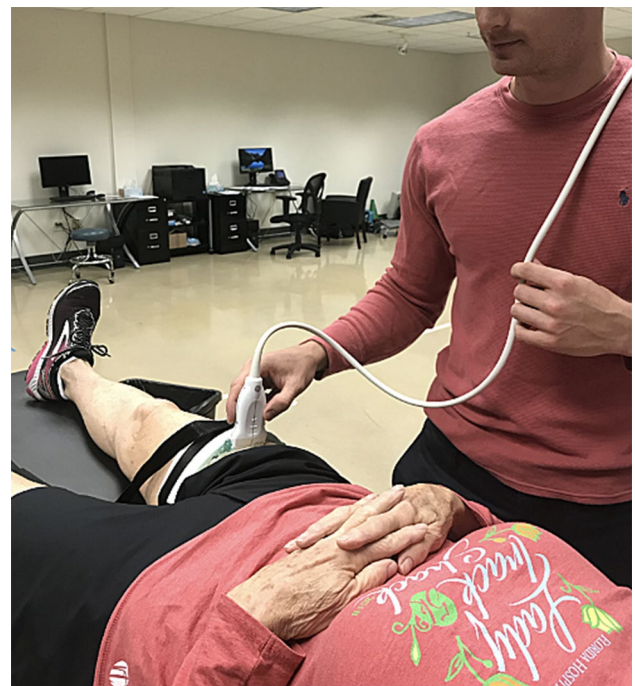


Fig. 1 Example of RF ultrasonography data collection

corrected for SCAT using the following equation created by Young et al. [18] (Fig. 2).

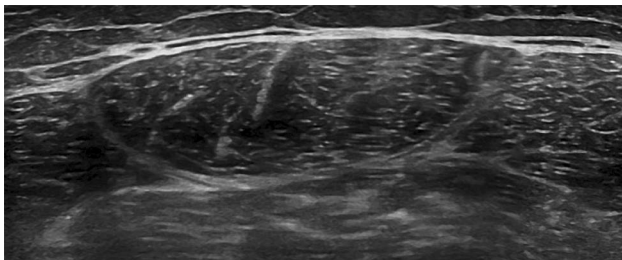
$$\text{Corrected EI} = \text{Raw EI} \\ + (\text{Subcutaneous fat thickness [cm]} \times 40.5278)$$

### 30-second chair stand test

The protocol for the 30-second chair stand test was adapted from Jones et al. [36]. The test was administered using a chair without arms and a seat height of 17 inches. The chair was placed against a wall to prevent it from moving during testing. The participant began seated in the middle of the chair, with their back straight, arms crossed, and feet approximately shoulder-width apart. The instructions provided were to rise to a full stand and then return back to a fully seated position. The participant was encouraged to complete as many full repetitions as possible within 30 s. Following a demonstration by the investigator, the participant was encouraged to perform a practice trial of one repetition, followed by the 30-second test trial. The total score was the number of correctly executed stands performed within 30 s.

### Heel-rise test

The protocol for the heel-rise test was adapted from Lunsford and Perry [37]. The test was administered with the participant in a standing position. The participant was instructed to rise and lower on the ball of their dominant foot as many times as possible. During testing, the participant was allowed to touch the wall in front of them for balance. The test was terminated if a participant leaned too far forward, excessively flexed their knee, or decreased plantar-flexion range of motion by more than 50%. Following a demonstration by the investigator, the participant was encouraged to perform



**Fig. 2** Example B-mode ultrasonography image of the RF. All images were taken in the transverse plane with the participant lying on a treatment table. All images were captured and analyzed by the same investigator

as many repetitions as possible, and the total score was the number of correctly executed heel rises.

### Functional reach test

The protocol for the functional reach test was adapted from Duncan et al. [38]. To begin, a yardstick was secured to the wall, level with the participant's right acromion. The participant was asked to stand so their shoulders were perpendicular to the wall and then instructed to flex their right arm to shoulder height while making a fist. The position of the end of their third metacarpal was recorded. The participant was then instructed to reach as far forward as possible without losing their balance or taking a step. The position of the end of their third metacarpal was recorded again. The trial was terminated if a participant's upper extremity touched the wall or if they took a step forward. During testing, one investigator was responsible for monitoring form and recording measurements, while another investigator was responsible for guarding the participant. Following testing, functional reach was defined as the mean difference between positions over three trials.

### Grip strength test

The protocol for grip strength testing was adapted from Hamilton et al. [39]. The test was administered with the participant in a seated position with their elbow flexed to approximately 90°. A handheld dynamometer was placed in the participant's dominant hand and the testing procedure was explained. The participant was instructed to squeeze the dynamometer as hard as possible and then relax for 3 s between trials. Three trials were conducted, during which the investigator was allowed to provide encouragement to squeeze harder. During testing, the measurement unit used was kilograms. Following testing, grip strength was defined as the mean over three consecutive trials.

### Assessment of Fast Gait Speed

Fast gait speed was measured using the NIH Toolbox 4-Meter Walk Test [40]. This test is adapted from the 4-meter walk test in the Short Physical Performance Battery [41]. Participants were asked to walk a short distance (4 m) at a fast pace during one practice trial, followed by two timed trials. Raw scores were recorded as the time in seconds required to walk 4 m on each of the two-timed trials, with the better trial being used for analysis. Lastly, the time in seconds required to walk 4 m during the best trial was converted to meters per second (Fig. 3).



**Fig. 3** Example of the measurement of fast gait speed using the NIH Toolbox 4-Meter Walk Test

**Statistical analyses**

The mean, median, SD, and range were computed for all descriptive variables. A Pearson product moment correlation (*r*) was used to determine the relationship between fast gait speed and CSA, SCAT, and EI for each of the four muscles. Correlation coefficients of *r*=0.10, 0.30, and 0.50 represented weak, moderate, and strong associations, respectively [42]. The 95% confidence interval (CI) for each correlation coefficient was also computed. Stepwise regression evaluated two prediction analyses. The initial analysis utilized each of the muscle morphology variables as independent variables. The secondary analysis included the muscle morphology variables and the functional outcomes as independent variables. To monitor multicollinearity, the variance inflation factor (VIF) was calculated using the equation  $VIF = 1/(1-r^2)$ . A VIF greater than 10 has been suggested to indicate problematic multicollinearity [43]. All statistical procedures were performed using SPSS (Version 24.0, IBM Corporation, Armonk, NY, USA). An alpha level of  $p \leq 0.05$  was utilized to determine statistical significance for all data analyses.

**Results**

Descriptive data for the skeletal muscle morphology and functional performance outcomes have been displayed in Tables 1 and 2, respectively. As shown in Table 3, 11 out of the 12 muscle morphology variables demonstrated

**Table 1** Descriptive statistics for all ultrasound variables

	RF			VL			MG			LG		
	CSA (cm <sup>2</sup> )	SCAT (cm)	EI (A.U.)	CSA (cm <sup>2</sup> )	SCAT (cm)	EI (A.U.)	CSA (cm <sup>2</sup> )	SCAT (cm)	EI (A.U.)	CSA (cm <sup>2</sup> )	SCAT (cm)	EI (A.U.)
Mean	5.0	1.18	109.2	15.0	1.01	102.4	11.3	0.95	91.7	6.24	0.80	97.6
Median	5.4	1.12	103.8	14.1	0.98	99.2	10.4	0.96	88.4	5.97	0.66	95.4
SD	2.2	0.60	30.1	4.5	0.58	31.5	3.5	0.37	25.3	2.06	0.35	26.5
Minimum	1.8	0.16	56.8	8.0	0.11	44.3	4.9	0.19	50.3	2.43	0.05	46.8
Maximum	12.3	3.53	197.1	35.3	3.00	216.3	19.5	1.96	172.8	12.55	1.95	198.9

**Table 2** Descriptive statistics for fast gait speed and functional outcomes

	Fast gait speed (m/s)	30-second chair stand (repetitions)	Heel-rise (repetitions)	Functional reach (cm)	Grip strength (kg)
Mean	1.93	12	9	31.2	27.1
Median	1.84	12	8	31.6	23.8
SD	0.41	4	6	6.9	9.6
Minimum	1.27	0	0	10.6	13.5
Maximum	3.36	28	34	48.5	56.5

statistically significant associations with fast gait speed. However, all of the correlations were considered weak-to-moderate. Tables 4 and 5 display the results from the regression analyses. The initial regression analysis indicated that the combination of MG CSA and SCAT explained 22.8% of the variance in fast gait speed ( $R^2 = 0.228$ , adjusted  $R^2 = 0.210$ ,  $F = 12.7$ ,  $p < 0.001$ ). MG EI and all measures from the VL, RF, and LG were excluded. The secondary analysis demonstrated that performance during the 30-second chair stand, heel-rise, and grip strength tests explained 45.5% of the variance ( $R^2 = 0.455$ , adjusted  $R^2 = 0.435$ ,  $F = 23.6$ ,  $p < 0.001$ ), but each of the morphological variables and functional reach were excluded.

### Discussion

The findings from previous studies have suggested that fast gait speed is a useful assessment tool in older adults [10, 44]. The purpose of this study was to determine the predictors of fast gait speed, with the primary hypothesis being that B-mode ultrasound derived EI would explain a substantial portion of variance. The results indicated that most of the ultrasound variables exhibited weak-to-moderate correlations with fast gait speed ( $|r|$  range = 0.168–0.416). In contrast to our primary hypothesis, stepwise regression revealed that the combination of MG CSA and SCAT significantly predicted fast gait speed. Equally fascinating, performance on the 30-second chair stand, heel-rise, and grip strength tests explained even greater variance, with no further contribution from the muscle morphology variables and functional reach.

B-mode ultrasonography has been frequently used to measure characteristics of muscle morphology over the last decade, and recently there has been increased interest in using EI to determine muscle quality [16–19]. A muscle that is considered high quality appears dark on an ultrasound image and contains small amounts of non-contractile tissue. Low muscle quality is associated with a muscle that appears

**Table 3** Results of the Pearson product moment correlation used to determine the relationship between fast gait speed and the muscle morphology variables

	RF			VL			MG			LG		
	CSA	SCAT	EI	CSA	SCAT	EI	CSA	SCAT	EI	CSA	SCAT	EI
<i>r</i>	0.335	-0.360	-0.300	0.326	-0.251	-0.282	0.237	-0.416	-0.328	0.267	-0.302	-0.168
<i>R</i> 95% CI	0.138–0.506	-0.527 to -0.166	-0.477 to -0.100	0.128–0.499	-0.435 to -0.047	-0.462 to -0.08	0.032–0.423	-0.573 to -0.229	-0.501 to -0.130	0.064–0.449	-0.479 to -0.102	-0.362 to 0.04
<i>p</i>	0.001	< .0001	0.004	0.002	0.017	0.007	0.025	<0.001	0.002	0.011	0.004	0.115

**Table 4** Stepwise regression summary for predicting fast gait speed with skeletal muscle morphology variables

Independent variable	$R^2$	Adjusted $R^2$	Unstandardized $\beta$ (standard error)	Standardized $\beta$	$p$
Model 1	0.174	0.164			<0.001
Intercept			2.37 (0.112)		
MG SCAT			- 0.469 (0.110)	- 0.417	
Model 2	0.228	0.210			0.015
Intercept			2.053 (0.169)		
MG SCAT			- 0.466 (0.107)	- 0.414	
MG CSA			0.028 (0.011)	0.234	

**Table 5** Stepwise regression summary for predicting fast gait speed with the skeletal muscle morphology and functional performance variables

Independent variable	$R^2$	Adjusted $R^2$	Unstandardized $\beta$ (standard error)	Standardized $\beta$	$p$
Model 1	0.326	0.318			<0.001
Intercept			1.265 (0.108)		
30 s chair stand			0.054 (0.008)	0.571	
Model 2	0.424	0.411			<0.001
Intercept			0.949 (0.130)		
30 s chair stand			0.050 (0.008)	0.526	
Grip strength			0.014 (0.004)	0.316	
Model 3	0.455	0.435			0.032
Intercept			0.961 (0.128)		
30 s chair stand			0.039 (0.009)	0.408	
Grip strength			0.013 (0.004)	0.312	
Heel rise			0.015 (0.007)	0.211	

lighter and greyer, with higher amounts of non-contractile tissue [20]. Multiple studies have shown muscle quality is associated with various aspects of function in older adults. Cadore et al. [26], as well as Mota and Stock [17], reported that RF EI was significantly correlated with lower extremity strength in elderly men. Radaelli et al. [21] suggested strength training performance of elderly women and muscle quality were significantly correlated. Lopez et al. [24] concluded there was a significant correlation between quadriceps EI and performance on the 30-second chair stand test in elderly men. Wilhelm et al. [25] found a significant correlation between quadriceps EI, functional capacity, and muscular power in older men. Guadagnin et al. [28] reported a significant correlation between VL EI and gait parameters in older adults. Given the discrepancy among study designs and results, further research is required to determine if EI is truly a reliable predictor of functional capacity in older adults.

According to the results of the present study, clinicians treating geriatric patients with impaired gait speed should place more emphasis on the results of functional tests as opposed to the quality and size of muscular tissue seen on imaging studies. Our results also suggest that sarcopenia and declines in muscle tissue over time may not be the best predictors of functional performance changes and gait speed

in geriatric patients [45]. Functional performance tests, such as the ones utilized in this study, are commonly employed by clinicians to assess physiologic parameters associated with independent functioning [46]. Many of these functional tests have been validated and proven to be useful in the evaluation of physical mobility in older adults [46]. Previous studies have found the 30-second chair stand test can be used to predict endurance capacity in patients with cardiorespiratory dysfunction [47] and recommend it as an evaluation tool for functional decline and frailty [48]. On the heel-rise test, older adults demonstrated decreased performance due to age-related declines in muscle strength and measures of balance [49]. On the functional reach test, the ability to maintain balance outside of the center of pressure excursion deteriorates with age and is associated with older adults attempting to minimize altering their center of gravity to avoid falling [38]. Lastly, handgrip strength has been shown to have an inverse relationship with 2-year loss of instrumental activities of daily living function [50]; more specifically, each 10 kg increase correlates to 5% decreased odds of losing function in activities of daily living within 2 years [50].

Original work by Goodpaster et al. [29] concluded that rates of leg strength decline were approximately three times greater than rates of loss in lean leg mass. Our results support

this claim given that variance in fast gait speed is better predicted by functional testing in comparison to morphological measures. Clark and Manini [14] associated inactivity with onsets of both sarcopenia and dynapenia; the impact both these terms have on function in older adults further explains why functional testing predicts greater variance in fast gait speed in comparison to morphological characteristics. In comparison to previous publications, the present study has important contributions to the current state of literature explaining predictors of fast gait speed in older adults. First, these findings suggest that other tests of functional performance can be used to infer fast gait speed and its association to mortality risk without accounting for muscle morphology, thus validating the use of such tests against ultrasound imaging. Second, it demonstrates clearly that characteristics of muscle morphology alone are not strong predictors of fast gait speed. We suggest that improved functional performance can positively influence fast gait speed, thereby presenting opportunities for intervention across the life span. On the contrary, decreased performance on commonly used functional tests may help identify older adults at high risk for decline in fast gait speed, allowing clinicians to reason which preventive actions to take for combating further decline.

Seeing how our study demonstrated that fast gait speed is a highly applicable measure in the identification of older adults at risk for functional limitations, we suggest fast gait speed be included as a clinical assessment tool due to its advantages of being safely performed and requiring low exertion [8]. While Clark et al. [10] concluded that age-related neuromuscular activation impairment limits maximum 10-m walking speed, our study further evaluated the utility of fast gait speed for use in clinical assessment to detect and monitor age-related functional decline. Our results have important implications for designing clinical assessments and interventions to detect and counter age-related impairments associated with mobility and disability. Including specific measures of physical performance in our study provided us with a more comprehensive understanding of the older adult and highlighted modifiable variables that can be targeted by clinicians if found to be abnormal during assessment. In comparison to Stock et al. [13], which concluded that measures of absolute and rapid squat strength were associated with short and long-distance fast gait speed in older adults, but that leg lean mass was not an important predictor, our study included a larger sample, several additional measures of muscle morphology, and functional performance outcomes to further explain variance in fast gait speed.

The functional tests that best predict variance in fast gait speed in this study's participants were the 30-second chair stand test, heel-rise test, and grip strength test. These findings are in line with previous research that suggests these three tests are effective for assessing functional capacity in older adults [48–50]. In line with the results of this study, the 30-second chair stand test has been proven to be effective at

predicting functional capacity, fall risk, and anticipated age-related decline in older adults, and discriminating between sedentary and active older adults [51]. A key finding of this study was that grip strength was a significant predictor of fast gait speed. Even though the muscles involved with grip strength differ from the muscles involved with producing adequate gait speed, previous studies have shown that gross grip strength is not limited solely to upper extremity function [50]. Overall, the results of this study suggest that assessment tools, such as the 30-second chair stand test, heel-rise test, and grip strength test, can be used to predict functional performance in older adults [48–50].

The results of the present investigation are not meant to diminish the significance of imaging studies, for we understand that morphological characteristics are critical for diagnosing many disease conditions. Ultrasonography represents one form of diagnostic imaging; however, clinicians today have at their disposal a multitude of imaging techniques, each with their own distinct utility and advantages. For example, regarding diagnosis of metabolic bone diseases, such as osteoporosis, plain radiographs offer the advantage of identifying structural changes and alignment with greater resolution, while magnetic resonance imaging is superior at detecting changes in soft tissue and bone marrow earlier in the disease process [52]. Although osteoporosis represents only one example of a disease process affecting older adults, advancements in its diagnosis have seen use of various imaging and assessment techniques. Currently, the gold standard for diagnosis of osteoporosis is based on bone mineral density as assessed by dual X-ray absorptiometry [53]. Most recently, based on the concepts that bone strength depends not only on bone mass but also on bone quality, and that dual X-ray absorptiometry does not accurately reflect bone microarchitecture, Bonaccorsi et al. [54] concluded that a novel method, called Trabecular Bone Scoring, offers an advantage in comparison to dual X-ray absorptiometry. Seeing how bone mineral density is influenced by body mass index and metabolic changes in adipose tissue, Boneaccorsi et al. [54] proposed that Trabecular Bone Scoring can support bone mineral density assessments in the stratification of older adults with a high body mass index. As demonstrated by the aforementioned studies by Woo et al. [52] and Boneaccorsi et al. [54], individual imaging techniques and analytical tools contribute their own strengths and can be complementary to each other in the diagnosis of geriatric diseases; on this note, we believe that measures of physical function also prove to significantly bolster the diagnostic process and substantially assist clinicians in fully understanding an older adult's health status.

## Limitations

A few methodological considerations and potential limitations are worthy of consideration. It should be noted that the results of this study are specific to fast gait speed in older adults 60 years and older. It is unclear if other functional assessments, or ultrasound images of other muscle groups (e.g., gluteus maximus), would have brought about different results. Although we studied both sexes, additional studies with larger samples are needed to fully determine if disparities exist between the sexes. Furthermore, the cross-sectional design of this study did not permit tracking of participants over time. Perhaps a longitudinal approach would allow us to determine cause and effect relationships between variables. As a final note, the external validity of this study is relatively low, because all participants were recruited from the same education learning group, with the majority being Caucasian women living independently in the greater Orlando, Florida area.

In summary, the results of this study indicated that other measures of physical function are better predictors of fast gait speed than lower-extremity CSA, SCAT, and EI, highlighting a potential dissociation between skeletal muscle morphology and gait speed [45]. The relationship between functional testing and fast gait speed in older adults should be further investigated in a larger cross-sectional study with a more equal distribution of men and women. Our suggestions for further research include investigating differences in pre-functional and functional variables between older adults in distinct age brackets (i.e., 60–69, 70–79, 80–89, 90–100). In addition, a randomized controlled trial investigating improvement in fast gait speed with various interventions (e.g., strength training, gait training, balance training) may prove to bolster the results of our current study. As the present study was the first to test the hypothesis that MG EI determines the largest variance in fast gait speed, additional replication studies are needed to confirm these findings.

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## Compliance with ethical standards

**Conflict of interest** All authors declare no conflicts of interest in the reporting of this research.

**Ethical approval** All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committee (University of Central Florida's Institutional Review Board [#IRB00001138]) and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

**Informed consent** Informed consent was obtained from all individual participants included in the study.

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