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Cognitive and Physical Indicators of Gait Speed in the Community-dwelling Older Adult

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Abstract

Gait speed has been correlated to quality of life and has been called the sixth vital sign. The purpose of this study was to understand the factors that comprise fast and comfortable gait speed. 90 older adults provided demographic, cognitive, and functional performance data. Hierarchical linear regression models revealed predictors for comfortable gait speed to be lower-extremity strength ($B = 1.13$, $\beta = 0.233$, $P < .05$), comorbid health ($B = -2.95$, $\beta = -0.22$, $P < 0.05$), and gender($B = 8.28$, $\beta = 0.19$, $P < .05$). For fast gait speed lower-extremity strength ($B = 1.96$, $\beta = 0.26$, $P < .05$), functional reach ($B = 2.45$, $\beta = 0.20$, $P < .05$), and balance ($B = -25.29$, $\beta = -0.22$, $P < .05$). This study revealed lower-extremity strength continues to be a strong predictor of comfortable and fast gait speeds, while cognitive measures may not be.

Keywords

Comfortable gait speed; fast gait speed; cognition; hierarchical regression

1. Introduction

The population of older adults aged 65 and older is roughly 8.5% of the world's population and is expected to reach upwards of 17% by the year 2050 resulting in an estimated 1.6 billion people [1]. As the older adult population continues to grow, it becomes increasingly important to be able to predict, monitor, and track changes in health status of those older adults. A method to be able to assess these health qualities also must be easy to administer, time efficient and valid for its intended purpose. Gait speed has been shown to be a valid and reliable measure for predicting health status in the older adult population [2-6]. Gait speed has been shown in the research to be useful as a tool for clinicians, so much so that it has been called the sixth vital sign [7]. While gait speed is a great predictor of health status, improvements in gait speed also reduce morbidity and mortality [8]. Gait speed has implications on an individuals overall quality of life, fall risk, level os societal participation, and overall life satisfaction [2, 5, 8, 9]. For a clinician, it is important to understand potential variables that comprise gait speed.

Gait speed throughout the literature has been measured in a multitude of ways; such as variations in the length of course used for example the 10 meter walk test versus the 4 meter walk talk, a dynamic vs static start, and the dictated speed (comfortable/usual or fast). Two subsets of gait speed have been used in the literature: usual gait speed, also called comfortable gait speed, and fast gait speed; each subset is a predictor of health decline and therefore both are measured. A recent systematic review suggested that the use of a 4-meter track at a comfortable gait speed suggested best clinical use due to its feasibility [2]. However, as suggested by Guralnik et al. when measuring usual gait speed, length of track is not a factor of an individuals usual gait speed [9]. Van Kan and colleagues reported that use of easily remembered cut-off points would help clinicians to quickly discriminate between those at risk for future decline. A cut-off score of 0.8 m/s was used to establish those at greater risk for adverse outcomes and 0.6 m/s for those who are already functionally impaired [2]. When it comes to starting protocol for gait speed assessment, there is insignificant difference between starting dynamically or statically [10]. What is significant is the difference between an individuals fast and comfortable gait speed [10, 11]. Fast gait speed is frequently assessed by clinicians and researchers, and has similar predictive abilities as comfortable gait speed [3, 12]. While fast gait speed demonstrates similar predictive properties, comfortable and fast gait speeds are correlated with each other, and it is unclear whether it provides additional value. The difference between fast gait speed and comfortable gait speed has been discussed as a marker for functionality as it demonstrates the ability for an individual to change their velocity. Many researchers and clinicians collect both fast and comfortable gait speed because they are unclear as to which provides the best representation of health [10]. Understanding the variables that are associated with fast and comfortable gait speed may shed light on their unique qualities and allow clinicians to create interventions to specifically target those aspects.

Current literature demonstrates a number of factors correlatingto gait speed that include functional performance measures, balance, demographics (i.e. age and body mass index), cognitive function, and muscular strength [13, 14]. However, the shared variance among these variables and their contribution to the overall construct is largely not well defined or understood. Lower extremity strength has been shown in the literature to have been correlated to both comfortable and fast gait speed whether that be lower extremity strength or power [9, 15].

Balance has also been shown to be important for ambulation through kinematic testing. There is increased stability when ambulating at slower speeds and a linear relationship exists with increasing velocities and variability [16]. Increasing gait velocity decreases stability through decreased double limb support time and more kinematic variability. Thus, those who have decreased balance opt for a more efficient maintenance of balance at a slower velocity. Standing balance assessments through postural sway have demonstrated correlations for fast and comfortable gait speeds [14, 17]. However, There is some conflicting evidence on balance, and might be limited to fast gait speed [18]. Furthermore, perception of balance through the Activities of Balance Confidence Scale have been shown to be predictive in gait speed [19]. Decreases in gait could have psychological factors in addition to actual physical performance.

The literature has also documented a relationship between gait speed and cognition, namely that a decline in gait speed is associated with a decline in cognition. Interestingly, a stronger predictive association appears to exist between fast gait speed and cognition than between comfortable gait speed and cognition. Global cognitive function (as measured by the MMSE) does not contribute to the prediction of comfortable gait speed, but does contribute to the prediction of fast gait speed [13]. Likewise, fast gait speed was more predictive of cognitive decline than comfortable (usual) walking speed. Fitzpatrick and colleagues found that risk of low cognitive function was significantly greater for older adults with slower fast-walking pace; while associations between cognitive function and usual-paced walking were marginal [20]. Further, greater cognitive impairment is associated with poorer walking speed reserve, limiting the ability to increase speed and walk quickly [21]. These findings suggest that functional tasks requiring greater reserve are more sensitive to the relationship between motor function and cognition and are better for assessing risk of cognitive decline, though decline in comfortable (usual) gait speed has been observed as a precursor to decline in cognitive functioning and may also be used as a tool to assess cognitive functioning [22].

Research has further indicated a relationship between gait speed and executive function (EF), a global construct used to refer to different components of higher-order cognitive processes such as inhibition, cognitive flexibility (also known as task-switching), and processing speed. In older adults with amnestic mild cognitive impairment (aMCI), flexibility (as measured by the Trail Making Test part B), and inhibition (as measured by the Stroop Word Color Test) were associated with usual gait speed demonstrating that slower usual gaits peed is associated with lower EF performance [23]. The association between EF and gait speed is also present in healthier older adults; Watson and colleagues found that even when excluding performance of older adults with cognitive decline and MCI, similar associations between EF components and gait speed were present as in the whole sample [24]. Other studies have also found similar results where poorer processing speed and inhibition are associated with slower gait speed [22, 25-28]. Gait control mechanisms and aspects of cognition such as executive functioning have been demonstrated to rely on similar brain areas and functional networks [29-31].

Despite all this evidence, differing results continue to raise questions of whether gait speed decline precedes cognitive decline or vise versa [22, 24, 25, 32]. While certain studies have found that cognitive decline precedes and predicts gait speed decline, others have conversely found that motor function as measured by gait speed declines as much as 12 years before cognition and MCI [22, 25, 33]. The suggested relationship between gait speed and cognition has thus far been that EF synthesizes sensory information and exercises some level of control in coordinating movements

[31]. During dual-task situations such as walking and talking, higher-order cognitive processes are required to sustain performance on two tasks;thus,this results in a decline in gait performance. This is explained on the basis that because attentional resources are used for both cognitive and functional processes, the cognitive resources are not enough to accommodate performance on both tasks simultaneously causing the secondary task to decline in performance [34]. Conflicting results have led to the suggestion that cognition and motor function may not be causally related and are instead associated in that they have a common underlying pathophysiology [22, 24, 35]. Best and colleagues found that baseline 3MS predicted an early change in gait speed, and an early change in gait speed predicted a late change in 3MS. They also found that baseline gait speed was a significant predictor of early and late changes in DSST [22]. These findings, as well as other conflicting results in the literature show that the relationship between gait speed and cognition may not be as simple as one preceding the other, supporting the need for further research.

Age is also an independent variable to predict gait speed. As age increases gait speed declines and has established norms based on age ranges. Age is an unalterable trait, however, age related changes such as muscular strength, balance, and vision can all contribute to the underlying gait speed which are subject to intervention. Height is a variable that is correlated to gait speed as it relates to stride length. Kerrigan et al. showed that with increasing age cadence does not decrease however stride length does. Those that are taller inherently have longer stride lengths and therefore faster gait speed [36, 37]. Weight is another body composition variable that is correlated with gait speed, namely as as it relates to muscle strength. During primary aging there is a decrease in type II muscle fibers and an increase in overall adipose tissue mass resulting in sarcopenia [38]. The result is a decrease in overall strength and leads to further potential decrease in functional ability [39, 40]. A recent study has shown that while muscle morphology is correlated with gait speed, it did not contribute additional predictive ability of fast gait speed over functional strength measures [41].

Other studies have looked at many of the same variables; however, have not looked at cognition concurrently. Trapuzzano et al. has demonstrated the relationships between physical performance, demographics and cognition; though, the population size and variability limit its ability to generalize findings. The present study aims to expand the understanding of cognitions role as a unique predictor of both fast and comfortable gait speed in the community dwelling older adult.

2. Methods

2.1 Participants

This study was a cross-sectional observational design in adults ≥ 60 years of age. Ninety older adults (57 women, mean ± SD age = 75 ± 6 years; 33 men, mean ± SD age = 76 ± 6 years); participated in this study. To be included in this study a participant needed to be 60 years or above and be able to walk at least 20 feet without an assistive device. Participants were excluded for having any neurological, neuromuscular, or musculoskeletal conditions that could impair the ability to perform any of the functional performance tests or follow directions.

Data was collected during the spring of 2019. Participants were recruited from the Learning Institute for Elders at the University of Central Florida. All testing occurred at the Innovative Mobility Initiative (IMOVE™) Lab at UCF and the Neuromuscular Plasticity Lab during a one time visit lasting roughly 90 minutes. Each participant performed the protocol in a quiet and controlled room to decrease external variables. Each investigator performed a series of specified tests that was kept consistent. Each testing protocol is described below. All participants were made aware of the study procedures prior to enrollment. Verbal informed consent was obtained from each participant over the phone prior to their appointment, immediately before the collection of data, and a physical copy was offered to the participant for their records. This study was approved by the University of Central Florida Institutional Review Board (BIO-18-14016).

2.2 Measures

Demographic data was collected during an interview process at the beginning of the session. Participants were asked about their perceptions of overall health, exercise minutes per month, fall history and listed comorbidities. Self-described health status and comorbidities are used as a proxy for overall health status [42]. Other assessments were included into two different blocks based on previous literature; cognitive performance and physical performance [9, 13, 43]. Cognitive Performance measure included the Clock Drawing Test, Trail Making Test - Part B, Digit Symbol Substitution test, simple reaction time, and the NIH toolbox Flanker Test. All tests were performed on pencil and paper except for the Flanker Test and the simple reaction test which was completed on an iPad. Physical Performance measures included the 30 Second Chair Stand test, Functional Reach, Biodex Balance m-CTSIB the Heel Rise test and grip strength. Each block was performed in the same order with cognitive assessments occurring first.

2.2.1 Gait Speed

Gait speed was assessed on a 12-foot GAITRite system (CIR Systems, Inc. Franklin, New Jersey) which is an electronic walkway that assesses spatiotemporal gait variables. Three feet were marked prior to and at the end of the GAITRite to allow for acceleration and deceleration. Participants were asked to walk at their “usual comfortable speed” for a total of two trials that were averaged together. Participants were then asked to complete two trails of their fastest walking speed. Participants were told to “walk as quickly as you can while still maintaining safety.” The average of the two fast trials were also taken.

2.2.2 Balance

Balance was assessed using the Biodex Balance System SD (Biodex Medical Systems, Shirley NY) using their m-CTSIB protocol. The Biodex Balance System SD has been a valid and reliable measure for assessing balance in the older adult [44]. The Biodex Balance System SD uses a sensory integration to assess overall balance under four conditions 1) Flat surface eyes open 2) flat surface eyes closed 3) Foam surface eyes open 4) foam surface eyes closed. A foam pad is provided from the Biodex Balance System SD. Each Participant was asked to stand as still as possible for 30 second during each condition and was given a 10 second rest between conditions as per Biodex protocol. An overall Composite score of the four conditions is reported as a Sway Index that represents a participant’s balance. A higher Sway index score represents more movement during the testing and therefore more unbalanced. Functional Reach was also used to assess a participant’s balance. Functional reach measures a participants limit of stability and follows the protocol of Duncan et al [45]. Participants were instructed to stand close to the wall without touching it and position their arm at 90 degrees of shoulder flexion while making a fist. Zero was recorded from the third metacarpal. Participants were then instructed to "Reach as far forward as you can without taking a step." The final location of the 3rd metacarpal was recorded using a yardstick.

2.2.3 Grip Strength

Grip Strength was used to assess general overall body strength. The test was administered with the participant in a seated position with their elbow flexed to approximately 90°. The handheld dynamometer was explained and demonstrated to participants on use. The handheld dynamometer was placed in the participant's dominant hand. The participant was instructed to squeeze the dynamometer as hard as possible and then relax for 30s between trials. Three trials were conducted. The force was recorded in pounds on the NIH Toolbox. Grip strength was defined as the mean pounds of force over the three trials [46].

2.2.4 30-Second Chair Stand Test

The 30-second chair stand test (30-SCS) is a functional measure test that is used to measure the participants lower body strength and ability to perform high demand daily activities [47]. The 30SCS has been correlated to a maximum weight leg press r=0.78 in men and r=.71 in women [47]. The 30-SCS assessed lower-extremity strength by counting the number of full stands from a standard 17-inch chair without use of arms from a seated position in 30 seconds [47]. If a participant was unable to complete a single repetition without the use of hands, a score of zero was recorded.

2.2.5 Flanker

The Flanker Inhibitory Control Test was used to assess cognitive inhibition, executive function and attention of the participant [48]. The Flanker Test was administered using the NIH Toolbox ® application with an Apple iPad. Flanker test provides a measure of inhibitory control in the context of visual selective attention [49]. The participant is asked to indicate the left–right orientation of the central stimulus while simultaneously inhibiting two potentially incongruent stimulus surrounding the central stimulus. Scoring is based on a combination of accuracy and reaction time both on a scale 0f 0-5. Accuracy is considered first for an individual. If accuracy levels are 80% or less than the final "total" computed score is equal to the accuracy score [50]. If accuracy level is more than 80%, the reaction time score and accuracy score are combined. Higher scores indicate higher levels of ability to react to relevant stimuli and inhibit attention from irrelevant stimuli. The NIH Toolbox produces a few normative scores, this study used the uncorrected T-score which compares the score of the test taker to the entire population of adults not accounting for any variable.

2.2.6 DSST

The Digit Symbol Substitution Test (DSST) is a paper and pencil test used for psychomotor performance [51]. Participants are given a key grid of numbers and the matching symbols below. The test section has rows of numbers and empty boxes. The test consists of filling as many empty boxes as possible with a symbol matching each number. The test time is 90 seconds in duration. The DSST requires participants to use sequential short term memory to encode the number in the test region and search for the corresponding symbol and in return encode the symbol for short term memory use. The DSST is scored by number of correct responses in a standardized 90 second time.

Higher scores on the DSST demonstrate higher psychomotor performance. DSST has also been inversely correlated with morbidity and mortality as well as correlated with gait speed [52].

2.2.7 Clock Draw

The Clock Drawing Test is a paper and pencil test used for screening for cognitive impairment and dementia. Participants are given a sheet of paper with a pre-drawn circle and asked to draw the numbers on the clock face, and subsequently draw the hands of the clock at a fixed time. Clock draw requires participants to utilize their memory, visuospatial skills, and constructive skills. The Clock Drawing test is scored by the method of Watson and Colleagues with the clock divided into four quadrants through the center of the clock and 12 then a perpendicular line bisecting the first. Each quadrant is then counted for total numbers inside the qudrant which should result in three. If there is an error in qudrants 1-3 starting from the top right and moving clockwise will result in 1 point of an error. If quadrant 4 has an error than 4 point will be given. The higher scores on the Clock Draw test indicate greater cognitive impairment [53].

2.2.8 Trail-Making

The Trail-Making Test – Part B is a paper and pencil test used as a measure of cognitive flexibility, also referred to as set-shifting. Participants are given a sheet of paper with different numbers and letters printed on it and are asked to connect the numbers and letters in order in an alternating fashion (number, letter, number). The Trail-Making Test – Part B is scored by time to completion. With less time indicating high cognitive flexibility.

2.2.9 Simple Reaction Time

Simple reaction time was measured in milliseconds using the Psych101 iPad app. Simple reaction time was scored by the time required to touch the iPad after a visual stimulus.

A smaller number for simple reaction time indicates better/faster reaction time.

2.3 Statistical Analysis

Data were entered in the SPSS Statistical Software (Version 22.0, IBM Statistics) for analysis. Bivariate correlation analyses (Pearson's *r*) were used to determine the level of association between the demographic, performance, cognitive, and self-report variables. The results from this analysis determined the independent variables used in the hierarchical linear regression models. The authors of this study analyzed the correlation data and unanimously decided on variables based on past research findings, theoretical constructs, and strength of correlation to include in the nested hierarchical linear regression models. Three nested hierarchical linear regression models were created to examine the association of the independent variables with comfortable and fast gait speeds. The final models were constructed with functional performance measures, cognitive measures, and demographic information (gender, self-reported comorbidities and exercise minutes per month). Some variables that were correlated with fast or comfortable gait speed were not included in the regression models. Multicollinearity was also addressed between independent variables as they may weaken the overall analysis [54]. Variables with bivariate correlations of *r* greater than 0.70 would be limited to one of the variablesto maintain adequate power of analysis.

This statistical approach was chosen to better understand the interplay between constructs of functional performance, cognition and demographicson usual and fast gait speeds. The alpha value was set at 0.05 for all statistics.

3. Results

The participant characteristics are presented in Table 1. The average age of the participants was 73 years (SD 6.1) and 63% were female. This sample demonstrated a highly educated group with 87 having graduated college and 47 of those college graduates having higher than a bachelor's degree. The participants in the study had an average comfortable gait speed of 1.12 m/s (SD 0.12) and an average fast gait speed of 1.82 m/s (SD 0.32). Mean scores for the ABC Scale was 92 percent (SD 7 percent). The mean ABC score for this population indicated that the sample overall were confident that they would not fall while performing activities [55]. The mean score for the MMSE was 26 (SD 2.4). The mean comorbid health conditions was 2 and mean exercise minutes per week was 268 (SD 194).

Table 1 Descriptive Statistics (N=90).

Variable (unit)	Mean (SD)	Range
Age (years)	73	60-88
Comorbid health conditions	2	0-6
Exercise (minutes/week)	269 (195)	0-900
Height (in)	66 (4)	59-76
Weight (lbs)	161 (36)	93-330
MMSE (total)	26 (2)	19-30
Functional Reach (in)	12 (2.7)	4.2- 19
Comfortable Gait Speed (cm/sec)	113 (21)	54-161
Fast Gait Speed (cm/sec)	183 (33)	81-308
Biodex mCTSIB (Avg Sway Index)	1.6 (0.29)	1.0-2.3
ABC (percent)	92 (7.8)	56-100
30SCS (number of stands)	12 (4.3)	0-28
TMT	89 (37)	40-217
DSST (number completed)	49 (9.8)	29-74
RT (milliseconds)	306 (38)	216-401
RT (number of Trials)	72 (7.6)	20-75
Grip Dominant (lbs)	59 (21)	30-124

MMSE; Mini-Mental Status Exam, mCTSIB; Modified Clinical Test of Sensory Integration, ABC; Activity Specific Balance Confidence Scale, 30SCS; 30 seconds Chair Stand Test, TMT; Trial Making Test, DSST; Digit Symbol Substitution Test, RT; Reaction time.

Bivariate correlation coefficients are represented in Table 2. Comfortable gait speed was significantly associated with demographic data of age, height, and weight, self-reported health, performance measures of balance (Biodex m-CTSIB) and 30-SCS test, but only the DSST for cognitive measures. Fast gait speed significantly correlated with age, self-reported health, all physical performance measures, and cognitive measures that include DSST, RT, and Flanker test.

Table 2 Pearson Correlation Matrix (N=90).

Variable	Comfortable Gait speed (cm/sec)	Fast Gait Speed (cm/sec)
Gender	.213[b]	0.155
Overall Health	.243[b]	0.203
Age	-.330[a]	-.416[a]
Comorbid health conditions	-.392[a]	-.286[a]
Exercise (mins/ week)	.264[b]	.214[b]
Height (in)	-.223[b]	0.165
Weight (lbs)	-.290[a]	-0.059
Flanker Uncorrected	0.185	.219[b]
Reaction Time	-0.131	-.323[a]
Digit Symbol Substitution Test (number Completed)	.295[a]	.222[b]
Trail Making Test	-0.094	-0.079
Grip Dominant (lbs)	0.036	.336[a]
Biodex mCTSIB Sway Index	-.214[b]	-.408[a]
ABC Percentage	.483[a]	.460[a]
30-Second Chair Stand	.427[a]	.491[a]

Notes: [a]*p < .01,* [b]*p < .05*

Hierarchical linear regressions are represented in Tables 3 and 4 for comfortable gait speed and fast gait speed respectively. Functional performance measures explained 17% of the variance (adjusted r^2) for comfortable gait speed. The addition of cognitive measures did not significantly contribute to the prediction of comfortable gait speed. Model 3 added in demographic data of gender and comorbid health conditions which significantly added to the predictors of comfortable gait speed (F Change = 4.682; p = 0.005). The full model (model 3), included functional performance, cognition, and demographic information, explained 27% of the variance (adjusted r^2) in comfortable gait speed. Unique predictors remaining in the full model for comfortable gait speed included 30 SCS (B = 1.13, β = 0.233, P< .05), Comorbid health (B = −2.95, β = −0.22, P < 0.05), and gender(B = 8.28, β = 0.19, P < .05). This indicates that individuals who demonstrated greater lower extremity strength, had few comorbidities, and were male were able to walk faster at a comfortable pace. When looking at fast gait speed 35% of the variance was explained by physical performance measures (adjusted r^2) specifically the 30SCS, FR, and the Biodex Balance m-CTSIB. Cognitive measures or demographic data did not significantly add to the overall variance of fast gait speed. Unique predictors remaining in the full model (Model 3) of fast gait speed included 30 SCS (B = 1.96, β = 0.26, P < .05), FR (B = 2.45, β = 0.20, P < .05), Biodex Balance mCTSIB (B = −25.29, β =−0.22, P < .05). This indicates that individuals had greater lower extremity strength, and better balance walked faster in the fast gait speed condition.

Table 3 Hierarchical Linear Regression Summary for Comfortable Gait Speed (cm/s) (N= 90).

Independent Variable	Comfortable Gait Speed					
	R^2	*R*^{2} Change	Adjusted *R*^{2}	Unstandardized B (Standard Error)	Standardized βeta	*P*
Model 1	0.189	0.189	0.17			
Biodex mCTSIB Sway Index				-6.266 (7.446)	-0.086	0.402
30-SCS				1.94 (0.495)	0.399	0.001
Model 2	0.207	0.018	0.179			
Biodex mCTSIB Sway Index				-4.685 (7.495)	-0.064	0.534
30-SCS				1.706 (0.521)	0.351	0.002
DSST completed				0.313 (0.226)	0.145	0.17
Model 3	0.321	0.115	0.272			
Biodex mCTSIB Sway Index				-5.717 (7.102)	-0.078	0.423
30-SCS				1.132 (0.531)	0.233	0.036
DSST completed				0.302 (0.219)	0.14	0.172
Gender				-8.284 (4.001)	-0.19	0.041
Comorbid Health Conditions				-2.95 (1.382)	-0.216	0.036
Exercise Min/week				0.016 (0.011)	0.146	0.141

Notes: mCTSIB, Modified Clinical Test of Sensory integration and Balance; 30-SCS, 30 Second Chair Stand Test; DSST complete, Digit Symbol Substitution Test number completed

Table 4 Hierarchical Linear Regression Summary for Fast Gait Speed (cm/s) (N=90).

Independent Variable	Fast Gait Speed					
	R^2	*R*^{2} Change	Adjusted *R*^{2}	Unstandardized B (Standard Error)	Standardized β	*P*
Model 1	0.381	0.381	0.352			
Grip Dominant (lbs)				0.28 (0.14)	0.18	0.052
Functional Reach (average)				2.21 (1.08)	0.18	0.044
30SCS				2.60(0.70)	0.35	0
Biodex mCTSIB Sway Index (average)				-26.29 (10.76)	-0.23	0.017
Model 2	0.382	0.001	0.337			
Grip Dominant (lbs)				0.28 (0.15)	0.18	0.055
Functional Reach (average)				2.18 (1.09)	0.18	0.05
30SCS				2.54 (0.75)	0.34	0.001

Biodex mCTSIB Sway Index (average)				-25.31 (11.23)	-0.22	0.027
Flanker Uncorrected				0.15 (0.53)	0.03	0.771
DSSTCompleted				0.04 (0.33)	0.01	0.905
Model 3	0.406	0.024	0.347			
Grip Dominant (lbs)				0.28 (0.14)	0.18	0.058
Functional Reach (average)				2.45 (1.10)	0.20	0.028
30SCS				1.96 (0.81)	0.26	0.018
Biodex mCTSIB Sway Index (average)				-25.29 (11.16)	-0.22	0.026
Flanker Uncorrected				0.12 (0.52)	0.02	0.816
DSST Completed				0.10 (0.33)	0.03	0.771
Comorbid health conditions				-2.57 (2.06)	-0.12	0.215
Exercise (Mins/ week)				0.02 (0.02)	0.09	0.342

Notes: mCTSIB, Modified Clinical Test of Sensory integration and Balance; 30-SCS, 30 Second Chair Stand Test; DSST complete, Digit Symbol Substitution Test number completed

4. Discussion

Normal comfortable gait speed has been reported to be in the range of 1.13 - 1.52 m/s for men and 1.06 - 1.48 m/s for females within the age range of 70-79 [56]. Normal fast gait speed has been reported between 1.71 - 2.44 m/s for men and 1.46 - 2.03 m/s for females (70-79 years of age) [56]. Our sample demonstrates they are within the normal ranges for both comfortable and fast gait speed. The mean ABC score for this population indicated that the sample overall were confident that they would not fall while performing activities [55]. The mean MMSE demonstrating overall good cognitive ability and ability to follow directions [57]. Given the average reported exercise minutes reported and comorbid health conditions demonstrated this sample was active and relatively healthy. Overall, the sample population represents an older, highly educated, and healthy sample.

This research adds to the body of knowledge on understanding the unique properties of both comfortable and fast gait speeds. The primary objective of this paper was to continue to shed light on the variables that contribute to gait speed. This study revealed that comfortable gait speed is predicted by physical performance on the 30SCS, Gender, and premorbid conditions while fast gait speed is predicted by physical performance on the 30SCS, and Balance measures.

In accordance with previous literature physical performance on the 30SCS continues to be a strong predictor of both comfortable and fast gait speeds. Knee extensor, hip extensor, and plantar flexor strength have all been shown to be factors for lower extremity strength and is normally assessed with handheld dynamometry [15]. The 30SCS is a functional tool that requires the use of knee extensors and hip extensors to perform. The association between 30SCS and Lower extremity strength is well established and can be used as a tool for assessment when there is a gait speed deficit [47, 58].

Age is still correlated with gait speed but underlying factors of age related change is largely what these authors attribute this relationship to. Chronological age classifications has little meaning to the overall construct and therefore was left out of the regression models. Age related changes were likely going to be explained in other variables measured. Comorbid health conditions were significant in predicting comfortable gait speeds. Examples of the health conditions asked was high blood pressure, arthritis, back problems, diabetes and so on. Many of the health conditions can be amenable to intervention and promotion of a healthy lifestyle. It is important for a clinician to have an understanding of a participants health condition as it is a predictor of their usual gait speed.

Balance has not been studied as much as lower extremity strength however data does indicate balance as a predictor of gait speed. Previous studies have shown the maximum distance between an anterior sway and posterior sway with eyes closed as being a factor of fast gait speed [18]. Mantel et al. has shown the limits of stability as a factor for both comfortable and fast gait speeds. This study included both postural sway and limits of stability as indicators for balance as these variables are different. Results show that balance measures were predictive in fast gait speed but not comfortable gait speed. England et al. demonstrated that at faster walking velocities hip, knee and ankle joints are less stable requiring more neuromuscular control [16]. Factors that affect the dynamic stability with increasing speeds are a decrease in double limb support time, decreased step width, and increased segmental moments all requiring greater demands from the neuromuscular system to attenuate those disturbances.

This data reveals a different picture than what previous studies have found when it comes to cognitive testing. Physical performance measures continued to demonstrate as strong predictors of both comfortable and fast gait speed; the relationship between cognitive measures and gait speed remains difficult to interpret. A previous study has shown that cognitive function was predictive of gait speed, specifically executive function for comfortable gait speed and processing speed in fast gait speed [59]. In the present study, while cognitive measures were significantly associated with gait speed, they did not significantly account for the variance in performance for both comfortable and fast gait speed. This is perplexing and is suspected by the authors of this paper to be due to the cognitive health and education level of the population sample. This population, unlike previous studies, had a higher level of academic achievement. 87 of the 93 participants have graduated college with a bachelors or higher, leading to the possibility of a cognitive protective effect. Because this sample population has a high cognitive load, deficits in gait speed could be masked by the high cognitive reserve. More sensitive cognitive testing may be needed to examine a population with a higher education background. Future research using transcranial magnetic stimulation could lead to a better understanding of cognitive function and gait speed. These findings are supported by other research demonstrating that functional tasks requiring greater reserve are more sensitive to the relationship between motor function and cognition [22].

4.1 Future Directions

As previously discussed, processing speed has been demonstrated to be associated with gait speed, though the nature of the relationship remains poorly understood [22, 25]. Recently, it has been suggested that gait and cognitive function may not have a causal relationship but instead may be related on a physiological level [22, 24, 35]. Processing speed is the rate at which cognitive tasks are performed by an individual, suggesting that it may be based on neural architecture and therefore measurable as central motor conduction time. Future research using transcranial magnetic stimulation to measure central motor conduction time could lead to a better understanding of the relationship between cognitive functions such as processing speed and gait speed.

4.2 Limitations

This study is not without its limitations. The sample for this study was largely homogenous made up of mostly well-educated white women. The generalizability of these study results is limited due to the nature of the study population.

4.3 Conclusion

This research continues to demonstrate that comfortable and fast gait speeds are predicted by performance measures of strength. However, fast and comfortable gait speeds do not have the same constructs, and both should be measured in a clinical setting. Strength and balance are major predictors for fast gait speed and continued studies of direct measures of risk are warranted. More research needs to be conducted to further understand the impact of cognitive function on gait speed and whether intervention can impact this variable.

Author Contributions

AP: Data collection, manuscript preparation; LS: Manuscript preparation; AT: Research methodology and design, data collection, manuscript preparation; MS: Research methodology and design, data collection, data analyses; ND: Research methodology and design, data collection, data analyses, manuscript preparation.

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Competing Interests

The authors have declared that no competing interests exist.

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