Journal of Frailty, Sarcopenia and Falls

Original Article

# Balance performance and grip strength as predictors of cognitive function among community-dwelling older adults in the USA

**Jennifer Blackwood[1], Reza Amini[2], Gerry Conti[3], Quinn Counseller[3], Rebekah Taylor[3], Deena Fayyad[4]**

[1]*Physical Therapy Department, University of Michigan-Flint, Flint, Michigan, USA;*
[2]*Department of Public Health and Health Sciences, University of Michigan-Flint, Flint, Michigan, USA;*
[3]*Occupational Therapy Department, University of Michigan-Flint, Flint, Michigan, USA;*
[4]*Department of Psychology, University of Michigan, Ann Arbor, Michigan, USA*

**Abstract**

**Objectives**: To investigate how balance and grip strength predicts the probability of cognitive function impairment (i.e., executive function: mild and mild-to-moderate impairment, and delayed recall) over eight years in community-dwelling older adults in the US, controlling for sex and race/ethnicity. **Methods**: The National Health and Aging Trends Study dataset (2011 – 2018) was employed. Dependent variables included the Clock Drawing Test (Executive Function) and Delayed Word Recall Test. Longitudinal ordered logistic regression examined the association between cognitive function and predictors (i.e., balance and grip strength) over eight waves (n=9800, 1,225 per wave). **Results**: Those who could complete side-by-side standing and semi-tandem tasks were 33% and 38% less likely to have mild or mild-to-moderate executive function impairment, respectively, relative to those who could not complete these tests. One score decrease in grip strength increased the executive function impairment risk by 13% (Odds Ratio: 0.87, CI: 0.79-0.95). Those who completed the side-by-side tasks were 35% (Odds Ratio: 0.65, CI: 0.44-0.95) less likely to experience delayed recall impairments than those who could not complete this test. With one score decrease in grip strength, the risk of delayed recall impairment was increased by 11% (OR: 0.89, CI: 0.80-1.00). **Conclusions**: A combination of these two simple tests (i.e., semi-tandem stance and grip strength) can screen for cognitive impairment among community-dwelling older adults to identify people with mild and mild-to-moderate cognitive impairment in clinical settings.

**Keywords:** Cognition, Memory, Health, Postural stability, Successful aging



## Introduction

In 2018, it was estimated that 5.7 million Americans aged 65 years and older had Alzheimer's disease or related dementias (ADRD), which will double in the next few decades[1]. Of these, the number of Americans with mild cognitive impairment (MCI) is expected to increase nearly three-fold from 6.1 million, 12-18% of adults 60 years or older, in 2017 to 15.0 million by 2060[2]. Of those with MCI, 10-15% progress to dementia at a rate of 7.1% per year[3,4]. This increasing trend of MCI cases will increase both direct medical costs, such as hospitalization, physician visits, and long-term care[5], and indirect costs, such as caregiver support[6]. Considering the growing number of people with MCI, especially those remaining undiagnosed for a long time, it is critical to identify these cases in the early stages to prevent the progression of diseases and possible consequences, such as falling and repeated hospital admission[5].

A growing body of literature describes relationships

*The authors have no conflict of interest.*

***Corresponding author:*** *Reza Amini, 303 E Kearsley Street, Flint, Michigan, USA 48502*

***E-mail:*** *dramini@umich.edu*

***Edited by:*** *Dawn Skelton*

***Accepted*** *19 January 2023*

between cognitive function and aspects of physical function (mobility, balance, and grip strength) in older adults[7]. Lower levels of cognitive function (CF) and increased risk of dementia have been associated with a greater prevalence of physical impairments[8] and diminished functional independence[6,9]. In older adults with MCI (i.e., impairment in one or more CF domains), decreases in standing balance are frequently reported without impacting daily function[10-12].

Older adults with better mobility (i.e., gait, lower extremity function, and balance) have been found to also perform better on measures of processing speed and global cognition: executive function (EF) and memory[7]. Nonetheless, EF has the strongest reported associations with mobility when compared to other cognitive domains[13]. Similarly, as balance and mobility decline, EF may become more impaired in older adults, leading to a greater chance of developing dementia. Additionally, impaired motor performance can predict cognitive decline in older adults[14]. Handgrip strength is also associated with cognitive function. A scoping review of 15 longitudinal studies of adults over 60 years of age reported that cognitive loss with advancing age might be predicted by reduced handgrip strength over time[15]. Among those participants over 80 years of age impaired memory and spatial ability are significantly associated with decreased handgrip strength[16].

As declines in both cognitive and physical function may occur along the age continuum, and strong evidence exists describing the association between cognitive and physical performance[7,17,18], the long-term trajectory of cognitive decline in comparison to changes in balance and grip strength has not been well described[19]. The primary purpose of this study was to examine relationships between measures of balance performance, grip strength, and cognitive function (as shown with EF and delayed recall) over an eight-year period in community-dwelling older adults with and without mild cognitive impairment, using the National Health and Aging Trends Study data.

## Methods

Longitudinal secondary data from the National Health and Aging Trends Study (NHATS) 2011-2018 were used. NHATS collects data from Medicare beneficiaries aged 65 years and older in different stages, starting with selecting counties or a group of counties; then, within each county, ZIP codes were selected using a publicized sampling strategy[20]. The de-identified dataset is publicly available; we received and used the sensitive data (i.e., sex, race/ethnicity, and age) in a separate inquiry. Each participant has a unique sample person identification number across all waves.

Inclusion criteria: Living in the United States, 65 and older, Medicare beneficiary.

After appending eight (2011-2018) datasets, we used the sample person identification number and year (time-variable) to balance the dataset, meaning that all the participants remaining in the data had participated in all eight years (waves), and were aged 65 to 95, (n=9800, 1,225 per wave); then, we created global variables (i.e., dependent, independent, and control variables) using year and sample person identification number.

Exclusion criteria: Those participants older than 95 years old, participants that did not participate in all eight waves, participants living in residential care facilities, and those with moderate, severe, and very severe CDT were excluded from the data.

Memory was assessed using the Delayed Word Recall Test (DWRT), which provides clinically predictive values for MCI and Alzheimer's disease or related dementias[10], with 94% sensitivity and 85% specificity[21]. For this assessment, ten nouns were displayed on a computer screen and read to participants, who were instructed to remember as many as they could. The participants then completed another cognitive measure, the Clock Drawing Test. After approximately two minutes intervals between the immediate word recall test, the participants were asked to recall as many words as possible from the list. The number of correctly recalled words was recorded per person. Memory impairment was based on the number of words participants recalled and categorized into three levels: 0-4 (severe), 5-6 (mild), and seven or more (normal)[22].

The Clock Drawing Test (CDT) is a widely used, reliable, and valid test of EF (68.8% sensitivity and 84.2% specificity)[23]. Participants were given two minutes to draw the face and hands of a clock showing a specific time (i.e., 'ten minutes past eleven')[24]. Each clock test was scored from zero to five, where zero indicated very severe impairment and five indicated no EF impairment, and then scores were reverse-coded (i.e., zero: normal, 1: mild, 2: mild-to-moderate,3: moderate, 4: severe, 5: very severe impairment).

Balance was assessed using measures of side-by-side, semi-tandem, single-leg stance, and tandem stance times, all reliable measures from the SPPB[25]. Participants were required to stand unsupported for ten seconds with their eyes open in each position. Participants who attempted and completed the test were considered "completed" (1), whereas those who attempted and did not complete the test or were not qualified to attempt the test due to safety reasons were considered "not-completed" (0)[26].

Grip strength was measured by having participants squeeze a digital handheld dynamometer at their maximal effort while seated with the arm at their side and elbow bent at 90 degrees, which is a valid and reliable method[27,28]. The best score of three trials on each side was recorded. Grip strength was categorized into five levels: zero ("Not eligible, Not attempted for safety reasons; Attempted, but not completed"), one (<19.5 kg), two (19.51-25.30 kg), three (25.31-34.00 kg), and four (>34.01 kg)[26]. Those with zero scores were excluded from the regression model.

The Functional Comorbidity Index (FCI) was used to categorize comorbidity levels. One point each was allocated if participants reported having arthritis, osteoporosis, lung

| | | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|
| | | N (%) | N (%) | N (%) | N (%) | N (%) | N (%) | N (%) | N (%) |
| Executive Function† | Normal | 349 (28.49) | 412 (33.63) | 379 (30.94) | 554 (45.22) | 511 (41.71) | 523 (42.69) | 468 (38.20) | 571 (46.61) |
| | Mild | 628 (51.27) | 627 (51.18) | 673 (54.94) | 483 (39.43) | 560 (45.71) | 564 (46.04) | 586 (47.84) | 480 (39.18) |
| | Mild-Moderate | 248 (20.24) | 186 (15.18) | 173 (14.12) | 188 (15.35) | 154 (12.57) | 138 (11.27) | 171 (13.96) | 174 (14.20) |
| Delayed Recall | Normal | 107 (8.73) | 138 (11.27) | 138 (11.27) | 140 (11.43) | 146 (11.92) | 128 (10.45) | 125 (10.20) | 109 (8.90) |
| | Mild | 462 (37.71) | 471 (38.45) | 461 (37.63) | 462 (37.71) | 433 (35.35) | 456 (37.22) | 414 (33.80) | 397 (32.41) |
| | Severe | 656 (53.55) | 616 (50.29) | 626 (51.10) | 623 (50.86) | 646 (52.73) | 641 (52.33) | 686 (56) | 719 (58.69) |
| Side by Side | Not completed | 16 (1.34) | 32 (2.66) | 38 (3.19) | 57 (4.77) | 49 (4.03) | 63 (5.20) | 78 (6.45) | 92 (7.65) |
| | Completed | 1182 (98.66) | 1172 (97.34) | 1153 (96.81) | 1138 (95.23) | 1167 (95.97) | 1149 (94.80) | 1132 (93.55) | 1110 (92.35) |
| Semi-Tandem | Not completed | 61 (5.14) | 55 (4.67) | 62 (5.36) | 85 (7.48) | 73 (6.24) | 78 (6.78) | 101 (8.90) | 125 (11.19) |
| | Completed | 1125 (94.86) | 1122 (95.33) | 1094 (94.64) | 1051 (92.52) | 1097 (93.76) | 1073 (93.22) | 1034 (91.10) | 992 (88.81) |
| Full-Tandem | Not completed | 257 (22.76) | 259 (23.00) | 267 (24.41) | 271 (25.86) | 296 (27.16) | 332 (30.88) | 336 (32.28) | 372 (37.27) |
| | Completed | 872 (77.24) | 867 (77.00) | 827 (75.59) | 777 (74.14) | 794 (72.84) | 743 (69.12) | 705 (67.72) | 626 (62.73) |
| Single-Leg Eye Open | Not completed | 607 (68.67) | 626 (71.06) | 596 (71.46) | 561 (72.29) | 601 (75.22) | 563 (75.37) | 551 (77.28) | 518 (80.31) |
| | Completed | 277 (31.33) | 255 (28.94) | 238 (28.54) | 215 (27.71) | 198 (24.78) | 184 (24.63) | 162 (22.72) | 127 (19.69) |
| | | Mean (SD) | Mean (SD) | Mean (SD) | Mean (SD) | Mean (SD) | Mean (SD) | Mean (SD) | Mean (SD) |
| Grip Strength[1-4] | | 2.69 (1.08) | 2.65 (1.09) | 2.68 (1.08) | 2.62 (1.08) | 2.55 (1.09) | 2.48 (1.07) | 2.46 (1.09) | 2.40 (1.08) |
| FCI§ | | 2.83 (1.69) | 2.85 (1.58) | 2.91 (1.64) | 3.03 (1.67) | 3.15 (1.64) | 3.29 (1.74) | 3.38 (1.70) | 3.52 (1.74) |
| BMI, kg/m²§§ | | 28.24 (5.64) | 28.15 (5.63) | 28.08 (5.59) | 28.09 (5.64) | 27.99 (5.62) | 27.90 (5.65) | 27.75 (5.59) | 27.60 (5.46) |

***Notes***. *†Clock Drawing Test was used; §FCI: Functional Comorbidity Index, §§BMI: Body Mass Index; NHATS: National Health and Aging Trend Study; SD: Standard Deviation.*

**Table 1.** Executive function, delayed recall, grip strength, balance, and control variables among community-dwelling older adults (NHATS 2011-2018).

disease, hearing problem, heart disease, heart attack, diabetes mellitus, back pain, visual impairment, depression (PHQ-2), anxiety (GAD-2), or obesity (BMI>29.9 kg/m²). FCI scores ranged from zero (no comorbidity) to 12.

Self-reported years of education were coded from one to five as grade level 0-8, high school and high school diploma, vocational and some college degree, Bachelor's degree, and graduate degrees, respectively. Race/ethnicity was categorized as non-Hispanic White, African American, Hispanic, and others.

### *Statistical Analyses*

Employing Stata 16.0 SE, we composed a global variable for each of the dependent, independent, and control variables

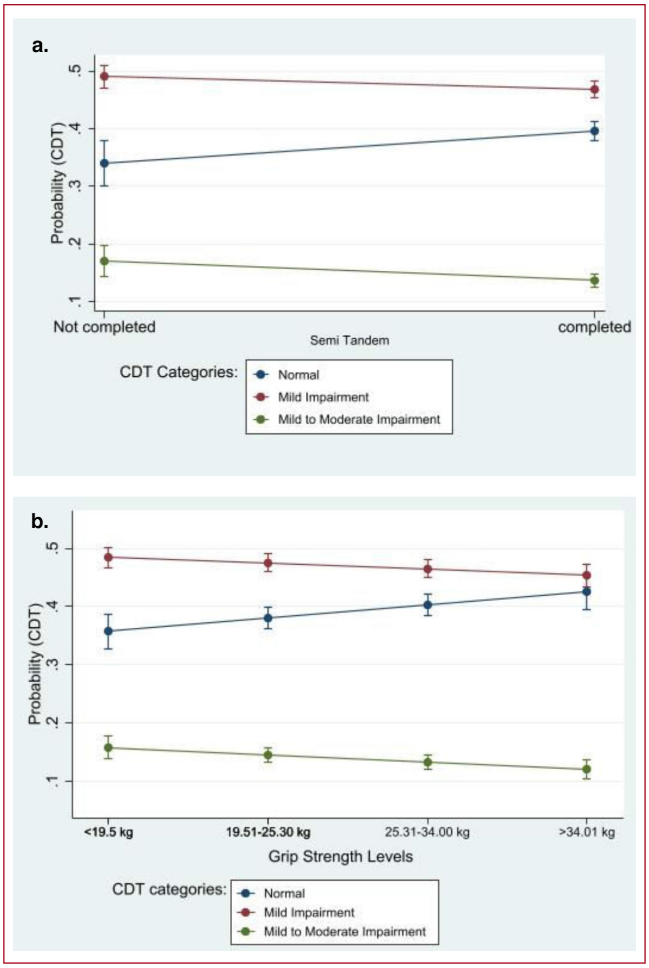


**Figure 1.** Predictive Margins of Clock Drawing Test (CDT) a) by Semi Tandem with a 95% Confidence Interval b) by Grip Strength with a 95% Confidence Interval.

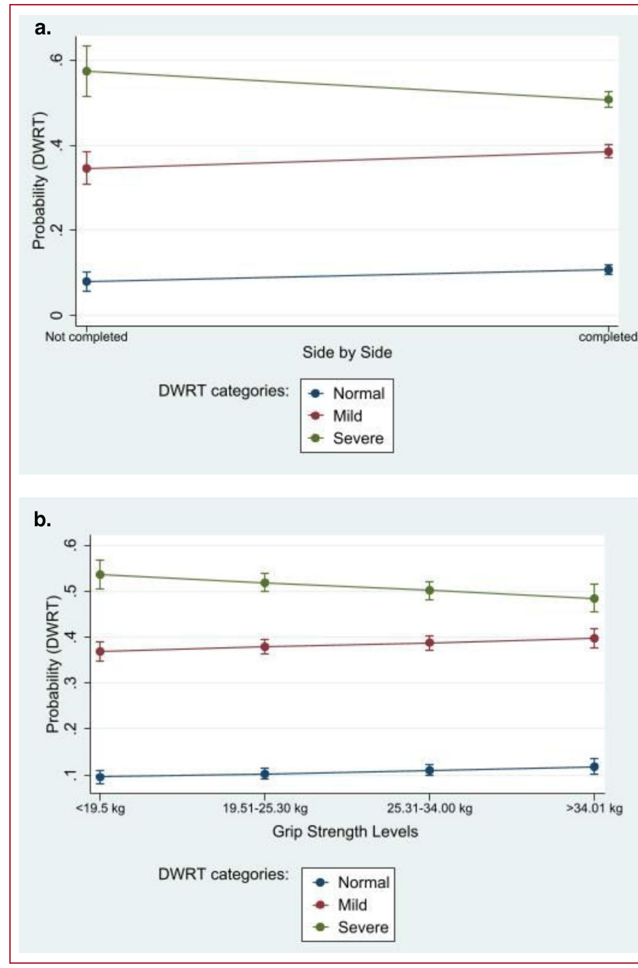


**Figure 2.** Predictive Margins of Delayed Word Recall TEST (DWRT) a) by Side by Side with a 95% Confidence Interval b) by Grip Strength with a 95% Confidence Interval.

(i.e., FCI, BMI, age, education, race/ethnicity, sex, and year) based on the sample person identification number and year of participation. Using that data, we first described CF and grip strength categories and the percentage of the participants, by year, who were able to complete the balance measures. The maximum mixing value was 352 for FCI in 2012.

Analysis of Variance was used for the baseline (2011) data to examine the correlation between balance or grip strength and CF (i.e., CDT and delayed recall). Only those domains that were statistically correlated with CDT and delayed recall (in separate models) were entered into the regression models.

Since the dependent variables (CDT and DWRT) were ordinal variables, longitudinal ordinal logistic regression was used in stepwise models. The balance variables (i.e., side-by-side stance, semi-tandem balance, and tandem balance) and grip strength were entered into the models individually to determine the significance of each of the predictor variables. The multicollinearity of the predictors was tested, using tolerance (1/variance inflation factor), before they were entered into the models, and only the predictor variables that were not significantly correlated with one another (tolerance>0.1) remained in the models.

## Results

The average age of the participants was 74.19 years in 2011. More than half (57.71, n=707 in each wave) of the participants were women, 81.96% (n=1,004) non-Hispanic White, 13.22% (n=162) African American, 3.27% (n=40) Hispanic, and 1.55% (n=19) of other races/ethnicities in each wave. The majority of participants had high school education (33.61%, n=411 in each wave), followed by vocational/associate degree (27.47%, n=336), Bachelor's degree (16.35%, n=200), master's or higher degree (18.56%, n=227), and 0-8 grade (4.01%, n=49).

CDT results indicated that approximately 28.5%, 51.3%,

| CDT | | Model 1: Side by Side N=6,157 | | Model 2: Semi-Tandem N=5,941 | | Model 3: Side by Side, Semi-Tandem N=5,936 | |
|---|---|---|---|---|---|---|---|
| | | OR (SE) | 95% CI | OR (SE) | 95% CI | OR (SE) | 95% CI |
| Side by Side | | 0.67 (0.11) * | 0.49 – 0.91 | - | - | 0.86 (0.47) | 0.29 – 2.52 |
| Semi-Tandem | | - | - | 0.72 (0.08) ** | 0.57 – 0.90 | 0.72 (0.08) ** | 0.57 – 0.91 |
| Grip | | 0.87 (0.04) ** | 0.79 – 0.95 | 0.88 (0.04) ** | 0.80 – 0.97 | 0.88 (0.04) ** | 0.80 – 0.97 |
| FCI | | 1.02 (0.02) | 0.97 – 1.07 | 1.01 (0.02) | 0.97 – 1.06 | 1.01 (0.02) | 0.97 – 1.06 |
| BMI | | 0.99 (0.01) | 0.98 – 1.01 | 0.99 (0.01) | 0.98 – 1.01 | 0.99 (0.01) | 0.98 – 1.01 |
| Age, years | | 1.05 (0.01) *** | 1.03 – 1.07 | 1.05 (0.01) *** | 1.04 – 1.07 | 1.05 (0.01) *** | 1.03 – 1.07 |
| Education | | 0.68 (0.03) *** | 0.63 – 0.73 | 0.68 (0.03) *** | 0.63 – 0.74 | 0.68 (0.03) *** | 0.63 – 0.74 |
| Race/Ethnicity§ | Hispanic | 1.25 (0.32) | 0.76 – 2.07 | 1.21 (0.32) | 0.73 – 2.02 | 1.21 (0.32) | 0.73 – 2.02 |
| | African Americans | 2.81 (0.37) *** | 2.17 – 3.65 | 2.68 (0.36) *** | 2.06 – 3.48 | 2.65 (0.36) *** | 2.03 – 3.46 |
| | Others | 1.65 (0.62) | 0.79 – 3.44 | 1.70 (0.65) | 0.81 – 3.59 | 1.71 (0.65) | 0.81 – 3.59 |
| Women | | 0.64 (0.07) *** | 0.52 – 0.81 | 0.65 (0.08) *** | 0.52 – 0.82 | 0.66 (0.08) *** | 0.52 – 0.82 |
| Year | | 0.84 (0.01) *** | 0.82 – 0.86 | 0.84 (0.01) *** | 0.81 – 0.86 | 0.84 (0.01) *** | 0.81 – 0.86 |
| | | Log Likelihood=-5571.29 Chi$^2$= 343.62*** | | Log Likelihood=-5367.87 Chi$^2$= 332.67*** | | Log Likelihood=-5363.82 Chi$^2$= 329.84*** | |

***Notes***. *Longitudinal Ordered Logistic Regression, eight waves of data from 2011 to 2018. CDT: Clock Drawing Test; FCI: Functional Comorbidity Index; BMI: Body Mass Index; OR: Odds Ratio; CI: Confidence Interval; SE: Standard Error. § Non-Hispanic Whites were the reference group. *p<0.05, **p<0.01, ***p<0.001*

**Table 2.** Semi-Tandem and grip strength predict Executive Function among community-dwelling older adults.

and 20.2% of the participants had normal EF, mild, and mild-to-moderate EF impairment, respectively, in 2011 (Table 1). Testing the chance of transition from one state to another showed that the possibility of participants remaining at the same level of impairment across all eight waves (2011-2018) was 57%, 54.8%, and 34.3%, respectively. The risk of progression from mild to mild-to-moderate EF impairment was approximately 13%.

For the DWRT, 8.7% of the participants had normal, 37.7% mild, and 53.55% severe recall impairment in 2011 (Table 1). Among participants with a normal DWRT, the chance of remaining normal was 39.7%. For mild and severe cases, this chance was 49% and 71.7%, respectively. The risk of transition from normal to mild and severe were 45% and 15.4%, respectively. The risk of transition to severe for participants with mild DWRT was 37.8%.

Over the eight-year period, the prevalence of those who could not complete side-by-side standing, semi-tandem, and tandem balance significantly increased, indicating the risk of losing balance (Table 1). Also, over the eight years, a continuous trajectory of losing grip strength and increasing FCI was detected among participants. Linear regression analysis showed a significant increase in FCI score by 0.11 within one year (coefficient: 0.105, $p<0.0001$). The results of longitudinal OLS showed that the chance of losing grip strength increased by 26% each year (OR: 1.262, $p<0.0001$).

The regression models for the CDT indicated that those who were able to complete the side-by-side standing test were 33% less likely to have mild or mild-to-moderate EF impairment (Table 2, Model 1), whereas this probability was higher for those who completed semi-tandem (38%) (Model 2). After entering both tests in the third model, only semi-tandem remained a significant predictor of EF impairment without changes in the semi-tandem odds ratio. Contrarily, the side-by-side odds ratio increased to 0.86 and became insignificant (Table 2, Model 3). Figure 1a shows that the probability of completing semi-tandem among mild-to-moderate CDT impairment is significantly lower than mild CDT impairment and those with normal CDT results; also, a downward trend can be observed among participants with mild and mild-to-moderate CDT impairments.

Grip strength was inversely associated with EF impairment; the higher the grip strength, the lower the chance of EF impairment. One score increase in grip strength reduced this risk by 12%. Education was also a significant predictor of EF impairment. Women are significantly less likely (by 35%) to experience EF impairment compared with men. African Americans were 268% more likely to experience EF impairment than their non-Hispanic counterparts in our cohort (Table 2, Model 3). Figure 1b shows the downward trends of grip strength among people with mild and mild-to-

| DWRT | | OR (SE) | 95% CI |
|---|---|---|---|
| Side by Side | | 0.65 (0.13) * | 0.44 – 0.95 |
| Grip | | 0.89 (0.05) * | 0.80 – 0.99 |
| FCI | | 1.03 (0.03) | 0.98 – 1.09 |
| BMI, kg/m$^2$ | | 1.00 (0.01) | 0.98 – 1.02 |
| Age, years | | 1.13 (0.01) *** | 1.11 – 1.16 |
| Education | | 0.57 (0.03) *** | 0.52 – 0.64 |
| Race/Ethnicity§ | Hispanic | 4.74 (1.76) *** | 2.29 – 9.83 |
| | African American | 3.41 (0.61) *** | 2.40 – 4.84 |
| | Others | 1.35 (0.66) | 0.52 – 3.52 |
| Women | | 0.35 (0.05) *** | 0.27 – 0.47 |
| Year | | 0.90 (0.02) *** | 0.87 – 0.93 |
| | | Log Likelihood=-4834.32<br>Chi$^2$= 387.24*** | |

*Notes. Longitudinal Ordered Logistic Regression, eight waves of data from 2011 to 2018. DWRT: Delayed Word Recall Test; FCI: Functional Comorbidity Index; BMI: Body Mass Index; OR: Odds Ratio; CI: Confidence Interval; SE: Standard Error. § Non-Hispanic Whites were the reference group. *p<0.05, **p<0.01, ***p<0.001.*

**Table 3.** Side by Side Balance and Grip strength Predict Delayed Recall among community-dwelling older adults, N=6,157.

moderate CDT impairments.

Regarding DWRT, side-by-side balance was a significant predictor of impaired recall, indicating that those who were able to complete this test were 35% less likely to have impairments in delayed recall. Figure 2a showed the significant differences between levels of DWRT when severe and mild categories were more likely to “not complete” side-by-side tests. Like EF, grip strength was inversely associated with DWRT performance (Figure 2b), with one score increase in this test reducing the risk of memory impairment by 11%. Education level was also a significant predictor of memory impairment, as people with higher education were less likely to experience memory impairment. In our cohort, women were 65% less likely to have memory impairment compared with men. Hispanics and African Americans were more likely to have mild and severe DWRT performance impairment than non-Hispanic Whites in our cohort (Table 3).

## Discussion

This study suggests that semi-tandem stance, as a simple screening measure of balance, is a significant predictor of EF performance among community-dwelling older adults aged 65-95 years old in the USA. Older adults who successfully held the semi-tandem stance position for up to 10 seconds were 28% less likely to experience mild and mild-to-moderate EF impairment within eight years. Those who completed the side-by-side stance were significantly less likely to have mild or mild-to-moderate EF impairment by 33%; however, when the semi-tandem stance was added to the model, the odds ratio for EF impairment dropped to 14%. For DWRT performance, side-by-side standing was the only significant predictor in the final model; older adults living in the community who completed this test were 35% less likely to have mild or severe memory impairment.

Semi-tandem performance was a significant predictor of EF within regression modeling after controlling for covariates. Specifically, as semi-tandem performance decreased, the risk for EF impairment increased by 28%. This study is consistent with previous findings describing relationships between decreased balance and low cognitive status[29]. Still, it advances this area because these relationships were found using a simple measure of balance and EF and provide longitudinal evidence of declines over time. Aging has been linked to a decrease in tandem walking ability and a reduction in CF[30]. Results found in Table 1 indicate that over eight years, semi-tandem stance ability declined slightly (6%) as compared to tandem stance (14.5%), suggesting that perhaps the subtle changes in tandem stance performance may correspond to cognitive decline. However, further study of these relationships is warranted.

The ability to complete side-by-side balance was a significant predictor of impaired delayed recall in this population of older adults. This finding is consistent with that of Bahureksa, Najafi[31], who found MCI-related impairments in balance in the eyes-open condition only compared to the eyes-closed condition. Moreover, previous studies have reported a strong relationship between balance and CF, specifically memory, in older adults. As a simple balance screening measure, the inability to complete a side-by-side stance position may suggest further assessment of cognition, specifically recall. However, our wide confidence intervals and large standard error suggest that the population may be composed of both higher and lower performers on the recall measure. Therefore, further study is indicated.

Within each model, grip strength was significantly inversely associated with CF. Neither the odds ratios nor the confidence intervals differed for impaired EF when grip strength was considered. However, in the recall regression model, the confidence intervals closely approached 1, suggesting that grip strength may be more associated with EF rather than recall performance. While previous literature on grip strength and EF has been inconsistent, our findings indicate a relationship between these variables. Our results are consistent with evidence from previous studies that declines in grip strength may predict[32] or develop alongside declines in cognition[9]. It is still unclear whether baseline CF or grip strength affects the other in the long term[33]. The bi-directionality of this finding is similar to relationships found between declines in CF and gait and mobility reported in other longitudinal studies[34,35]. Furthermore, grip strength is considered a simple and inexpensive proxy for overall muscle strength and its decline in aging[36].

Regarding sex differences in cognitive function, Levine and colleagues, using a pooled cohort of five studies (1971-2017), reported that although women score better in global cognitive function than men, they experience a more rapid pace in losing their executive function, probably affected by sex hormone changes after menopause[37]. Berezuk and colleagues compared men and women in different domains of cognitive function to assess the role of sex in predicting the transition from MCI to ADRD. They reported that women are at more risk of losing delayed recall when the recall test was a predictor of losing cognitive function and risk of ADRD in both sexes[38]. Our findings show that women are more likely to score lower in both executive function and delayed word recall tests, which is consistent with previous findings.

The effect of race and ethnicity on the trajectory of losing cognitive function is associated with multiple factors, including a higher rate of poverty, economic instability, more prevalent chronic health issues, and social engagement, among African Americans, compared to their White counterparts[39]. Zsembik and Peek reported the correlation between race/ethnicity and cognitive function is mediated by other factors, such as lifestyle, health issues, income, education, and so forth[40]. Katz and colleagues reported the difference in the importance of social contact sizes between African Americans, Whites, and Hispanic Whites[41].

## Conclusion

Based on our findings, a combination of semi-tandem stance and grip strength, which are non-invasive, low cost, and simple tests, can be employed to screen cognitive function impairment, in particular mild and mild-to-moderate cognitive function impairment, among community-dwelling older adults.

### *Implications*

Since impairment in cognitive function is a predictor of a higher rate of hospitalization[5,42] and mortality[19,43], we recommend simple, noninvasive, and inexpensive semi-tandem and grip strength tests to screen for mild cognitive impairment, especially among women, race, and ethnicity minorities referring to clinical settings.

Future studies should be performed to determine the relationships between balance programs and CF in older adults, as well as their impact on cognition and balance in the long term. Performance on the single-leg stance test was impaired in most participants throughout the eight-year span of data analyses. Hence, further study can examine relationships between performance on this measure and the decline in CF.

### *Limitations*

This study is limited in that it was a secondary analysis of existing data, and missing data or incorrect categorization may have occurred. The measures of cognition and balance could be considered screening measures, and further study is indicated using more comprehensive measures. Although we included a measure of comorbidity, we did not control for the presence of increased comorbidities nor the type of comorbidity, like musculoskeletal diagnosis or falls which may have influenced performance on balance measures.

## *References*


1. 2018 Alzheimer's disease facts and figures. Alzheimer's & Dementia 2018;14(3):367-429.
2. Matthews KA, Xu W, Gaglioti AH, Holt JB, Croft JB, Mack D, et al. Racial and ethnic estimates of Alzheimer's disease and related dementias in the United States (2015-2060) in adults aged ≥65 years. Alzheimers Dement 2019;15(1):17-24.
3. Eshkoor SA, Hamid TA, Mun CY, Ng CK. Mild cognitive impairment and its management in older people. Clin Interv Aging 2015;10:687-93.
4. Roberts RO, Knopman DS, Mielke MM, Cha RH, Pankratz VS, Christianson TJ, et al. Higher risk of progression to dementia in mild cognitive impairment cases who revert to normal. Neurology 2014;82(4):317-25.
5. Amini R, Chee KH, Swan J, Mendieta M, Williams T. The Level of Cognitive Impairment and Likelihood of Frequent Hospital Admissions. J Aging Health 2019;31:967-88.
6. Reed C, Belger M, Vellas B, Andrews JS, Argimon JM, Bruno G, et al. Identifying factors of activities of daily living important for cost and caregiver outcomes in Alzheimer's disease. Int Psychogeriatr

2016;28(2):247-59.
7. Demnitz N, Esser P, Dawes H, Valkanova V, Johansen-Berg H, Ebmeier KP, et al. A systematic review and meta-analysis of cross-sectional studies examining the relationship between mobility and cognition in healthy older adults. Gait Posture 2016;50:164-74.
8. Buchman AS, Boyle PA, Leurgans SE, Barnes LL, Bennett DA. Cognitive function is associated with the development of mobility impairments in community-dwelling elders. Am J Geriatr Psychiatry 2011;19(6):571-80.
9. Sprague BN, Phillips CB, Ross LA. Age-Varying Relationships Between Physical Function and Cognition in Older Adulthood. J Gerontol B Psychol Sci Soc Sci 2019;74(5):772-84.
10. Quental NBM, Brucki SMD, Bueno OFA. Visuospatial function in early Alzheimer's disease: Preliminary study. Dement Neuropsychol 2009;3(3):234-40.
11. Mild Cognitive Impairment (MCI): Alzheimer's Association; 2021 [Available from: https://www.alz.org/alzheimers-dementia/what-is-dementia/related_conditions/mild-cognitive-impairment.
12. Tangen GG, Engedal K, Bergland A, Moger TA, Mengshoel AM. Relationships between balance and cognition in patients with subjective cognitive impairment, mild cognitive impairment, and Alzheimer disease. Phys Ther 2014;94(8):1123-34.
13. Sunderaraman P, Maidan I, Kozlovski T, Apa Z, Mirelman A, Hausdorff JM, et al. Differential Associations Between Distinct Components of Cognitive Function and Mobility: Implications for Understanding Aging, Turning and Dual-Task Walking. Front Aging Neurosci 2019;11:166.
14. Finkel D, Ernsth-Bravell M, Pedersen N. Temporal dynamics of motor functioning and cognitive aging. Journals of Gerontology: Series A, Biological Sciences and Medical Sciences 2016;71(1):109-216.
15. Fritz N, McCarthy C, Adamo D. Handgrip strength as a means of monitoring progression of cognitive decline- A scoping review. Ageing Research Reviews 2017;35:112-23.
16. Praetorius Björk M, Johansson B, Hassing L. I forgot when I lost my grip- Strong associations between cognition and grip strength in level of performance and change across time in relation to impending death. . Neurobiol Aging 2016;38:68-72.
17. Hesseberg K, Tangen GG, Pripp AH, Bergland A. Associations between Cognition and Hand Function in Older People Diagnosed with Mild Cognitive Impairment or Dementia. Dement Geriatr Cogn Dis Extra 2020;10(3):195-204.
18. Zammit AR, Robitaille A, Piccinin AM, Muniz-Terrera G, Hofer SM. Associations Between Aging-Related Changes in Grip Strength and Cognitive Function in Older Adults: A Systematic Review. The Journals of Gerontology: Series A 2019;74(4):519-27.
19. Yaffe K, Peltz CB, Ewing SK, McCulloch CE, Cummings SR, Cauley JA, et al. Long-term Cognitive Trajectories and Mortality in Older Women. J Gerontol A Biol Sci Med Sci 2016;71(8):1074-80.
20. Kasper JD, Freedman VA. National Health and Aging Trends Study Round 1 User Guide: Beta Release 1.0. National Health and Aging Trends [Internet]. 2012. Available from: https://nhats.org/sites/default/files/2021-01/NHATS_User_Guide_and_Documentation_Round1Version1_05_14_12_0.pdf.
21. Sotaniemi M, Pulliainen V, Hokkanen L, Pirttilä T, Hallikainen I, Soininen H, et al. CERAD-neuropsychological battery in screening mild Alzheimer's disease. Acta Neurol Scand 2012;125(1):16-23.
22. Takayama Y. A delayed recall battery as a sensitive screening for mild cognitive impairment: follow-up study of memory clinic patients after 10 years. J Med Dent Sci 2010;57(2):177-84.
23. Can SS, Gencay-Can A, Gunendi Z. Validity and reliability of the clock drawing test as a screening tool for cognitive impairment in patients with fibromyalgia. Compr Psychiatry 2012;53(1):81-6.
24. Kasper JD, Freedman VA. National Health and Aging Trends Study (NHATS) Round 1 User Guide: Beta Release 1.0. In: Health JHUSoP, editor. Baltimore 2012.
25. Olsen CF, Bergland A. "Reliability of the Norwegian version of the short physical performance battery in older people with and without dementia". BMC Geriatr 2017;17(1):124.
26. Kasper JD, Freedman VA, Niefeld MR. Construction of performance-based summary measures of physical capacity in the National Health and Aging Trends Study. NHATS Technical Paper #4. In: Health JHUSoP, editor. Maltimore, USA2012.
27. Gadkaree SK, Sun DQ, Huang J, Varadhan R, Agrawal Y. Comparison of simple vs. performance-based fall prediction models: data from the National Health and Aging Trends Study. Gerontol Geriatr Med 2015;1.
28. Mathiowetz V, Weber K, Volland G, Kashman N. Reliability and validity of grip and pinch strength evaluations. J Hand Surg Am 1984;9(2):222-6.
29. Stijntjes M, Pasma JH, van Vuuren M, Blauw GJ, Meskers CG, Maier AB. Low cognitive status is associated with a lower ability to maintain standing balance in elderly outpatients. Gerontology 2015;61(2):124-30.
30. Seraji-Bzorgzad N, Paulson H, Heidebrink J. Neurologic examination in the elderly. Handb Clin Neurol 2019;167:73-88.
31. Bahureksa L, Najafi B, Saleh A, Sabbagh M, Coon D, Mohler MJ, et al. The Impact of Mild Cognitive Impairment on Gait and Balance: A Systematic Review and Meta-Analysis of Studies Using Instrumented Assessment. Gerontology 2017;63(1):67-83.
32. Rantanen T, Guralnik JM, Foley D, Masaki K, Leveille S, Curb JD, et al. Midlife hand grip strength as a predictor of old age disability. JAMA 1999;281(6):558-60.
33. Kobayashi-Cuya KE, Sakurai R, Suzuki H, Ogawa S, Takebayashi T, Fujiwara Y. Observational Evidence of the Association Between Handgrip Strength, Hand Dexterity, and Cognitive Performance in Community-Dwelling Older Adults: A Systematic Review. J Epidemiol 2018;28(9):373-81.
34. Tian Q, An Y, Resnick SM, Studenski S. The relative temporal sequence of decline in mobility and cognition among initially unimpaired older adults: Results from the Baltimore Longitudinal Study of Aging. Age Ageing 2016;46(3):445-51.
35. Hartley P, Monaghan A, Donoghue OA, Kenny RA, Romero-Ortuno R. Exploring bi-directional temporal associations between timed-up-and-go and cognitive domains in the Irish longitudinal study on ageing (TILDA). Arch Gerontol Geriatr 2022;99:104611.
36. Sallinen J, Stenholm S, Rantanen T, Heliövaara M, Sainio P, Koskinen S. Hand-grip strength cut points to screen older persons at risk for mobility limitation. J Am Geriatr Soc 2010;58(9):1721-6.
37. Levine DA, Gross AL, Briceño EM, Tilton N, Giordani BJ, Sussman JB, et al. Sex Differences in Cognitive Decline Among US Adults. JAMA Network Open 2021;4(2):e210169-e.
38. Berezuk C, Khan M, Callahan BL, Ramirez J, Black SE, Zakzanis KK. Sex differences in risk factors that predict progression from mild cognitive impairment to Alzheimer's dementia. J Int Neuropsychol Soc 2022:1-9.
39. Zahodne LB, Manly JJ, Azar M, Brickman AM, Glymour MM. Racial Disparities in Cognitive Performance in Mid- and Late Adulthood: Analyses of Two Cohort Studies. J Am Geriatr Soc 2016; 64(5):959-64.
40. Zsembik BA, Peek MK. Race Differences in Cognitive Functioning Among Older Adults. The Journals of Gerontology: Series B 2001;56(5):S266-S74.
41. Katz B, Turney I, Lee JH, Amini R, Ajrouch KJ, Antonucci TC. Race/Ethnic Differences in Social Resources as Cognitive Risk and Protective Factors. Research in Human Development 2020;17(1):57-77.

42. Amini R, Kawser B. Impact of the interaction between mild and mild-to-moderate cognitive impairment with chronic health problems on hospital admission among community-dwelling older adults. Geriatr Gerontol Int 2020;20(12):1213-20.

43. Tamosiunas A, Sapranaviciute-Zabazlajeva L, Luksiene D, Virviciute D, Bobak M. Cognitive Function and Mortality: Results from Kaunas HAPIEE Study 2006-2017. Int J Environ Res Public Health 2020; 17(7):2397.