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Gait and Balance in Alzheimer's Disease: A Retrospective Analysis Across Varying Levels of Cognitive Impairment

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GAIT AND BALANCE IN ALZHEIMER'S DISEASE:
A RETROSPECTIVE ANALYSIS ACROSS VARYING LEVELS OF COGNITIVE
IMPAIRMENT

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A doctoral project submitted in partial fulfillment
of the requirements for the

Doctor of Physical Therapy

Department of Physical Therapy

School of Allied Health Sciences

Division of Health Sciences

The Graduate College

University of Nevada, Las Vegas

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Doctoral Project Approval

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The University Of Nevada, Las Vegas

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This doctoral project prepared by

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**Gait and balance in Alzheimer's disease: a retrospective analysis across
varying levels of cognitive impairment**

is approved in partial fulfillment of the requirements for the degree of

Doctor of Physical Therapy

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ABSTRACT

Background: It was once thought that Alzheimer’s disease (AD) affected mostly cognition with minor motor impairment; however, it is becoming apparent that motor impairment may also be a prominent feature. Determining the extent of motor impairments throughout the continuum of cognitive impairment is critical in developing timely interventions for this population.

Purpose/Hypothesis: The aim of this study was to gain a greater understanding of motor impairment in AD by exploring the relationships among gait, balance, and falls. Specifically, we explored the association of fall history to measures of cognition and performance-based balance measures in individuals with AD. We hypothesized that falls would increase as balance impairments became more severe. Additionally, we mapped the trajectory of gait and balance function along the continuum of cognitive impairment in individuals with AD. We hypothesized that balance and gait would be worse for those in the lower quartiles of cognitive function compared to those in the upper quartiles. Lastly, we sought to determine if fall history worsened as cognition declined. We hypothesized that falls history would be worse in lower quartiles of cognitive impairment compared to upper quartiles of cognitive impairment.

Subjects: Retrospective data of 419 patients with brain health conditions and an initial evaluation for physical therapy at the Cleveland Clinic Lou Ruvo Center for Brain Health were extracted from electronic records. Of those 419, 155 were diagnosed by a neurologist with AD (age=77.4 ± 9.5; 69 males, 86 females) and were subsequently analyzed for this study.

Materials/Methods: Patients were stratified into cognitive quartiles using scores from the Montreal Cognitive Assessment (MoCA): 0-9 (very severe cognitive impairment), 10-14 (severe cognitive impairment), 15-20 (Moderate to severe impairment), 21-30 (mild to moderate impairment). These cognitive function quartiles were then compared across the following measures: fall history (falls in last year, falls in the last 30 days, and fall injuries in the last year), 5 times Sit To Stand (5STS), Timed Up and

Go (TUG), TUG cognitive (TUGcog), Preferred Gait Speed (PGS), Fast Gait Speed (FGS), 6 Minute Walk Test (6MWT), and Mini Balance Evaluation Systems Test (MBT).

Results: For our first aim, there were no statistically significant differences between fallers and non-fallers for cognition, age, and measures of gait and balance ($p \geq .068$), except non-fallers walked farther on the 6MWT ($p = .030$). There were no statistically significant differences for recent (last 30 days) fallers and non-fallers across the same measures ($p \geq .082$). Fallers who had experienced an injury as a result of a fall in the last year performed more poorly on the 6MWT ($p = .034$) and MBT SOT ($p = .008$); all other comparisons were not statistically significant ($p \geq .085$). For our second aim, there were no statistically significant differences among the four cognitive quartiles for 5STS ($p = .456$), TUG ($p = .060$), FGS ($p = .181$), 6MWT ($p = .468$), MBT ($p = .321$); however, there were for TUGcog ($p = .046$) and PGS ($p = .033$). The mild to moderate impairment quartile was significantly faster than the severe quartile ($p = .006$) for the TUGcog. For PGS, the mild to moderate was significantly faster than the very severe quartile ($p = .039$) and the moderate to severe was significantly faster than the severe and the very severe quartiles (severe, $p = .036$; and, very severe, $p = .016$). For our third aim, there were no statistically significant differences in the proportions of fallers ($p = .636$), recent fallers ($p = .868$), and injured fallers ($p = .565$) across the four cognitive quartiles.

Discussion: Despite impairments recognized in our study compared to normative data, patients in the study with a fall history were not significantly worse across most measures of gait and balance, except fallers had poorer walking endurance as measured in the 6MWT. Additionally, the proportion of fallers did not increase as severity of cognitive impairment increased, although walking impairment as measured with PGS and TUGcog, especially with cognitive demand, is more prominent in those with more severe cognitive impairment.

Conclusions: Balance and gait dysfunction were prominent at all levels of cognitive impairment in our study of patients with AD and appears to become more prominent at the most severe cognitive

impairment levels. These progressive deficits represent potentially mitigable motor impairment features of AD that warrant physical therapy.

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INTRODUCTION

It was once thought that Alzheimer's disease (AD) affected mostly cognition with minor motor impairment; however, it is becoming apparent that motor impairment may also be a prominent feature in individuals with AD. AD is the most common cause of dementia in older adults,¹ but it is difficult to diagnose due to the slow progressive nature of the neurodegeneration with no distinctive onset of symptoms.² Though it is challenging to conduct research on this population due to variability in timely diagnosis, recent research has shown that individuals with very mild AD already exhibit impaired motor performance.³ Determining the extent of motor impairments throughout the continuum of cognitive impairment is critical in developing timely interventions for this population.

Decreased gait speed is one of the more consistently reported motor impairments in those who are cognitively impaired. Research has acknowledged slower gait speeds in individuals with dementia when compared to healthy controls, with some evidence of greater decline associated more severe dementia.^{4,5} More recently, slower preferred gait speeds have been associated with lower mental performance in adults with very mild AD as well as elderly individuals with an increased risk of developing dementia.^{3,6} Similarly, research also shows an increase in time required to perform the TUG in individuals with very mild AD.³ Gait changes are important because it can be a predictor for future health as a decrease in gait speed has been associated with decreased survival in older adults.^{7,8}

Another manifestation of motor impairments in people with AD is an increase in falls.⁹⁻¹¹ Individuals with cognitive impairment are at least twice as likely to fall compared to cognitively intact older adults with unintentional falls being the leading cause of fatal and nonfatal injuries in adults over 65.^{12,13} While the etiology of falls is multifactorial, many have been attributed to balance impairments found in individuals with AD.^{3,14} Executive components to balance may also contribute to the decreased performance of

individuals with AD on balance testing.¹⁴ The consequences of motor impairments leading to falls will result in a decreased quality and quantity of life in adults with AD.

While there is some evidence of motor impairment in individuals with cognitive impairment, further research is warranted to objectively quantify the extent of the relationship to allow for viable and timely treatment options for this population. From a clinical perspective, it is important to understand the extent of cognitive impairment on motor performance throughout the neurodegenerative process. By utilizing objective measures to identify motor impairments in this population, we will be better equipped to address relevant impairments to improve function and quality of life for individuals with AD. Specifically, our first aim was to explore the association of fall history to measures of cognition and performance-based balance measures in individuals with AD. Our second aim was to map the trajectory of gait and balance function along the continuum of cognitive impairment in individuals with AD. Our third aim was to determine if fall history worsened as cognition declined.

METHODS

Study Design

A cross-sectional research design was utilized wherein balance, gait, and fall characteristics were extracted from patient records at the Cleveland Clinic Lou Ruvo Center for Brain Health (CCLRCBH). Specifically, records were extracted for those with memory loss (mild cognitive impairment (MCI), Alzheimer's disease (AD), and other cognitive diseases). For the purposes of the present study, only the AD data were used. For the first aim, fallers (≥ 1 fall) were compared to non-fallers across several gait and balance measures. Fall history was determined using patient and family/caregiver report. Operationally, a fall was considered "any unexpected fall to the ground during routine daily tasks."¹⁵ Patients and family/caregivers were asked about fall history including number of falls over the past 12 months (fallers), number of falls over the past one month (recent fallers), and number of falls in the last year that resulted in an injury (injured fallers). For the second aim, patients were classified into four different cognitive impairment categories (discussed below) and then compared across several gait and balance measures. For the third aim, fall history was compared across the four aforementioned cognitive impairment groups. This study was conducted with approval from the (blinded) Institutional Review Board.

Participants

All patients with a physical therapy initial evaluation at the CCLRCBH in 2014 and 2015 were identified from billing records. As mentioned previously, only patients designated with memory loss conditions were included in the screening for participation in this study. The records of 419 community dwelling individuals were collected, of which 155 were diagnosed by a neurologist with AD (age= 77.4 ± 9.5 ; 69 males, 86 females) and were analyzed for this study. Refer to the flow chart in Figure 1.

Instrumentation

Cognition. Level of cognitive impairment was determined based on scores from the Montreal Cognitive Assessment (MoCA).¹⁶ The MoCA was used due to its sound psychometric properties, including good sensitivity, excellent test-retest reliability (correlation coefficient = 0.92), and excellent positive/negative predictive values for AD.¹⁶ For the purposes of this study, patients were stratified into cognitive quartiles based on their MoCA score as follows: 0-9 (very severe cognitive impairment), 10-14 (severe cognitive impairment), 15-20 (moderate to severe impairment), and 21-30 (mild to moderate impairment). Since cognitive impairment would limit the reliability and validity of self-report measures of gait and balance, these types of measures were not included in the study.

Balance. The Mini Balance Evaluation Systems Test (MBT), a performance-based measure of balance, was used to assess the following balance domains: anticipatory postural responses, reactive postural control, sensory orientation, and dynamic gait. The MBT exhibits excellent interrater reliability (ICC = 0.98).¹⁷

Gait. The following performance-based gait measures were included: Timed Up and Go Test (TUG), Timed Up and Go Cognitive Test (TUGcog), Preferred Gait Speed (PGS), and Fast Gait Speed (FGS). For individuals with AD, the TUG exhibits excellent test-retest reliability (ICC = 0.987) and both intrarater (ICC = 0.91) and intertester reliability (ICC = 0.92).¹⁸ For community dwelling elderly, the TUGcog also exhibits excellent intrarater reliability ICC of 0.94.¹⁹ For older adults, both PGS and FGS exhibit excellent reliability (ICC = 0.94, 0.96 respectively).²⁰

Strength and Endurance. The Five times Sit-to-Stand Test (5STS) and the Six Minute Walk Test (6MWT) were used to determine lower extremity functional strength and walking endurance, respectively. For community-dwelling elderly, the 5STS exhibits excellent test-retest reliability (ICC = 0.957).²¹ For individuals with AD, the 6MWT exhibits excellent test-retest reliability (ICC = 0.982-0.987),¹⁸ and both interrater (ICC = 0.97 - 0.99)²² and intrarater reliability (ICC = 0.76 - 0.9).²²

Data Analysis

All analyses were conducted using SPSS 23.0 (IBM SPSS Statistics for Windows, Armonk, NY: IBM Corp) with $\alpha = 0.05$. To address the first aim of the study (fall history), independent samples t-tests were used to explore the difference between AD fallers and non-fallers on cognitive level (MoCA) and performance-based gait and balance measures (MBT and subscales, TUG, TUGcog, PGS, FGS, 5STS, and 6MWT). In many of the cases, patient fall history was not recorded since the caregiver and/or patient could not confidently recall a fall. Therefore, only known cases of fall status were analyzed. Additionally, in several cases, measures of balance which were not examined in this study were used by the assessing therapist; therefore, those cases also had missing data and were not analyzed. In the comparison of recent fallers to non-recent fallers and injured fallers to non-injured, there were few recent and injured fallers and also a non-normal distribution; therefore, non-parametric Mann-Whitney U analyses were used instead. For the second aim of the study (cognitive quartiles), the trajectory of gait and balance function along the continuum of cognitive impairment were analyzed using ANOVAs. Pairwise comparisons were analyzed using the Tukey method. Specifically, patients were classified into cognitive quartiles (0-9 (very severe cognitive impairment), 10-14 (severe cognitive impairment), 15-20 (moderate to severe impairment), 21-30 (mild to moderate impairment)) and then compared across all of the performance-based gait and balance measures (MBT and subscales, TUG, TUGcog, PGS, FGS, 5STS, and 6MWT). Additionally, the association between the MoCA raw scores and the performance-based

measures were analyzed using Spearman rho rank-order correlational analyses. Patients with missing data were excluded from the analyses. For the third aim, the proportion of those classified as fallers was compared across the cognitive quartiles using Chi square analyses.

RESULTS

Fall History

There were no statistically significant differences between fallers and non-fallers for cognition, age, and measures of gait and balance ($p \geq .068$), except non-fallers walked farther on the 6MWT ($p = .030$) (Table 1). There were no statistically significant differences for recent (last 30 days) fallers and non-recent fallers across the same measures ($p \geq .082$) (Table 2). Fallers who had experienced an injury as a result of a fall in the last year performed more poorly on the 6MWT ($p = .034$) and MBT SOT ($p = .008$) than those who did not have a fall injury (Table 3); all other comparisons were not statistically significant ($p \geq .085$).

Cognitive Quartiles

There were no statistically significant differences among the 4 quartiles for 5STS ($p = .456$), TUG ($p = .060$), FGS ($p = .181$), 6MWT ($p = .468$), MBT ($p = .321$), MBT Anticipatory ($p = .823$), MBT Reactive ($p = .657$), MBT SOT ($p = .120$), and MBT Gait ($p = .340$); however, there were for TUGcog ($p = .046$) and PGS ($p = .033$) (Table 4). Pairwise comparisons revealed that the mild to moderate impairment quartile was significantly faster than the severe quartile (moderate to severe, $p = .051$; severe, $p = .006$; and, very severe, $p = .085$) for the TUGcog (Figure 2). For PGS, the mild to moderate was significantly faster than the very severe quartile (moderate to severe, $p = .782$; severe, $p = .082$; and, very severe, $p = .039$) and the moderate to severe was significantly faster than the severe and the very severe quartiles (severe, $p = .036$; and, very severe, $p = .016$) (Figure 3).

Cognitive Quartiles on Fall History

There were no statistically significant differences in the proportions of fallers ($p = .636$), recent fallers ($p = .868$), and injured fallers ($p = .565$) across the four cognitive quartiles (Table 5).

DISCUSSION

Balance and gait dysfunction were prominent at all levels of cognitive impairment in our study of patients with AD and appears to become more prominent at the most severe cognitive impairment levels. These data further support the notion that balance and gait impairment are prominent disease features in AD.³⁻⁶ Despite impairments in measures of balance and gait in our study, the proportion of fallers did not increase as severity of cognitive impairment increased. Additionally, patients in the study with a fall history were not significantly worse across most measures of gait and balance. However, fallers had poorer walking endurance. Results from our study should be interpreted with some caution, as it appears that many of the measures may have been underpowered.

Gait performance scores across all of the cognitive quartiles were worse than normative values. The mean TUG times for each of the four cognitive quartiles was above the 95% confidence interval for males (7-11 sec) and females (8-10 sec) in a cohort of community dwelling, age-matched individuals²³ and also higher than the means of healthy older adults across other studies (8.4 sec^{19,24}). Additionally, the mean TUG times for those patients in the severe and very severe cognitive quartiles (Table 4) was higher than the cutoff time for fall risk in community dwelling adults (>13.5 sec).²⁴ Not surprisingly, the burden of cognitive demand taxed speed on the TUGcog. TUGcog mean completion times were considerably higher across all four cognitive quartiles than what has been observed in healthy older adults in the same age range (9.8 sec¹⁹ and 9.7 sec²⁴)(Figure 2). Similarly, mean PGS for community-dwelling older adults is around 1.17 m/sec, with a gait speed <1 m/sec indicative of a high risk for health-related outcomes, both values being faster than the mean PGS across all cognitive quartiles (Table 4 and Figure 3).²⁵ Age-matched (70s) healthy adults were also faster in both PGS (1.33 m/sec for males and 1.27 m/sec for females) and FGS (2.08 m/sec for males and 1.74 m/sec for females) when compared to all four cognitive quartiles.²⁶ In individuals with dementia, gait speed is affected by the

individual's cognitive capacity to process information⁶ as well as their physical performance measured in longer double stance times, shorter step length, and increased step variability.³⁻⁵ Based on our results, it appears that walking impairment, especially with cognitive demand, is more prominent in those with more severe cognitive impairment.

Strength and endurance scores, as well as balance outcome measures, were also decreased across most cognitive quartiles when compared to normative data. The mean time on the 5STS were considered worse than average performance for ages 60-69 (11.4 sec) and 70-79 (12.6 sec) year olds.^{27,28} Across all four cognitive quartiles the mean times were greater than 13.6 sec (Table 4), which is associated with increased disability and morbidity.²⁹ For the 6MWT, the means for all four cognitive quartiles were less than the normative data for 60-69 year olds (572 m for males and 538 m for females), 70-79 year olds (527 m for males and 471 m for females), and 80-89 year olds (417 m for males and 392 m for females)(Figure 4).²³ For the MBT, out of a maximum score of 28, normal ranges include 26.3 for ages 50-59, 24.7 for ages 60-69, 21.0 for ages 70-79, and 19.6 for ages 80-89.³⁰ All four cognitive quartiles were less than 21.0, which encompasses the mean age category for our subjects, and three of the four cognitive quartiles were less than 19.6 (moderate to severe impairment was greater than 19.6). Based on the findings in the present study, it appears that balance, strength, and endurance are all negatively affected in individuals with AD.

Our data suggest that while falling is fairly common in AD, it does not appear to be related to level of cognitive impairment. That is, there were no differences in fall history status across all levels of cognition. Contrary to our results, a systematic review by Muir found an association between cognitive impairment and increased fall risk.³¹ While our results support findings from other researchers who have found that falls were common in individuals with AD,^{9-11,13} our study also associated falling with a

significantly decreased performance on the 6MWT (Figure 4). Additionally, our study found that individuals who were injured from falling had a significantly decreased performance on the MBT SOT in addition to having a significantly decreased distance on the 6MWT. As the mean distance on the 6MWT was lower than normative data for older adults, this may suggest a general decreased gait speed which is an indicator for falls, or it may indicate decreased endurance. Fatigue from walking has been associated with decreased minimum foot clearance, increased sway, slower reaction times, and decreased lower extremity strength in older adults,^{32,33} all of which have the potential to increase the risk of falls. While the circumstances surrounding the falls are unclear, individuals with AD and altered sensory orientation or decreased endurance may be vulnerable to increased fall risk.

The trajectory of gait and balance function along the continuum of cognitive impairment in individuals with AD revealed statistically significant differences among the four quartiles of cognitive impairment for TUGcog and PGS. As discussed earlier, the mean PGS and TUGcog times for all cognitive quartiles were slower than the normative data. Decreased gait speed may occur secondarily to decrease in processing speed,⁶ which could explain the continued decline of gait speed with the severity of dementia. Cognition has been indicated as the main effect for decreased performance on the TUGcog in individuals with moderate AD.³⁴ The challenge added with dual tasking on the TUGcog further exemplifies the relationship of cognitive demand on motor tasks, supporting our results of poor performance on these outcome measures in individuals with AD.

These balance and gait deficits identified in this study represent potentially mitigable motor impairment features of AD that may warrant physical therapy. In a recent review, Barnes and Yaffe identified possibly modifiable risk factors for AD with physical inactivity being the most prevalent in the United States.¹ Physically active individuals have a decreased risk of developing AD compared to less physically

active people.^{35,36} Not only can exercise be used as a preventative measure, it can also be used as a treatment. Current evidence demonstrates that exercise can improve both cognitive and physical functioning in individuals with AD.³⁷⁻³⁹ Consequently, physical activity is the most promising candidate for combatting AD, in addition to improving balance, function, and quality of life.

Some limitations of our study stem from the retrospective nature of the study. We culled data from patient records that were not collected intentionally for future research. Therefore, there were inconsistencies in which gait and balance measures were used by the five different physical therapists at the clinic. For instance, some physical therapists utilized outcomes measures not included in this study such as the Berg Balance scale, Functional Gait Assessment, and Dynamic Gait Index. Several patients also required accommodations to tasks, such as using upper extremities on the 5STS or only being able to complete 2-4 min on the 6MWT. Another limitation was with the TUGcog testing; some patients were unable to complete the test by counting so they performed an alphabet test instead. In most of these instances, the data for the compromised outcome measure was not included, resulting in some missing data for most of the outcome measures. While there is evidence for the reliability of one year fall recall in older adults,⁴⁰ it is problematic in the present study as fall recall depends on a good memory and, in the case of the present study all patients presumably had memory problems since they were all diagnosed with AD. While caregivers assisted in the recording of fall history, this may have been problematic as they may not have been present for all falls and may not have been privy to all fall occurrences.

CONCLUSION

Balance and gait dysfunction were prominent at all levels of cognitive impairment in our study of patients with AD and appears to become more prominent at the most severe cognitive impairment levels. However, despite impairments recognized in our study compared to normative data, patients in the study with a fall history were not significantly worse across most measures of gait and balance, except fallers had poorer walking endurance as measured in the 6MWT. Additionally, the proportion of fallers did not increase as severity of cognitive impairment increased, although walking impairment as measured with PGS and TUGcog, especially with cognitive demand, is more prominent in those with more severe cognitive impairment.

APPENDIX A - TABLES

Table 1. Means and standard deviations for fallers and non-fallers for cognition, age, and measures of gait and balance (* denotes statistical significance).

	Fall history	N	Mean	Standard Deviation	P value
MoCA	Non-faller	40	14.7	5.5	.871
	Faller	29	15.0	6.7	
Age	Non-faller	45	77.4	9.2	.445
	Faller	34	79.0	9.4	
5STS	Non-faller	38	14.0	10.1	.214
	Faller	27	17.5	12.6	
TUG	Non-faller	44	13.5	14.3	.536
	Faller	32	15.3	8.9	
TUGcog	Non-faller	39	18.8	7.6	.358
	Faller	26	20.7	9.6	
PGS	Non-faller	43	0.86	0.30	.306
	Faller	31	0.79	0.26	
FGS	Non-faller	42	1.45	0.62	.084
	Faller	30	1.21	0.48	
6MWT	Non-faller	24	384.9	131.6	.030*
	Faller	21	297.6	128.4	
MBT	Non-faller	34	20.0	4.1	.120
	Faller	23	18.2	4.6	
MBT - Anticipatory	Non-faller	34	4.2	1.0	.835
	Faller	23	4.3	0.9	
MBT - Reactive	Non-faller	34	4.4	1.4	.068
	Faller	23	3.6	1.9	
MBT - SOT	Non-faller	34	5.3	0.9	.125
	Faller	23	4.8	1.3	
MBT - Gait	Non-faller	34	6.2	1.9	.203
	Faller	23	5.5	1.9	

Table 2. Means and standard deviations for recent fallers and non-recent fallers for cognition, age, and measures of gait and balance.

	Fall history	N	Mean	Standard Deviation	P value
MoCA	Non-recent faller	62	14.5	6.0	.502
	Recent faller	11	15.9	7.2	
Age	Non-recent faller	68	77.6	8.8	.644
	Recent faller	16	79.3	10.2	
5STS	Non-recent faller	58	15.6	11.9	.993
	Recent faller	11	14.7	7.7	
TUG	Non-recent faller	66	13.6	12.4	.421
	Recent faller	14	15.8	10.2	
TUGcog	Non-recent faller	56	18.8	8.8	.436
	Recent faller	11	19.9	6.9	
PGS	Non-recent faller	64	0.85	0.27	.550
	Recent faller	13	0.80	0.24	
FGS	Non-recent faller	63	1.40	0.58	.099
	Recent faller	13	1.12	0.39	
6MWT	Non-recent faller	41	360.0	131.5	.082
	Recent faller	7	256.1	164.2	
MBT	Non-recent faller	51	19.7	4.4	.591
	Recent faller	10	18.8	4.0	
MBT - Anticipatory	Non-recent faller	51	4.2	1.0	.567
	Recent faller	10	4.3	0.9	
MBT - Reactive	Non-recent faller	51	4.2	1.6	.952
	Recent faller	10	4.2	1.6	
MBT - SOT	Non-recent faller	51	5.2	0.9	.658
	Recent faller	10	4.9	1.4	
MBT - Gait	Non-recent faller	51	6.1	2.0	.179
	Recent faller	10	5.4	1.2	

Table 3. Means and standard deviations for non-injured and injured fallers for cognition, age, and measures of gait and balance (* denotes statistical significance).

	Fall history	N	Mean	Std. Deviation	P value
MoCA	Non-injured	56	15.4	6.2	.267
	Injured faller	10	13.1	5.2	
Age	Non-injured	66	77.8	9.1	.402
	Injured faller	11	80.8	9.8	
5STS	Non-injured	55	14.7	9.8	.780
	Injured faller	8	18.7	19.8	
TUG	Non-injured	63	13.8	12.9	.258
	Injured faller	10	15.2	9.1	
TUGcog	Non-injured	54	18.9	8.7	.543
	Injured faller	9	20.5	8.1	
PGS	Non-injured	61	0.86	0.28	.118
	Injured faller	10	0.73	0.26	
FGS	Non-injured	60	1.39	0.60	.121
	Injured faller	10	1.10	0.36	
6MWT	Non-injured	36	372.2	130.0	.034*
	Injured faller	8	245.9	139.2	
MBT	Non-injured	50	19.9	3.8	.124
	Injured faller	7	15.9	6.2	
MBT - Anticipatory	Non-injured	50	4.3	0.9	.384
	Injured faller	7	3.9	1.1	
MBT - Reactive	Non-injured	50	4.3	1.4	.085
	Injured faller	7	2.7	2.4	
MBT - SOT	Non-injured	50	5.3	0.8	.008*
	Injured faller	7	4.0	1.5	
MBT - Gait	Non-injured	50	6.0	1.8	.665
	Injured faller	7	5.3	2.6	

Table 4. Means, standard deviations, and 95% confidence intervals for the comparison of the cognitive quartiles for fall history and measures of gait and balance (* denotes statistical significance).

	MoCA quartiles	N	Mean	Standard Deviation	95% Confidence Interval for Mean		P value
					Lower Bound	Upper Bound	
Age	0-9	32	78.3	10.4	74.6	82.1	.456
	10-14	39	77.7	9.2	74.8	80.7	
	15-20	34	75.6	9.5	72.3	79.0	
	21-28	30	75.3	7.6	72.5	78.1	
5STS	0-9	25	14.5	6.8	11.7	17.3	.453
	10-14	33	17.6	11.7	13.4	21.8	
	15-20	29	15.6	11.4	11.2	19.9	
	21-28	26	13.8	6.6	11.1	16.4	
TUG	0-9	30	17.8	18.0	11.1	24.6	.060
	10-14	38	14.8	7.4	12.4	17.3	
	15-20	32	12.3	5.7	10.3	14.4	
	21-28	29	11.2	4.6	9.4	12.9	
TUGcog	0-9	21	18.9	8.7	15.0	22.9	.046*
	10-14	32	20.9	9.9	17.4	24.5	
	15-20	28	19.2	7.3	16.4	22.0	
	21-28	24	14.7	5.8	12.3	17.1	
PGS	0-9	27	0.74	0.31	0.62	0.87	.033*
	10-14	33	0.77	0.26	0.68	0.87	
	15-20	30	0.91	0.21	0.83	0.98	
	21-28	26	0.89	0.22	0.80	0.98	
FGS	0-9	24	1.20	0.38	1.04	1.36	.181
	10-14	31	1.23	0.55	1.02	1.43	
	15-20	30	1.46	0.61	1.23	1.69	
	21-28	25	1.36	0.37	1.21	1.51	
6MWT	0-9	15	318.8	108.3	258.8	378.7	.468
	10-14	20	300.7	140.4	235.0	366.4	
	15-20	21	322.4	155.3	252.0	393.4	
	21-28	22	366.7	140.0	304.6	428.8	
MBT	0-9	21	17.5	5.8	14.9	20.1	.321
	10-14	27	18.9	5.1	16.9	20.9	
	15-20	26	20.2	3.5	18.8	21.6	
	21-28	25	19.0	4.9	17.0	21.0	

MBT - Anticipatory	0-9	20	4.1	0.8	3.7	4.4	.823
	10-14	28	4.1	1.0	3.7	4.5	
	15-20	26	4.2	0.9	3.8	4.6	
	21-28	24	4.3	0.9	3.9	4.7	
MBT - Reactive	0-9	20	4.1	1.7	3.3	4.8	.657
	10-14	27	4.1	1.7	3.4	4.8	
	15-20	26	4.3	1.4	3.8	4.9	
	21-28	24	3.8	1.4	3.2	4.4	
MBT - SOT	0-9	20	4.5	1.3	3.9	5.0	.120
	10-14	27	4.7	1.4	4.1	5.3	
	15-20	26	5.0	1.1	4.5	5.5	
	21-28	24	5.3	0.7	4.9	5.6	
MBT -Gait	0-9	20	5.9	1.7	5.1	6.6	.340
	10-14	27	6.0	2.1	5.2	6.8	
	15-20	26	6.7	1.5	6.1	7.3	
	21-28	24	6.5	1.5	5.8	7.1	

Table 5. Count of fall history for recent fallers, fallers, and injury resulting from fall.

		Fall History		P value
		Yes	No	
Recent Fallers	0-9	3	17	.868
	10-14	2	18	
	15-20	3	12	
	21-28	3	15	
Fallers	0-9	8	9	.636
	10-14	8	11	
	15-20	5	12	
	21-28	8	8	
Injury	0-9	3	13	.565
	10-14	4	14	
	15-20	2	13	
	21-28	1	16	

APPENDIX B – FIGURES

Figure 1. Flow chart for patient inclusion

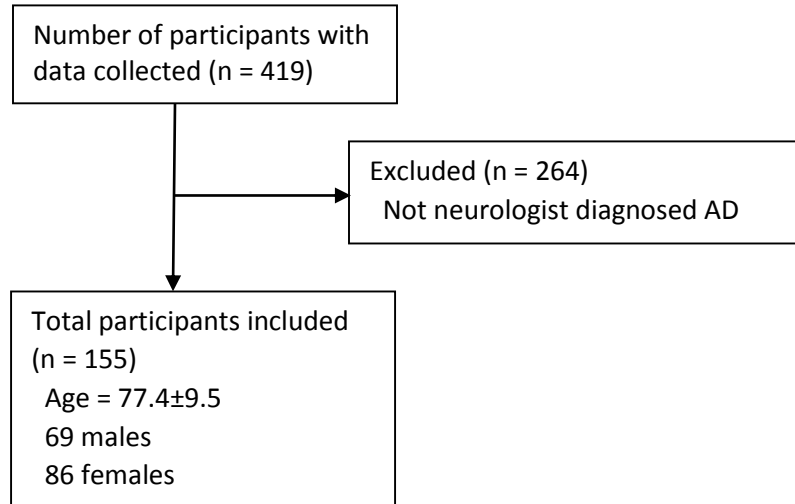


Figure 2. TUGcog times across the continuum of cognitive impairment compared to community values and fall risk.

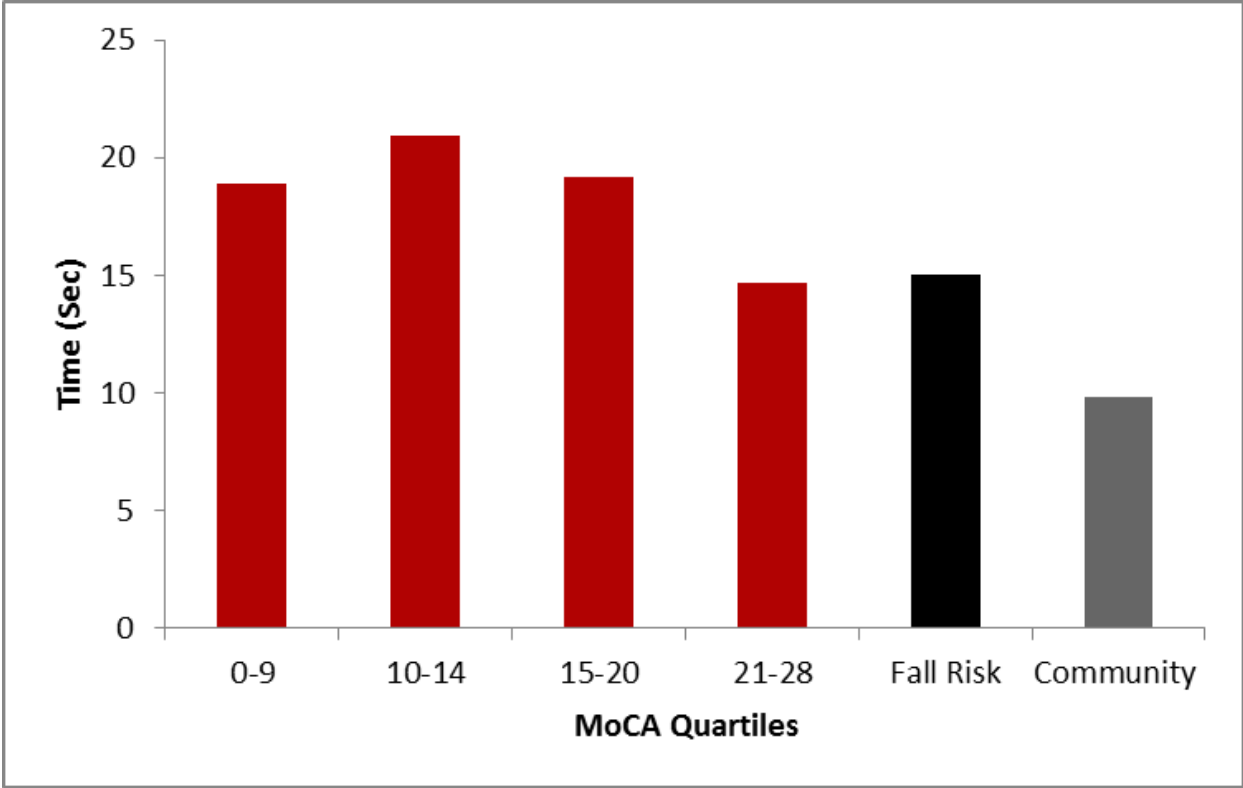


Figure 3. PGS across the continuum of cognitive impairment compared to community values and fall risk.

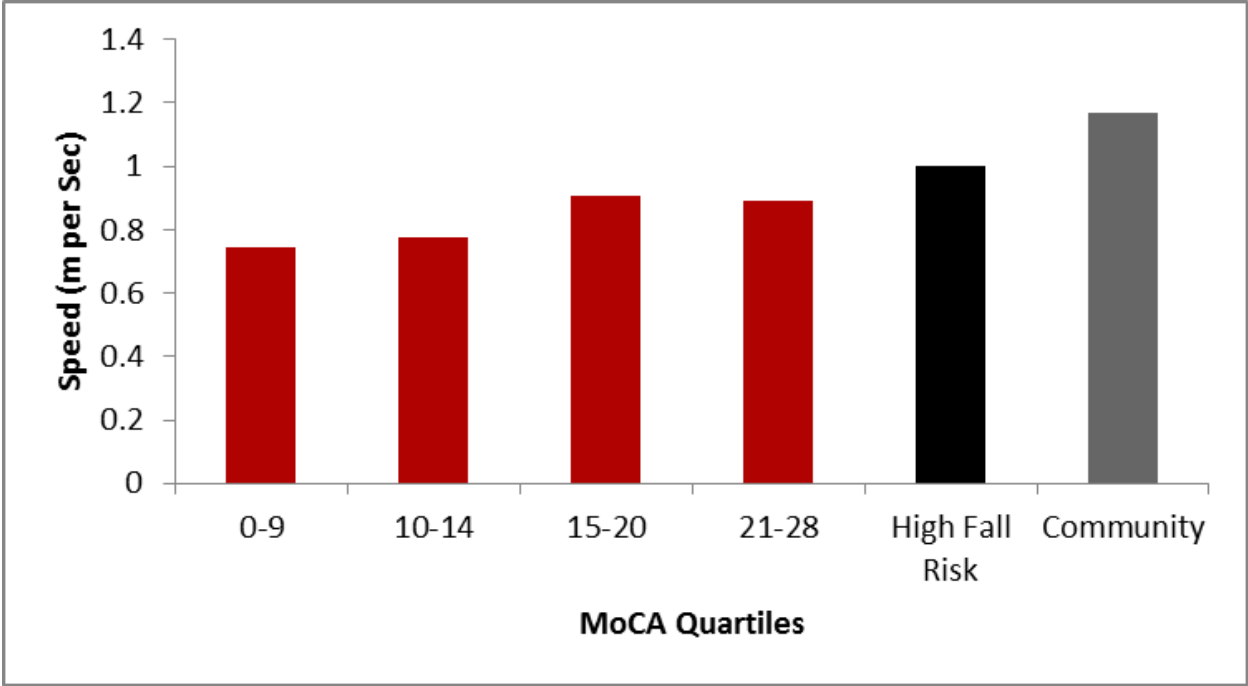
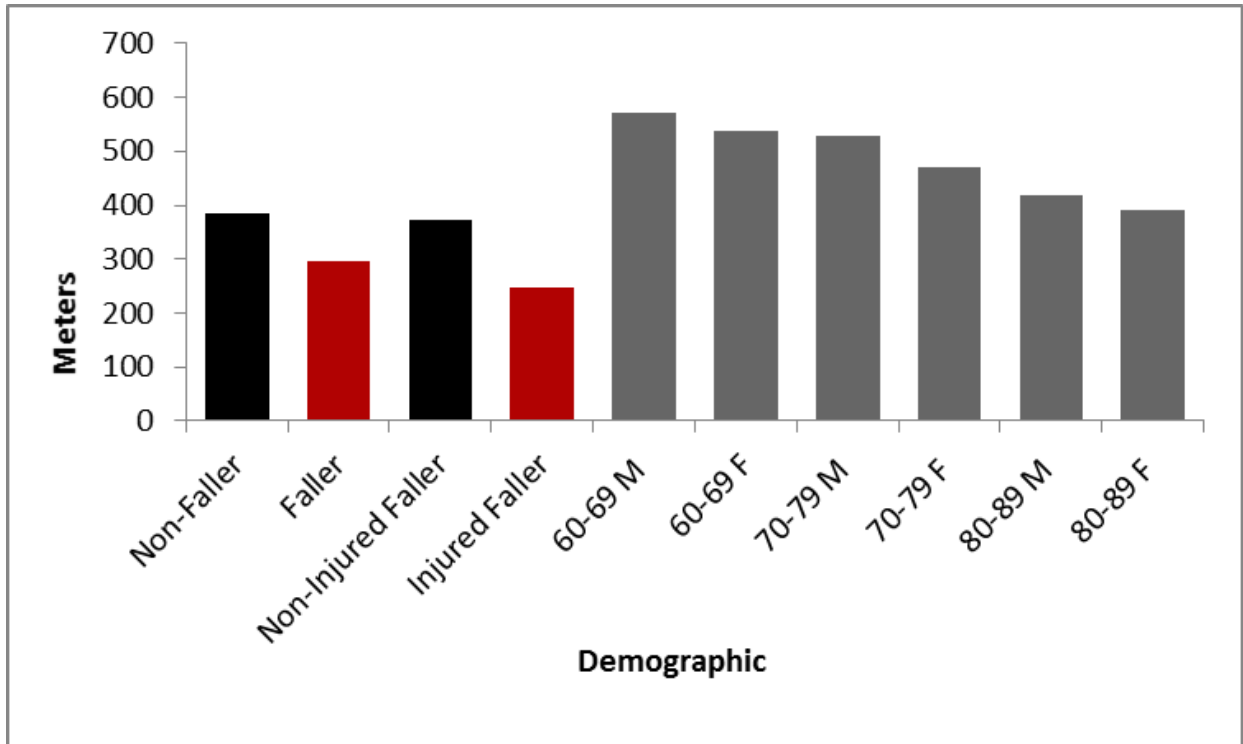


Figure 4. 6MWT for faller/non-faller and falls with injury compared to community values and fall risk.



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