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The Attentional Demands of Ambulating with an Assistive Device in Older Adults with Alzheimer's Disease

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Ambulation with a walker during complex path configurations induces a higher attentional cost for persons with Alzheimer's disease

ABSTRACT

Ambulation with a mobility aid is a unique real-life situation of multi-tasking. These simultaneous motor tasks place increased demands on executive function in healthy young and older adults, but the demands have not been evaluated in people with Alzheimer's disease (AD). Mobility problems are common among adults with AD, leading to provision of a mobility aid to optimize independent activity. The study objectives were: i) to determine the dual-task cost (DTC) associated with the use of a mobility aid in straight and complex path walking, and ii) to evaluate the association between executive function and ambulation with a mobility aid in older adults with AD and age-sex matched cognitively normal controls. Fourteen people (mean age±SD, 72.6±9.9 years) with a diagnosis of probable AD (MMSE range 12-25) and controls (mean age±SD, 72.9±9.5) walked at a self-selected pace and using a 4-wheeled walker in a 6 meter straight path and a Figure of 8 Test. Ambulation with the walker in a straight path produced a low DTC that was not different between the groups. Ambulation with the 4-wheeled walker in the complex path produced a significantly different DTC in the group with AD at -38.1±23.5% compared to -19.7±21.4% (p=0.041). Lower scores on executive function were associated with longer times across test conditions. Ambulation with a 4-wheeled walker, in particular maneuvering around obstacles, requires greater attentional costs in dementia. Future research should explore the timing for safely introducing mobility aids in AD and the role of improving executive function.

INTRODUCTION

Falls among older adults are a significant public health problem and have substantial consequences on an individual's quality of life and independence. An emerging area of falls research is the role of cognition in postural stability; a timely focus as the prevalence of dementia, and its attendant increased health care needs and utilization, is expected to increase dramatically in coming years.[1]

Ambulation with a mobility aid is a unique real-life situation of multi-tasking; the performance of these simultaneous motor tasks places increased demands on brain resources related to executive function.[2] Executive function, which comprises the set of cognitive processes that use sensory information to modulate behavior, is required for planning movements, dividing attention, and responding to changes in the environment.[3] Increased attentional demands have been observed in healthy young adults[4] and older adults[5] using mobility aids suggesting that executive resources are necessary for their proper use. The use of a mobility aid requires high levels of motor control and may challenge cognitive function to generate responsive motor patterns to multiple sensory inputs and environmental conditions.[2]

Decreased executive function is an early symptom in Alzheimer's disease (AD)[6] and a proven risk factor for falls[7]. In addition, gait and mobility impairments are common features in community-dwelling older adults living with dementia.[8] Older adults with cognitive impairment demonstrate decreased gait velocity and increased gait instability while multi-tasking, which are also associated with an elevated fall risk.[9] Rehabilitation interventions to reduce risk can include individualized exercise programs and the prescription of a mobility aid to compensate for deficits and allow maintenance of independent ambulation.

The use of a mobility aid is also associated with an elevated fall risk in older adults.[10] Mobility aid use could be a proxy for the presence of intrinsic functional limitations, such as balance or gait problems; but, the elevated risk remains even when those factors have been taken into account.[10] Additional considerations that would link mobility aid use to an elevated fall risk include interference with lower extremity movement during balance recovery to a perturbation, it prevents the use a person's hands to effectively reach for support when there is a loss of balance and it increases cognitive demands related to attentional processing and neuromotor control.[2]

Observing people during a gait or balance task while they perform a secondary task (the dual-task paradigm) is an accepted way to assess the interaction between cognition and mobility.[11] Cognitive demands relative to the cognitive capacity or reserve of the individual influence physical task performance. If the demands of executing two tasks simultaneously exceed the cognitive capacity, then overall performance will be degraded.[12] The configuration of the walking pattern in the dual task testing protocol is also relevant in the evaluation of functional abilities. Gait performance under a straight path condition is considered a low challenge activity, while curved or complex path walking can provide meaningful information about daily life walking ability, including adaptation of walking patterns to negotiate obstacles, change directions, or plan a path.[13]

There has been no research evaluating the "cost" on gait performance of using a mobility aid in older adults with dementia. Moreover, whether the use of assistive devices generates a "cognitive cost" on gait performance in older adults with AD is unknown though it is hypothesized that ambulation with a mobility aid for people with dementia will be associated with a high attentional load. We hypothesized the use of a mobility aid in older adults with AD

will adversely affect gait performance and be most affected under the test condition of walking with a mobility aid on a curved path test condition. The study objectives were: i) to determine the dual-task cost associated with the use of a mobility aid in straight path and complex path walking in older adults with Alzheimer disease and age-sex matched cognitively normal controls, and ii) to evaluate the association between executive function and the functional performance on ambulation with a mobility aid.

METHODS
Study subjects
A convenience sample of adults with a diagnosis of mild to moderate Alzheimer's disease was recruited from a day program for community-dwelling older adults with dementia. Referral to the day program is based on a confirmed diagnosis of dementia by a geriatrician according to the criteria of the National Institute of Neurologic and Communicative Disorders and Stroke-AD and Related Disorders Association (NINCDS-ARDRA).[14] Inclusion criteria: age greater than 50 years, medically stable, English speaking, no physical impairments that would necessitate use of a mobility aid, had not used a walker previously and able to understand simple instructions. People were excluded if they had any neurological, musculoskeletal, or cardiorespiratory impairment that could compromise safe administration of the testing protocol. All participants or their caregivers provided written informed consent prior to participation in the study.

Control participants were recruited by newspaper advertisement and from a community fitness program. The inclusion criteria for the control group were: no subjective memory complaints, normal performance on cognitive tests, absence of functional impairment, and ability to walk independently. The control participants were matched to the participants with dementia on sex and age, plus or minus 2 years. This study was approved by the _____ Research Ethics Board for Health Sciences Research Involving Human Subjects.

Medical and Cognitive Assessments
Sociodemographic information, co-morbidities, physical activity level, activities of daily living (instrumental and basic), Falls Efficacy Scale-International[15] and medications were recorded. Cognition was assessed using the Mini-Mental State Examination[16] (MMSE; score 0–30). The severity of dementia was categorized according to the MMSE score: mild dementia, MMSE > 20 points; moderate dementia, MMSE = 10-20 points; and severe dementia, MMSE < 10 points. Executive function was measured using the Trail Making Test[17] (TMT). The TMT has two parts: Part A (TMT-A) requires participants to draw lines sequentially connecting 25 numbers, and Part B (TMT-B) requires them to draw lines sequentially alternating between numbers and letters (e.g., 1, A, 2, B, . . .). The TMT assesses visual search ability, scanning, speed of processing, mental flexibility, and executive functioning.[18] Results are reported as the time in seconds required to complete the task; a longer completion time indicates greater impairment. The TMT is sensitive to a variety of neurological impairments and processes.[18]

Gait Assessment
In the straight path walking, participants were timed while walking at a self-selected usual speed for a 6 meter distance, with one meter at either end to allow for acceleration and deceleration. In the complex path walking, the Figure 8 Walk Test[19] protocol will be used and reliability for this test has been demonstrated in older adults with dementia.[20] Participants start in standing, midway between two cones placed 1.52 meters apart and walk in a figure-of-8 path around the cones. The total time and the number of steps was recorded. The dual-task test

condition required the person to perform both walking configurations using a four wheeled walker.

Sample size. Based on previous data from our research in people with dementia (dual-task cost: 15% in cognitively normal older adults, 38% in older adults with dementia)[9], a sample size of 12 participants was needed for a power of 80% with α error of 5% to detect a 15% difference in dual-task cost.

Data analysis: Baseline characteristics of demographic and mobility variables were calculated as means and SDs or frequencies and percentages, as appropriate. For the first objective, a two-way repeated measures ANOVA using a general linear model evaluated the time to complete each walk in each configuration and the number of steps in the complex path (3 models). When interactions were non-significant main effects were assessed. The dual-task cost percentage for time to complete the straight path and complex path, and the number of steps in the complex path were evaluated with unpaired t-tests between the controls and the people with AD. The *dual-task cost* (DTC), as a percentage, was calculated as [(single task value − dual task value) / single task value] × 100% for each walking condition, straight and curved path walking, under single and walking with the wheeled walker and the number of steps to complete the complex path with a walker for each group. A negative DTC indicates that gait performance was decreased under the condition of using the wheeled walker. For the secondary objective, linear regression analyses between executive function (Trail Making Test B) and the time to complete each walking test in each test configuration were performed (4 separate models). All statistical analyses were performed using SPSS version 23.0 (SPSS, Inc., Chicago, IL) with statistical significance set at p < 0.05.

RESULTS

Fourteen people with mild to moderate Alzheimer's disease and controls were recruited for the study. Analysis of demographic characteristics demonstrated differences between the two groups on cognitive function and physical activity (Table 1). The differences between groups on cognition were expected as this defines membership in each group. Also there was a difference in the performance of instrumental and basic activities of daily living, the controls demonstrating no deficits and the people with AD possessing deficits in both domains, greater in instrumental activities consistent with the diagnosis of dementia. Physical activity levels also differed significantly between the groups, though a fear of falling and a history of falls were not different.

In the straight path condition, only the main effect of group was significant. People with AD walked slower than the controls in the single task (p=0.021) and using a wheeled walker (p=0.020). In the complex path condition, the interaction of group x task was statistically significant for time (p<0.001) and number of steps (p<0.001). (Figure 1 and 2)

The DTC was not different between the controls and people with AD for the wheeled walker task (-0.53±10.14% versus -4.64±11.47%, p=0.324) under the straight path condition. In the complex path condition, the DTC was significantly different between people with AD and controls for the wheeled walker task (-38.1±23.5% versus -19.7±21.4%, p=0.041) indicating greater cognitive load in the people with Alzheimer's disease. The dual-task cost for the number of steps was also significant (-16.85±17.91% versus -34.20±19.61%, p=0.022).

The linear regression demonstrated that executive function was significantly related to the time to complete all walking tasks; longer times to complete the TMT-B were associated with longer times to complete the walking tests. (Figure 3) The unstandardized regression coefficients for the TMT-B were: simple path usual gait, β=0.006(0.003-0.01), p=0.001,

R^2=0.373; simple path with walker, β=0.008(0.003-0.013), p=0.002, R^2=0.352; complex path usual gait, β=0.019(0.007-0.032), p=0.001, R^2=0.291; and complex path with walker, β=0.024(0.010-0.037), p=0.001, R^2=0.346. The regression coefficient represents the amount of change in time, in seconds, to complete the walking test that is associated with each second increase in time to complete the TMT-B.

DISCUSSION

This study has demonstrated that ambulating with a walker in a complex pattern generates a significantly higher cognitive load in people with AD, as demonstrated by a larger dual-task cost compared to healthy controls. Our finding is consistent with previous research that has demonstrated an increased cognitive load with use of a walker in healthy younger and older adults[2,4,5]; and, to the best of our knowledge, this study is one of the first to show that people with dementia experience an even greater demand on already limited or fragile cognitive resources. This finding has important clinical implications for fall prevention strategies and mobility aid prescription among people with AD.

Interestingly, the time to complete the straight path with the wheeled walker was no different than the single-task activity of usual gait speed for either group. This highlights the importance of the test configuration for dual-task testing to detect deficits as a straight path is considered a low challenge scenario.[13,22] This study supports that even in people with mild to moderate AD this is a low challenge activity and does not represent real world situations that are encountered while using a wheeled walker, such as maneuvering around obstacles.

Current recommendations for fall prevention guidelines in people with dementia are limited.[23, 24] Unfortunately the strategies that successfully reduce falls in the cognitively normal have not translated successfully to the cognitively impaired,[26] though there is accumulating evidence of benefit in community-dwelling older adults with dementia[27]. Rehabilitation interventions to reduce fall risk can include individualized exercise programs and the prescription of a mobility aid to compensate for deficits to allow maintenance of independent ambulation. Possible explanations for the overall greater fall risk in people with dementia include different underlying mechanisms, the magnitudes of association for risk factors that are shared with cognitively normal older adults is greater and there may be unique risk factors that are not present in cognitively normal adults. In addition to the development of new strategies, the present study emphasizes we must also understand the impact of our current rehabilitation interventions in order to develop programs that meet the unique health care needs of older adults with dementia.

Impairment in executive function is associated with falls[7], and balance and gait problems in older adults with and without a diagnosis of dementia [13,22,23]. This study also demonstrated a significant relationship between executive function and walking, such that lower scores on executive function were associated with longer times to complete each walking task. As hypothesized, walking in a straight path without a walker had the lowest magnitude of association to executive function and walking in a complex path with a walker had the highest. Though the association was statistically significant, executive function only explained a small amount of the variation in the time to complete the walk. As all people were new to using a mobility aid, there may be a greater variation that was not explained by executive function in the people with AD as a result of limited motor learning of a novel task creating anxiety of using something unfamiliar and lower efficiency with execution of the movement. Further research is

warranted on the effects of training in people new to use of mobility aids and among people experienced in using a mobility aid.

Difficulty maneuvering around obstacles can be a result of altered visuospatial abilities and executive function, which combined with limited memory for retaining teaching of the safe use of the equipment can pose a fall risk problem.[27, 28] The people with AD in this study had a higher prevalence of vision problems than the cognitively healthy controls. Vision impairment in depth perception and contrast sensitivity occurs in up to 60% of people with AD[30], these changes can affect safe navigation around obstacles with a mobility aid and importantly also increase cognitive load and therefore increase fall risk. The role of vision impairment in balance and gait function among people with AD using a mobility aid has not been evaluated and merits research.

It should be emphasized that the people with AD in this study were naïve to use of a mobility aid and were not in need of using a mobility aid for ambulation. The study was to evaluate the early learning effects of using an assistive device, independent of any functional limitations that would usually necessitate a prescription for a walker. Future research should focus on the timing of mobility aid prescription and the potential for learning effects with repeated exposure to use of the equipment. It has been demonstrated that people with AD possess intact implicit motor-learning capacities and therefore the potential for a reduction in cognitive load while using a mobility aid is a possibility with training.[32]

There are several strengths to this study. Our samples were age and sex-matched to remove these possible confounders as a source of any differences identified between the groups. We were also able to perform several tests of cognitive function to provide a broad overview of abilities between the groups. Additionally, all participants were able to complete the full assessment protocol without loss of study participants. Some limitations to the study include we did not include another manual task challenge for comparison, such as walking while carrying a glass of water as a comparison of magnitude of cognitive load across different tasks. While a sample size calculation was performed using data from other gait studies in people with Alzheimer's disease, the variation in scores was much greater than expected and may impact magnitude of associations found in this study.

CONCLUSIONS

Ambulation with a wheeled walker, in particular maneuvering the walker around obstacles, creates a greater attentional load in people with dementia than cognitively healthy peers and presents a potential fall risk. In adults with dementia, the timing of gait aid prescription to facilitate independent mobility may coincide with fragile brain function that cannot accommodate greater resource utilization, ultimately leading to instability, unsafe use of the aid and falls. Future research should explore the timing for safely introducing mobility aids among people with AD and the role of improving executive function.

Conflicts of interest: none

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Table 1. Demographic and clinical characteristics of study participants stratified by cognitive status.

Variable	Older Adults Controls (n=14)	Older Adults with Dementia (n=14)	Group Comparison* (p-value)
Age in years (SD; range)	72.9 (9.5; 58-87)	72.6 (9.9; 57-85)	0.94
Female, n (%)	8 (57.1%)	8 (57.1%)	
Years of education (SD; range)	15.1 (2.7; 12-21)	13.4 (2.6; 6-16)	0.10
Number of medications (SD; range)	1.8 (1.9; 0-5)	3.0 (2.5; 0-9)	0.15
Co-morbidities, n (%)			
Hypertension	4 (28.6%)	3 (21.4%)	
Diabetes	1 (7.1%)	1 (7.1%)	
Osteoarthritis	4 (28.6%)	4 (28.6%)	
Stroke/TIA	0 (0%)	3 (1%)	
Vision problems	9 (64.3%)	12 (85.7%)	
Cardiac problems	4 (28.6%)	3 (21.4%)	
Activities of Daily Living			
Lawton-Brody IADL (SD; range)	8 (0)	2.71 (2.27; 0-7)	<0.001
Lawton-Brody BADL (SD; range)	6 (0)	5.43 (0.94; 3-6)	0.032
Falls-related information			

Falls in the last 12 months, n (%)	1 (7.1%)	2 (14.3%)	0.611
Fear of falling, n (%)	2 (14.3%)	4 (28.6%)	0.407
Falls Efficacy Scale (SD; range)	19.5 (4.0; 16-30)	19.3 (4.0; 16-31)	0.891
Physical activity level			
Vigorously active, n (%)	13 (92.9%)	3 (21.4%)	<0.001
Moderately active, n (%)	1 (7.1%)	8 (57.1%)	
Seldom active, n (%)	0 (0%)	3 (21.4%)	
Cognitive Tests			
MMSE (SD; range)	28.7 (1.6; 25-30)	18.6 (3.8; 12-25)	<0.001
Trail making test A (seconds)(SD; range)	39.6 (10.7; 25.3-67.3)	122.5 (79.6; 44.6-300.0)	<0.001
Trail making test B (seconds) (SD; range)	94.9 (56.1; 52.0-275.0)	232.8 (111.9; 110.0-436.0)	<0.001

*, group comparison using unpaired t-test, $p < 0.05$ set as statistical significance; Vision problems, the total number of the presence of cataracts, cataract surgery, macular degeneration; cardiac problems, the total number of the presence of myocardial infarction, arrhythmia, atrial fibrillation; TIA, Transient Ischemic Attack; IADL**,** Instrumental Activities of Daily Living Scale; BADL, Basic Activities of Daily Living Scale; MMSE, Mini-Mental State Examination; MoCA, Montreal-Cognitive Assessment.

Table 2. Time to complete and number of steps for the walking tasks of single task and ambulation with a 4-wheeled walker in a straight and complex path configuration.

	Task	Group	
		Control (n=14)	AD (n=14)
Straight Path*			
Time (sec)	Single task	5.09 (0.76)	6.05 (1.26)
	Wheeled walker	5.11 (0.95)	6.34 (1.58)
Complex Path†			
Time (sec)	Single task	8.28 (2.45)	11.25 (4.87)
	Wheeled walker	9.58 (1.81)	15.01 (5.60)
Number of steps	Single task	14.86 (2.28)	17.36 (5.85)
	Wheeled walker	17.07 (1.77)	22.93 (7.25)

Values are means with S.D. in parentheses. *, main effect of group only was significant at p<0.05 in ANOVA; †, interaction (group x task) was significant at p<0.05 in ANOVA for time and number of steps. AD, Alzheimer disease group.

Table 3. Dual-task cost of ambulation with a 4-wheeled walker in a straight and complex path configuration.

	Dual-Task Cost (%)	
	Control (n=14)	**AD (n=14)**
Straight path time	- 0.53 (10.14)	- 4.64 (11.47)
Complex path time	- 19.7 (21.4)	- 38.1 (23.5)
Complex path number of steps	-16.85 (17.91)	-34.20 (19.61)

Values are means with S.D. in parentheses. Analyses were significant at $p<0.05$ for all between group comparisons. Negative values indicate a slower time and an increase in the number of steps while using the 4-wheeled walker.

Figure 1. The effect of single task walking and walking with a 4-wheeled walker on time to complete a complex walking configuration in controls and people with Alzheimer's disease (AD).
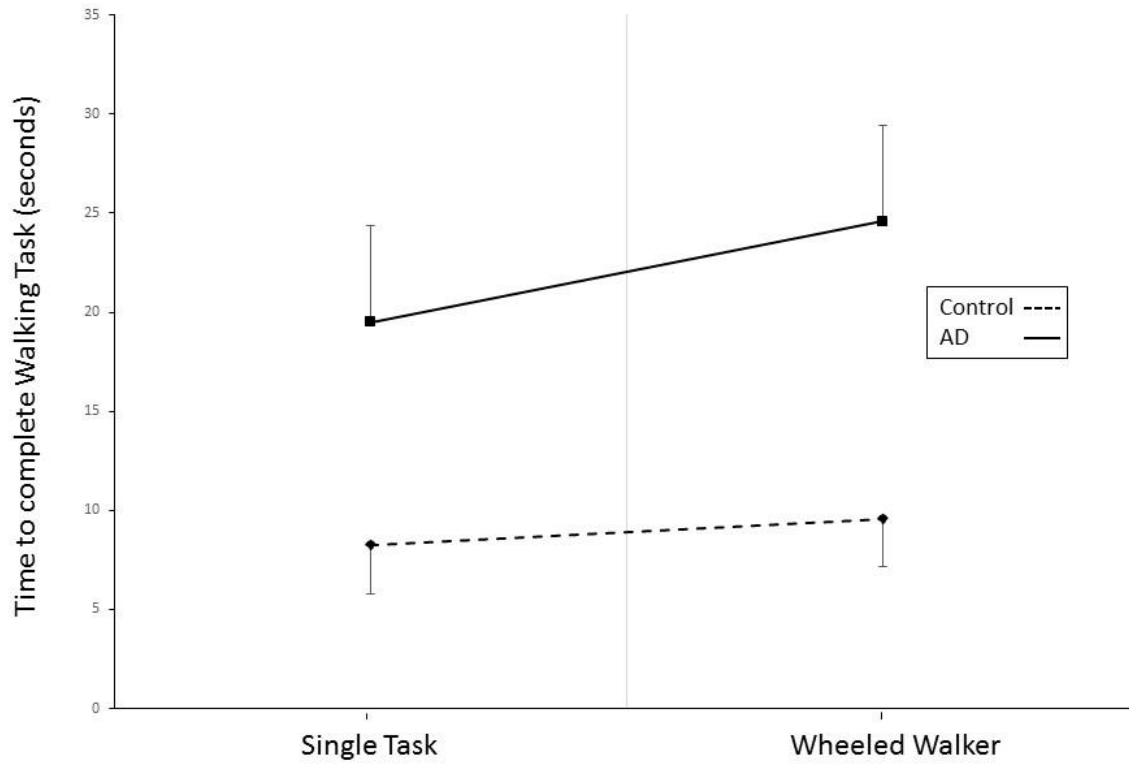
Figure 2. The effect of single task walking and walking with a 4-wheeled walker on the number of steps to complete a complex walking configuration in controls and people with Alzheimer's disease (AD).
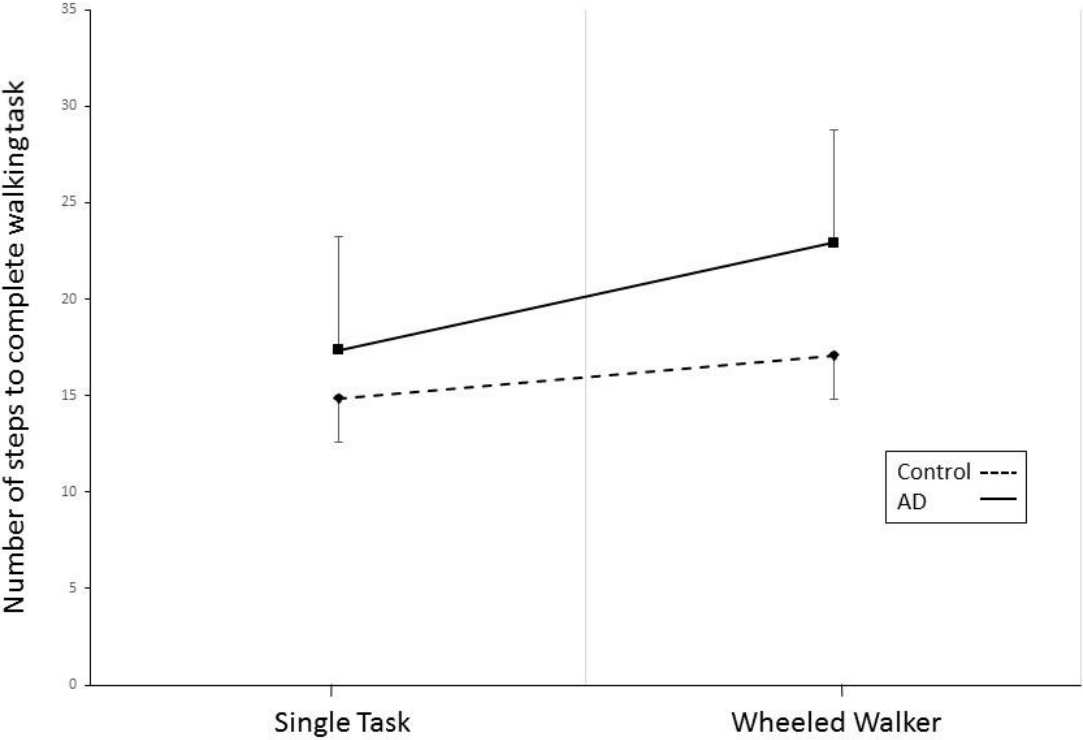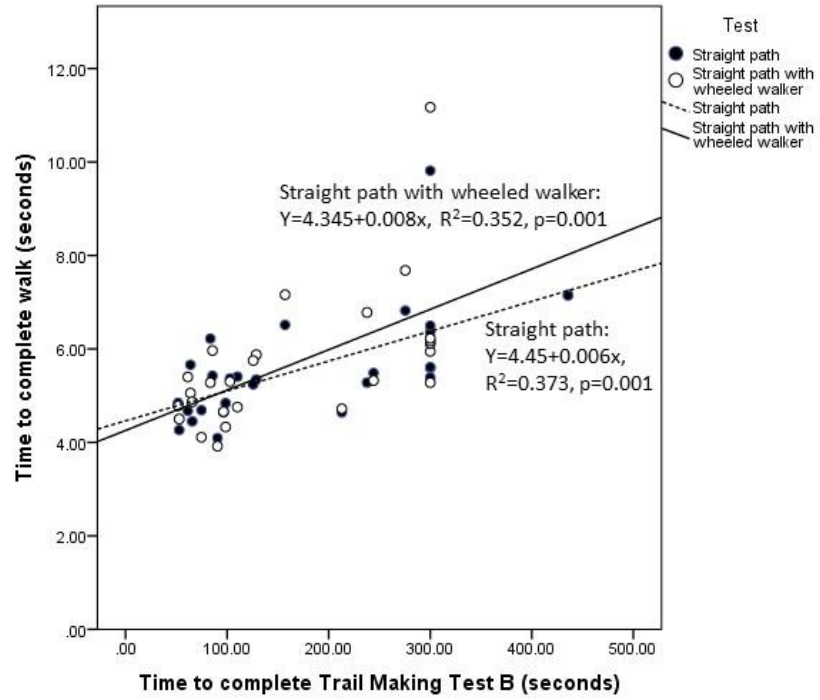
Figure 3. Results of linear regression of association between the time to complete the Trail Making Test-B (TMT-B) and the time to complete the gait tests as a single task and using a 4-wheeled walker in a simple path (A) and complex path (B) configuration.

A.

Chart axes and labels:

Y-axis: Time to complete walk (seconds) — 12.00, 10.00, 8.00, 6.00, 4.00, 2.00, .00

X-axis: Time to complete Trail Making Test B (seconds) — .00, 100.00, 200.00, 300.00, 400.00, 500.00

Legend: Test
● Straight path
○ Straight path with wheeled walker
---- Straight path
— Straight path with wheeled walker

Straight path with wheeled walker:
$Y=4.345+0.008x$, $R^2=0.352$, $p=0.001$

Straight path:
$Y=4.45+0.006x$, $R^2=0.373$, $p=0.001$

B.