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Effect of dual-tasking on walking in adults with Alzheimer's dementia experienced in 4-wheeled walker use

ABSTRACT

Background: Learning to walk with a 4-wheeled walker increases cognitive demands in people with Alzheimer's dementia (AD). However, it is expected that experience will offset the increased cognitive demand. Current research has not yet evaluated gait in people with AD experienced in using a 4-wheeled walker under complex gait situations.

Research Question: What is the effect of dual-task testing on the spatial-temporal gait parameters and cognitive performance of people with AD experienced with a 4-wheeled walker?

Methods: Twenty-three adults with mild to moderate AD (87.4 ± 6.2 years, 48% female) and at least 6 months of walker use experience participated. Three walking configurations: 1) straight path (SP), 2) Groningen Meander Walking Test (GMWT), and 3) Figure of 8 path (F8) were tested under two walking conditions: 1) single-task (walking with aid) and 2) dual-task (walking with aid and completing a cognitive task). Tri-axial accelerometers collected velocity, cadence and stride time variability (STV). Gait and cognitive task cost were the percentage difference between single-task and dual-task conditions. Two-way repeated measures ANOVAs were used to answer the study question.

Results: A significant interaction between walking configuration and condition was found for velocity ($p=0.002$, $\omega^2=0.36$), cadence ($p=0.04$, $\omega^2=0.15$) and STV ($p<0.001$, $\omega^2=0.53$). Velocity and cadence decreased and STV increased with increasing walking configuration complexity and upon dual-tasking. Dual-task gait and cognitive task cost deteriorated in all walking configurations, but gait was prioritized in the GMWT and F8 configurations.

Despite familiarity, experienced walker users with AD exhibit impaired gait when walking in complex situations which increases falls risk. Upon dual-task, individuals with AD self-prioritized a posture-first strategy in complex configurations.

Significance: Dual-task testing in experienced users results in slower walking, fewer steps and increased STV, which increases falls risk in people with mild to moderate AD and becomes most pronounced in complex environments.

Keywords: Multitasking behavior, Gait, assistive devices, walkers, Alzheimer Disease

1. INTRODUCTION

A main feature of Alzheimer's dementia (AD) is decreased physical function and deteriorated balance and gait.[1] Healthcare professionals prescribe mobility aids to compensate for balance and walking impairments. However, using a mobility aid is independently associated with a 3-fold increased likelihood of falls in people with dementia.[2] Although the addition of a mobility aid expands an individual's base of support, mobility aid use is a complex motor task which adds to the usual cognitive demands of walking.[3] The cognitive impairments with AD are well recognized, but people also have difficulty with motor planning and completing complex tasks.[4] The additional cognitive demands of using a mobility aid and incorporating it into the gait pattern may prove too challenging for people with AD to complete safely.[3]

Ambulation requires executive function with several concomitant challenges, such as the need to communicate, avoid obstacles, and make turns all while remaining stable.[3,5] The addition of a secondary concurrent task (e.g., talking) to gait is known as dual-tasking. If simultaneous performance of the two tasks exceeds an individual's cognitive capacity, then performance on one or both tasks will deteriorate.[6] Dual-tasking adds to the cognitive demand and complexity of normal gait to negatively affect gait velocity and stride time variability in individuals with AD not using mobility aids [7]. Our previous studies have determined that dual-task testing also affects spatial-temporal gait parameters in those learning to use 4-wheeled walkers [8], and that this effect is most pronounced in people with AD compared to healthy older adults. It is expected that training and experience should attenuate this effect and reduce cognitive load due to increased automaticity.[9] Wellmon et al.[10] noted during dual-task testing that cognitively-healthy older adults experienced with walker use exhibited increased attentional demands and decreased gait speed compared to individuals not requiring a mobility aid. Additionally, everyday life mobility can be demanding, from navigating turns to avoiding obstacles. These challenges require cognition, can be represented through curved path walking [11] and have been previously shown to be useful in those with cognitive impairment as a method to increase cognitive challenge.[12] The increased attentional demand of using a mobility aid in complex scenarios may be especially problematic for individuals with AD due to difficulty with motor planning and limited attentional capacity.[4] Thus the added cognitive demands of using a mobility aid may not be attenuated with experience and this still needs to be evaluated in people with AD.

Current literature has not established how gait is affected in individuals with AD experienced in using a 4-wheeled walker when walking in cognitively challenging situations. The objectives were to: 1) to evaluate the effect of dual-task testing on spatial-temporal gait parameters in people with mild to moderate AD experienced in 4-wheeled walker use, and 2) to better understand task prioritization by evaluating gait and cognitive task cost while dual-tasking. We hypothesized that increasing motor task complexity, in conjunction with an additional cognitive task, would negatively affect spatial-temporal gait parameters.

2. METHODS

2.1 Participants

Study participants were recruited from a local day program for people with dementia. Participants had a probable AD diagnosis from a geriatrician based on the National Institute of Neurologic and Communicative Disorders and Stroke-AD and Related Disorders Association criteria.[13] The protocol was examined and approved by the University of Western Ontario Health Sciences Ethics Review Board. Informed written consent was provided by the participant or their substitute decision maker, who provided informed consent on their behalf, and then the participant provided assent to participate.

Inclusion criteria: participants were at least 50 years of age, spoke English and understood simple instructions, had at least six months of daily 4-wheeled walker experience to assist mobility, and had a physician diagnosis of probable AD. The assessment of mild to moderate AD severity was provided by the day program based on functional abilities and the need for support during daily activities. Excluded were those that had a concurrent neurological or musculoskeletal disorder resulting in walking impairment. An a priori sample size calculation indicated that a minimum of 12 participants would be required assuming α=0.05, β=0.20, and a 15% effect size based on our previous work[3]. All data were collected over 15 months from March 2017 to May 2018.

2.2 Outcome Measures

Participants or the substitute decision maker provided socio-demographic and medical information, including age, sex, body mass index, years of education, co-morbidities, prescription medications, history of falls in the previous 12 months, and basic and instrumental activities of daily living using Lawton-Brody Basic Activities of Daily Living (BADL) and Instrumental Activities of Daily Living (IADL) scales.[14] Physical activity levels were examined by asking participants or substitute decision maker which of the following best described typical activity levels: sedentary- prefers more sedentary activity (e.g., reading) and engages in physical activity less than three times weekly; moderate- engages in physical activity at least three times per week (e.g., gardening); vigorous- engages in structured exercise for 30 minutes at least three times weekly (e.g., swimming). Participants also completed the Iconographical-Falls Efficacy Scale (ICON-FES), as well as Trail Making Tests A and B.[15]

Vision assessments of contrast sensitivity and spatial relations were the Mars Contrast Sensitivity Test (Perceptrix®) and the Stereo Fly Test (Stereo Optical Company®), respectively.

Cognitive Single-Task Assessment

To understand the effects of dual-tasking on performance, we first recorded single-task cognitive performance while seated. The time to complete 10 consecutive subtractions by ones from 100 was recorded with a stopwatch to the nearest hundredth of a second. Total responses and number of correct responses were also documented.

Gait Assessment

Gait was assessed with two tri-axial accelerometers (Locomotion Evaluation and Gait System, LEGSys™, BioSensics, Cambridge, MA). The LEGSys™ system is reliable[16] and has been validated against other kinetic and kinematic gold-standards in a range of healthy and clinical sub-groups of older adults[17,18]. These sensors were attached to each of the participant's lower limbs just below the tibial tuberosity in the frontal plane to obtain spatial-temporal gait information. The gait parameters of interest were cadence, velocity and stride time variability. These were chosen to represent the gait domains of rhythm, pace, and variability respectively.[19] Stride time variability was quantified via the coefficient of variation (CoV) as follows:

$$CoV\ (\%) = \left(\frac{Standard\ deviation}{Mean}\right) x(100)$$

The gait assessment consisted of three walking path configurations: a straight path (SP) of 6 meters, the Groningen Meander Walking Test (GMWT) [20] and the Figure of Eight Walking Test (F8) [21]. Participants completed these configurations under two conditions: single-task (ST)- walking and using the 4-wheeled walker, and dual-task (DT)- walking and using the 4-wheeled walker while counting backwards from 100 by 1s. The number and accuracy of the cognitive task responses during the DT conditions were recorded. There was no instruction to prioritize any one task during dual-task testing.

Participants used their own personal 4-wheeled walker for testing and were given no specific instructions regarding its use. Usual performance of walker ambulation without talking was evaluated. Participants were given a practice trial for each walking test at a self-selected pace to accustom them to the protocol. Following the practice trials, testing consisted of two trials per condition which were then averaged for data analysis. Trials were repeated if participants stopped walking.

2.3 Data Analysis

Gait velocity, cadence, and stride time variability were tested for meeting assumptions of normality and homogeneity of variance with Shapiro-Wilks test, measures of kurtosis and skewness, and Levene's test. Stride time variability deviated from normality and statistical analyses were performed using $\log_{10}$ transformed data. For Objective 1, comparison of the gait parameters velocity, cadence and stride time variability across walking configurations (SP, GMWT, F8) and task conditions (ST, DT) was examined using separate 2-way repeated measures analysis of variance (ANOVA). We have reported associated *p*-values and ω^2 effect sizes to determine statistical and clinical significance.

For Objective 2, task costs were calculated to determine the effect of dual-task testing on gait and cognitive performance. Task cost for gait was calculated as the percentage change in velocity between the ST and DT conditions:

$$DTCgait = \left[\frac{DT - ST}{ST}\right] x(100)$$

To calculate task cost for the cognitive performance, the correct response rate (CRR) was first determined for the single-task cognitive test as:

$$Correct\ response\ rate\ (CRR) = responses\ per\ second\ x\ percentage\ of\ correct\ responses$$

CRR accounts for the speed and accuracy of the responses given.[22] Following calculation of CRR, cost for the cognitive task was calculated as follows:

$$DTCcog = \left[\frac{CRR\ walking\ in\ DT - CRR\ seated}{CRR\ \ seated}\right] x(100)$$

A negative task cost value indicates poorer performance in the DT condition while a positive value indicates improved performance. Repeated measures ANOVAs were conducted to examine the effect of configuration on gait and cognitive task cost separately. When interactions were not statistically significant, pairwise comparisons for main effects were calculated using the Holm-Bonferroni post hoc method.

Performance-resource operating characteristic (POC) plots were created with DTCgait (y-axis) and DTCcog (x-axis) for demonstration of the task trade-offs for gait and cognitive tasks during dual-task testing.[6] The POC can be divided into four quadrants: 1) upper left– improved gait performance with decreased cognitive performance, 2) upper right– improved performance on both gait and cognitive tasks, 3) lower left– decline in both gait and cognitive task performance, and 4) lower right– decline in gait performance with improved cognitive performance. Individuals that fall on the axes indicate no change in performance between ST and DT conditions. A reference line passes directly through quadrants 2 and 3 which indicates task prioritization during dual-tasking. Individuals falling on the left of this line prioritize gait, while those on the right prioritize the cognitive task.[23]

3. RESULTS

Twenty-five participants were recruited for this study, but two participants were unable to complete the dual-task conditions of the protocol and were thus withdrawn from analysis. In total, 23 participants (age 87.4 ± 6.2 years, 48% female) were included in the final analysis.

(Table 1). Participants in this study were primarily sedentary (65.2%), scored low on the IADL (1.4 ± 1.3) and presented with several comorbidities (6.0 ± 2.2). Values of gait velocity, cadence and stride time variability in each of the test conditions is presented in Table 2.

3.1 Gait Velocity

There was a significant interaction between path configuration and task condition ($p=0.002$, $\omega^2=0.36$). Gait velocity decreased with increased complexity in configuration and with the addition of the secondary cognitive task. (Figure 1a).

3.2 Gait Cadence

Cadence analysis showed a statistically significant interaction between path configuration and task condition ($p=0.04$, $\omega^2=0.15$). Cadence decreased with dual-tasking, but not with increased task complexity. (Figure 1b).

3.3 Stride Time Variability

There was a significant interaction between path configuration and task condition ($p<0.001$, $\omega^2=0.53$). STV increased with increasing task complexity in dual-tasking. (Figure 1c).

3.4 Dual-Task Costs

Participants exhibited mean gait task costs of -23.1%, -13.8% and -16.5% for the SP, GMWT and F8 configurations, respectively. Cognitive task costs were -0.17%, -9.14%, and -22.2% for SP, GMWT, and F8 configurations. There was a significant main effect of path configuration on gait ($p=0.04$, $\omega^2=0.14$) and cognitive ($p=0.001$, $\omega^2=0.42$) dual-task cost. Cognitive dual-task cost increased with increased task complexity, while gait dual-task cost decreased with increased task complexity. For gait dual-task cost, there was a significant difference between SP and GMWT ($p=0.042$), but not between SP and F8 ($p=0.09$) or between GMWT and F8 ($p=0.276$). For cognitive dual-task cost, there was a significant difference between SP and GMWT (p=0.042) and between SP and F8 (p=0.003), but not between GMWT and F8 (p=0.054). (Figure 2). POC graphs demonstrated mutual interference between the cognitive and gait tasks. Of note, 50% of participants prioritized gait performance in the SP configuration. A greater percentage of participants prioritized the gait task in the GMWT (59.1%) and F8 (72.7%) configurations. (Figure 3).

4. DISCUSSION

The study found that gait performance decreased with increasing task complexity and with the addition of the secondary cognitive task. Additionally, and upon dual-task testing, both gait and cognitive task performance deteriorated. Yet, in the more complex tasks participants self-prioritized gait performance over the cognitive task. To our knowledge this is the first study to investigate and report these effects on gait and cognitive demands in individuals with AD experienced in using a 4-wheeled walker.

In our study, a deterioration in gait performance was observed with increasing path complexity and under dual-task conditions. General deterioration of gait is common among individuals with cognitive impairment and the change is especially apparent with dual-tasking in complex environments [12]. Previous work has also demonstrated that gait velocity, cadence and stride time variability deteriorate under dual-task testing in people with AD and community-dwelling older adults.[24] Additionally, falls risk in cognitively impaired individuals has been associated with poorer outcomes in the variability domain [7]. Our study results are consistent with current literature whereby an increased cognitive load is associated with deteriorated gait performance and increased instability. The increase in cognitive load and resulting instability may be a mechanism through which falls risk is increased among people with dementia who use a mobility aid.

Experience and practice can generally mitigate the costs associated with learning a new task through the refining of skills with motor learning and the development of task automaticity. Evidence of improved performance in experienced individuals compared to novices has been demonstrated in many disciplines.[9,25,26] Compared to a previous study of novice 4-wheeled walker users with AD, we observed smaller gait and cognitive dual-task costs in our experienced cohort, especially in the more complex paths.[8] Decreased dual-task costs may suggest a learning effect in the experienced users resulting from increased automaticity and a decreased cognitive load. Yet, even with practiced use of a 4-wheeled walker there continues to be gait deterioration in experienced users especially with increased task complexity. Future research should examine differences between novel and experienced users more in depth to determine if a clinically significant difference exists.

Despite the cognitive impairment associated with AD, a preserved capacity for learning still exists.[27] Training protocols that use procedural (implicit) learning optimize acquisition and retention of new skills in people with AD.[4] There is emerging evidence that these methods may be clinically useful in assisting those with dementia learn and retain proper use of their walker.[28] Contrary to the existing research, the current starting point for most rehabilitation programs is through the use of explicit or declarative learning methods.[29] The observed dual-task cost among experienced walker users in our study may be a result of sub-optimal training protocols leading to improper learning. Future research should explore how implicit versus explicit learning methods affect skill acquisition and knowledge retention in individuals with AD learning the safe use of a mobility aid.

Although performance in both gait and cognitive tasks declined while dual-tasking, dual-task cost results show that with increasing task complexity participants were able to shift focus to prioritize gait, a posture-first strategy. More complex walking paths require more attentional resources and a level of executive functioning beyond that of SP walking.[12] Although there was a deterioration in gait with all dual-tasking conditions, individuals with AD minimized the overall impact in the more complex paths by prioritizing ambulation at the expense of cognitive task performance. Self-awareness is considered a key component of unconscious task prioritization that involves hazard estimation with an awareness of self and to the environment within which a task is done.[30] Future research should examine the length of time for motor learning to occur for people with AD to achieve maximal mobility aid function. Additionally, it still has to be determined if training using an implicit learning protocol can increase the likelihood of a posture-first response or accentuate this task prioritization to reduce gait instability in challenging situations, allowing for a decreased cognitive load and freeing of attentional resources to devote to safe movement. Moreover, the timing of the introduction of a mobility aid with respect to disease severity should also be evaluated in order to identify an optimal period for motor learning in this population.

This study had several limitations that should be considered in the interpretation of the findings. Our sample may not be generalizable to all people with AD due to variations in disease severity, common concomitant conditions that excluded individuals from participation and our participants were recruited from a specialty day program for people with dementia. Alzheimer's disease severity was based on functional mobility and not a specific standardized test. Participants exhibiting severe AD may not have been able to complete the protocol, thus the study sample was likely composed of those with a more moderate disease severity. Heterogeneity in Alzheimer's disease severity may explain the different levels of physical activity reported. A general understanding of a participant's lifestyle was assessed as reports of physical activity were not based on a validated questionnaire. Additionally, we only examined one motor (gait) and one cognitive (arithmetic) task in combination and our results cannot be compared directly with testing using other tasks. The assessment protocol was chosen to not overwhelm participants performance capacity and allowed for the best chance of completing the protocol. Our results demonstrate that the cognitive task chosen provided a sufficient challenge and highlights that small additional demands adversely impact gait. There are several strengths in this study we would like to highlight. We assessed people who had at least six months of experience using a 4-wheeled walker daily. We also assessed both gait and cognitive task cost, which allowed for the evaluation and comparison of task interference and the determination of task prioritization in complex dual-task situations.

5. CONCLUSION

The use of a walker while ambulating is a complex motor task that requires attentional and cognitive resources to perform successfully. Successful locomotion in daily life also requires individuals to navigate through their environment, including complex pathways to avoid obstacles and to complete other tasks simultaneously, such as walking and talking. The current study shows that even in experienced users, increases in environmental complexity and the addition of a secondary cognitive task results in decrements of spatial-temporal gait parameters while ambulating with a 4-wheeled walker, thus producing changes associated with gait instability and an increased risk of falls. Importantly, experienced walker users with AD were able to self-prioritize gait over the cognitive task in the more complex situations.

6. CONFLICT OF INTEREST/DISCLOSURE STATEMENT

The authors have no conflict of interest to report.

HIGHLIGHTS

- Walking with a 4-wheeled walker is a complex motor task.
- People with Alzheimer's dementia experienced using a 4-wheeled walker were tested.
- Complex walking paths and cognitive challenge resulted in increased instability.
- People self-prioritized gait over the cognitive task in the most complex tests.

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Table 1: Demographic and clinical characteristics of a sample of older adults with mild to moderate Alzheimer's dementia experienced in 4-wheeled walker use. (n=23)

Characteristics	**Mean (SD) or Frequency (%)**	**Range**
Age (years)	87.4 (6.1)	71-97
Sex (n, % female)	11 (48%)	
Body Mass Index (kg/m^2)	28.5 (6.4)	18.3-50.2
Education (years)	11.5 (3.2)	8-18
Iconographical Falls Efficacy Scale	18 (7.0)	10-36
Instrumental Activities of Daily Living	1.4 (1.3)	0-5
Basic Activities of Daily Living	4.9 (1.0)	2-6
Trail Making Test A (s)	155.72 (90.33)	47.81-300
Trail Making Test B (s)	265.31 (53.92)	145.26-300
History of falls in past 12 months (n, %)	14 (60.9%)	
Physical Activity (n, %):		
Sedentary	15 (65.2%)	
Moderate	7 (30.4%)	
Vigorous	1 (4.4%)	
High Contrast Sensitivity (logCS units)	0.36 (0.20)	0.1-0.8
Stereo Fly Test (circles, seconds of arc)	313.33 (270.37)	40-800
Number of Prescription Medications	7.5 (3.4)	0-15

Number of Comorbidities	6.0 (2.2)	2-10

Table 2: Gait velocity, cadence and stride time variability across walking path configuration and task conditions. (n=23)

		Mean (SD)		
Outcome Measure	**Task Condition**	**Configuration**		
		SP	**GMWT**	**F8**
Gait Velocity (m/s)	Single-Task	0.61 (0.17)	0.43 (0.11)	0.39 (0.10)
	Dual-Task	0.46 (0.15)	0.37 (0.10)	0.33 (0.11)
Cadence (steps/min)	Single-Task	89.45 (17.17)	80.87 (20.01)	85.36 (20.86)
	Dual-Task	73.51 (16.61)	71.52 (19.36)	74.78 (20.98)
Stride Time Variability (CoV%)	Single-Task	6.50 (5.40)	6.20 (3.72)	7.51 (3.30)
	Dual-Task	7.41 (4.21)	9.87 (8.01)	13.84 (12.57)

Note: Single-Task, walking with the use of a 4-wheeled walker; Dual-Task, walking with the use of a 4-wheeled walker and completing serial subtractions from 100 by 1s; SP, straight path configuration of 6 meters; GMWT, Groningen Meander Walk Test; F8, Figure of 8 Walk Test.

Figure Legends.

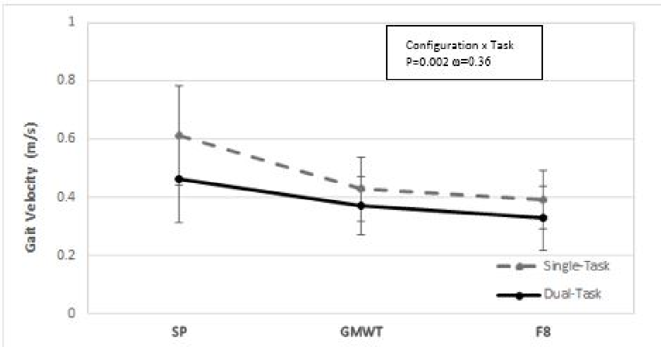
Figure 1: The effect of walking with a 4-wheeled walker under single-task and dual-task cognitive challenge on time to complete three walking configurations in people with mild to moderate Alzheimer's dementia. (A: Gait velocity, B: Stride Time Variability (STV), C: Cadence)

Figure 2: Gait and cognitive dual task costs in Straight Path (SP), Groningen Meander Walk Test (GMWT) and Figure of Eight (F8) configurations while walking using a 4-wheeled walker and counting backwards by ones in people with mild to moderate Alzheimer's dementia.

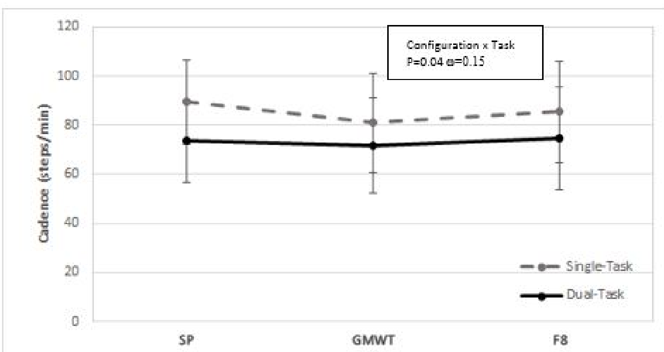
Figure 3: Performance-resource operating characteristic graphs comparing gait and cognitive performance in dual-task testing (walking while using a 4-wheeled walker and counting backwards by ones) in Straight Path (SP), Groningen Meander Walk Test (GMWT) and Figure of Eight (F8) configurations in people with mild to moderate Alzheimer's dementia.

Figure 1.

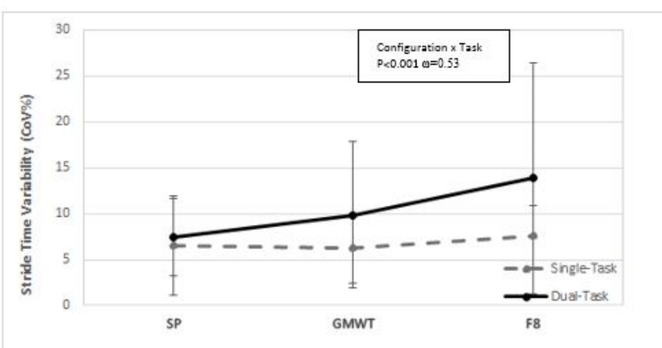
A



B

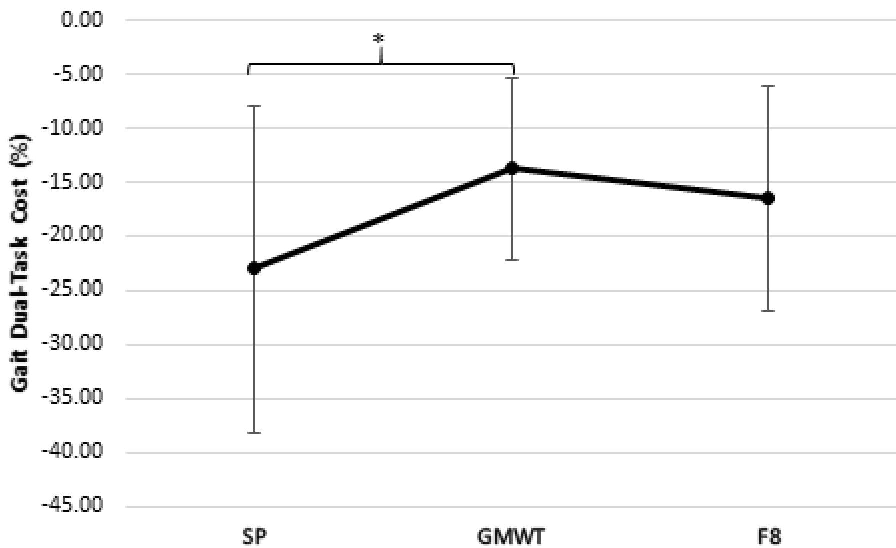


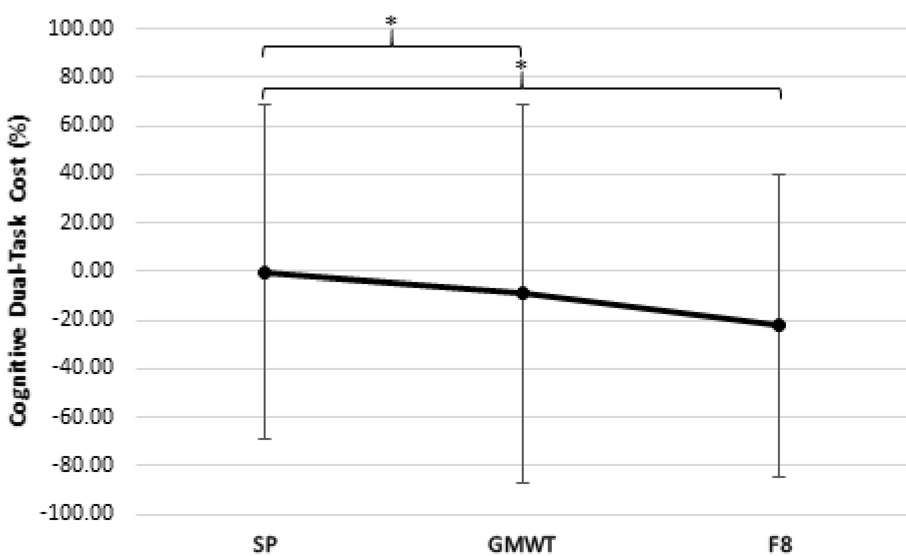
C



Note: SP, straight path configuration of 6 meters; GMWT, Groningen Meander Walk Test; F8, Figure of 8 Walk Test.

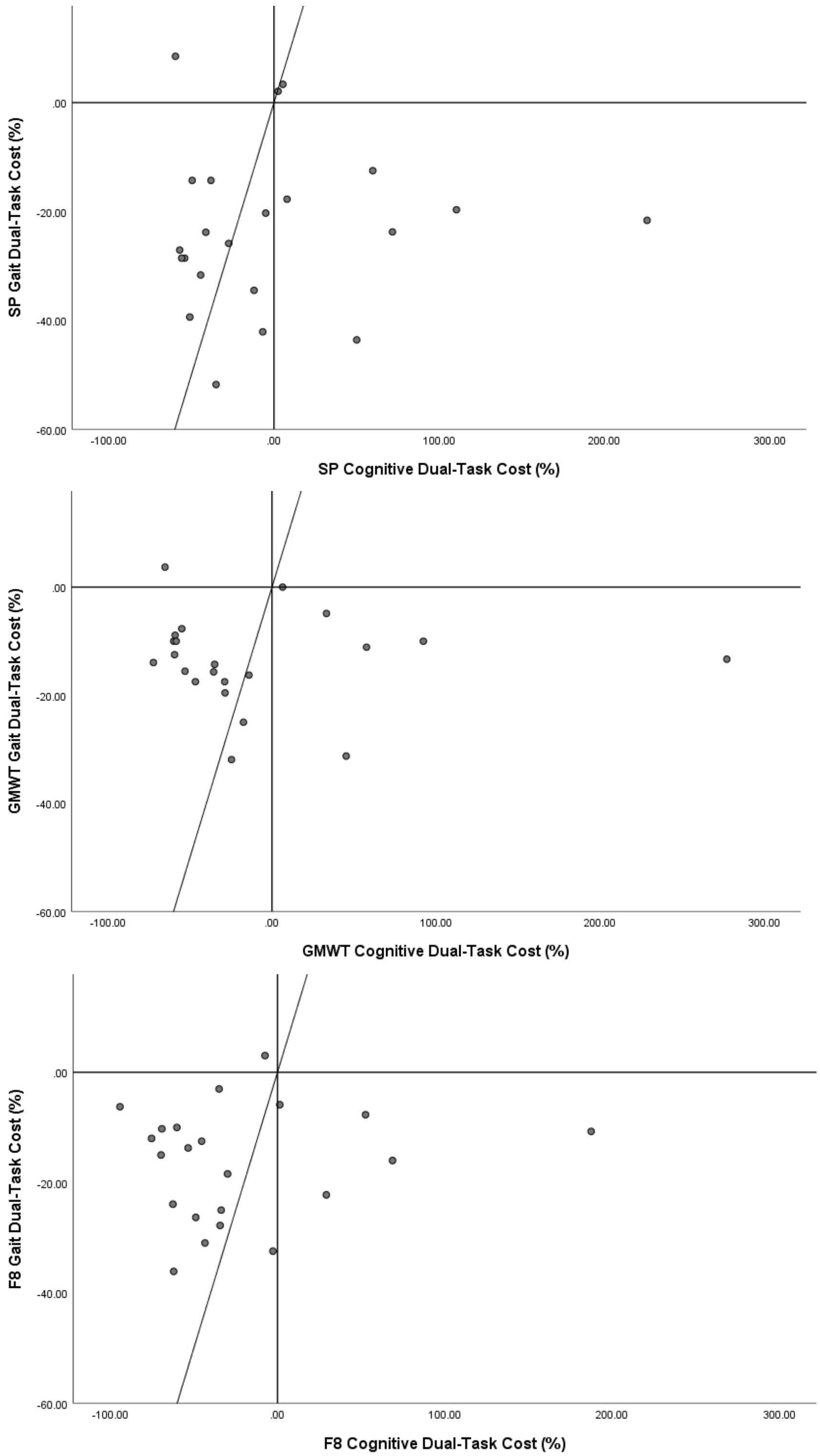
Figure 2





Note: SP, straight path configuration of 6 meters; GMWT, Groningen Meander Walk Test; F8, Figure of 8 Walk Test. * Denotes a statistically significant difference between path configurations ($p<0.05$).

Figure 3


SP Gait Dual-Task Cost (%)
.00
-20.00
-40.00
-60.00
-100.00
.00
100.00
200.00
300.00
SP Cognitive Dual-Task Cost (%)
GMWT Gait Dual-Task Cost (%)
.00
-20.00
-40.00
-60.00
-100.00
.00
100.00
200.00
300.00
GMWT Cognitive Dual-Task Cost (%)
F8 Gait Dual-Task Cost (%)
.00
-20.00
-40.00
-60.00
-100.00
.00
100.00
200.00
300.00
F8 Cognitive Dual-Task Cost (%)

Note: The upper left quadrant indicates improved gait but decreased cognitive performance. The upper right quadrant indicates improved gait and cognitive performance. The lower left quadrant indicates decline in both gait and cognitive performance. The lower right quadrant indicates decline in gait but improved cognitive performance. Points to the left of the reference line passing through quadrants two and three indicates gait was prioritized, while those on the right prioritized the cognitive task. Points directly on the reference line indicates there was no change between single-task and dual-task conditions.