



The effect of mental tracking task on spatiotemporal gait parameters in healthy younger and middle- and older aged participants during dual tasking

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Abstract

To evaluate the effect of dual tasking that combines walking with a mental tracking task on spatiotemporal gait parameters in younger and older adults. After completing the International Physical Activity Questionnaire (IPAQ), participants performed single tasks: preferred paced walk (PPW); fast paced walk (FPW); single-leg stance (SLS); spelling backwards cognitive task (CT). Thereafter, dual tasks: PPW + CT; FPW + CT; SLS + CT. Spatiotemporal gait parameters and the durations of SLS and SLS + CT were measured. Twenty younger and 20 older adults participated. The IPAQ scores were similar in both groups. Compared to the single task, stride length was shorter, stride time was longer, and stride length and time variability were higher during the PPW and FPW dual tasks in both groups. Older age was associated with shorter stride length during PPW and FPW, and longer stride time during FPW dual compared to single tasks. The older group exhibited shorter times during SLS and SLS + CT compared to younger group. Despite similar self-reported fitness, older age is associated with shorter stride length and longer stride time during FPW dual tasks as well as short times during SLS + CT, which may indicate diminished balance and posture stability.

Keywords Dual tasking · Gait · Older

Introduction

A decline in gait performance heightens the risk of falls in the elderly and, consequently, of morbidity and mortality (Newman et al. 2006). The reasons for alterations in gait performance are multifactorial and include joint abnormalities,

muscle impairments and cognitive deficits (Hollman et al. 2007). Studies focusing on cognitive demands during locomotion have reported that gait is not an automatic activity and deficits in cognitive function increase the risk of falls (Sheridan and Hausdorff 2007). Thus, gait is considered a complex task and the maintenance of its stability demands cognitive resources (Sheridan and Hausdorff 2007; Beurskens et al. 2014). Another important factor for normal gait is static postural stability, which can be tested using single-leg stance test (Talarico et al. 2017).

The cognitive demand on locomotion is more pronounced when a motor task is combined with a secondary task (Lu et al. 2015). The simultaneous execution of two tasks with different objectives such as walking (motor task) and counting backwards (cognitive task) is termed dual tasking (Yogev-Seligmann et al. 2012). Dual tasking is a common feature of daily activities and frequently involves a motor and a cognitive task (McIsaac et al. 2015). Although multiple tasks can proceed in parallel, the capacity sharing model theory argues that central processing capacity is limited and when two tasks share common neural pathways, the resources required can exceed the brain capacity;

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consequently, decrements of tasks' performance can occur (Tombu and Jolicoeur 2003; Patel et al. 2014).

Dual tasking has been used to assess alterations in gait and cognition using various cognitive and motor tasks. Gait is one of the most commonly used motor tasks, because of its importance in daily activities and its clinical relevance (Simoni et al. 2013). During dual tasking, decrements in gait and/or cognitive performance have been reported in younger and older adults (Yogev-Seligmann et al. 2010) or in younger compared to older adults (Hollman et al. 2007; Plummer-D'Amato et al. 2011; Beurskens et al. 2014). Cognitive and motor decline are strongly linked to aging (Montero-Odasso et al. 2012; Verghese et al. 2014) and gait can be further compromised during dual-tasking conditions (Montero-Odasso et al. 2014). The alterations in gait parameters determined during dual tasking in the elderly can be used to identify early stages of cognitive decline or motoric cognitive risk syndrome (Montero-Odasso et al. 2012; Verghese, et al. 2014). Deficits contributing to frailty have an early onset; although highly variable until age 45, there is a consistent gradual decline thereafter (Mitnitski et al. 2002; Rockwood et al. 2004). Thus, the lower limit of older adults in our study was 45 years, which was considerable younger than previous reports (Galletly and Brauer 2005; Reelick et al. 2009; Yogev-Seligmann et al. 2010; Asai et al. 2013; Simoni et al. 2013).

Different cognitive tasks, such as mental tracking, working memory and verbal fluency tasks, have been paired with walking (Al-Yahya et al. 2011) depending on the cognitive function being studied. During dual tasking, gait is altered depending on the cognitive task and its difficulty (Al-Yahya et al. 2011; Beurskens and Bock 2012; Liu et al. 2017; Smith et al. 2017). A recent review by Al-Yahya et al. (2011) reported that gait parameters appear to be disturbed more if the cognitive task involves internal interference (e.g., mental tracking tasks). According to the classification of cognitive tasks by Al-Yahya et al. (2011), mental tracking tasks require manipulating the information in working memory and, thus can be used to evaluate attention, working memory and speed of information processing. Spelling backwards is a type of mental tracking cognitive task that requires an individual to listen, process the word, and verbalize the letters in reverse order (Hollman et al. 2010). These steps involve executive functions, including attention and working memory, that are also utilized during walking. As a result, walking ability of individuals may be compromised during dual tasking and pose an increased risk of falls.

Several studies have paired a difficult mental tracking task such as spelling backwards with walking to identify changes in spatiotemporal gait parameters (Hollman et al. 2007, 2010). Even though many studies used different walking speeds during dual tasking in healthy young (Beurskens and Bock 2013; Patel et al. 2014; Wrightson et al. 2016), healthy

old (Beurskens and Bock 2013; De Cock et al. 2017) and pathological situations, as old with cognitive impairment (Theill et al. 2011), dementia (IJmker and Lamoth 2012), chronic stroke (Plummer-D'Amato et al. 2008; Dennis et al. 2009), Parkinson's disease (Strouwen et al. 2016; Baron et al. 2018) and Alzheimer's disease, they mainly focused on velocity as walking speed (speeding up or slowing down) is a requirement of activities of daily living. Most of these studies did not report other important gait parameters. For example, stride time appears to be more impacted by dual tasking than other gait parameters (MacAulay et al. 2014), but is not well documented in the literature.

A comprehensive breakdown and analysis of how gait is altered at slow and fast walking speeds are required to devise appropriate guidelines to inform individuals to minimize the risk of falls and the associated injuries. Methodological differences including heterogeneity of cognitive tasks and gait outcomes measured in dual tasking and lack of consideration of potential impact of participants' physical activity level on gait in dual-tasking studies poses a barrier in synthesizing evidence regarding the real influence of particular cognitive tasks on gait parameters. Therefore, this study analyzed a comprehensive set of gait variables during different walking speeds and concurrent performance of a unique cognitively demanding cognitive task (spelling backwards) as well as single-leg stance task performance, while considering the impact of physical activity levels. In addition, older adults with a lower age limit were recruited based on the threshold when cognitive and physical changes consistently decline to a frailty state (Rockwood et al. 2004; Mitnitski et al. 2002). Thus, the main purpose of this study was to evaluate the effects of dual tasking that combines walking at preferred or fast pace with a mental tracking task (spelling backwards) on spatiotemporal gait parameters in younger and older healthy adults. We hypothesized that gait performance during dual tasking would decrease and this decrement will be greater in older compared to younger healthy adults. In addition, individuals with high level of physical activity would have a lower decrement in gait during dual tasking.

Methods

Participants

Forty healthy participants (younger: 20; older: 20) were selected to participate in this study. They were recruited through emails and posters from the University of Toronto, nearby hospitals and community centers in Toronto, Ontario, Canada. The participants were included if they were aged 18–35 years for the healthy younger group (HYG) and ≥ 45 years for the healthy older group (HOG). Participants were excluded if they were smokers; experienced an acute

illness during the last 3 months; had unstable cardiovascular, neurological or musculoskeletal conditions that could interfere with independent ambulation and/or limit safe performance of the experimental protocol; had cognitive impairment or lacked English fluency that could interfere with informed consent or following study instructions. The study was approved by the Health Sciences Research Ethics Board at University of Toronto (protocol ID: 33466) and all participants provided written informed consent before data collection.

Procedures

After completing the International Physical Activity Questionnaire (IPAQ), participants performed four different single tasks: (1) preferred paced walk (PPW); (2) fast paced walk (FPW); (3) single-leg stance (SLS); and (4) spelling backwards cognitive task (CT) in a seated position. Afterwards, the participants performed dual tasks: (5) PPW + CT; (6) FPW + CT; and (7) SLS + CT. During the dual tasks, no instruction for prioritization of either task was given. All single tasks were randomly ordered; thereafter, all dual tasks were randomly ordered. For PPW tasks, participants were instructed to walk at their usual walking speed, while during FPW, they were instructed to walk as fast but as safely as they could walk. The entire protocol was completed during one 1.5-h (h) session.

International Physical Activity Questionnaire (IPAQ)

The IPAQ consists of 27 questions that ask about various physical activities that vary in intensity and location during the most recent 7 days. It has been extensively validated in several countries, in different languages and across age (Craig et al. 2003; Hagströmer et al. 2006; Wanner et al. 2016). The IPAQ was scored according to established methodology (<https://www.ipaq.ki.se>).

Walking protocol

Spatiotemporal gait parameters were quantified using a pressure-sensitive Zeno™ Walkway mat (ProtoKinetics, Havertown, PA, USA) in conjunction with the ProtoKinetics Movement Analysis Software (PKMAS). The mat is 5 meters (m) in length that contains a grid of 13,824 sensors. The location of the steps is recorded by the system based on the activation of the sensors. The concurrent validity and reliability of the Zeno™ Walkway were excellent for spatiotemporal gait parameters when compared to GAITRite walkways, a similar walkway extensively used in gait research. Participants' gait was evaluated for 30 m, which was comprised of six passes over the mat. The participants were instructed to walk along the center of the mat and to a

marker 0.5 m beyond the end of the mat, to turn around and walk back to their starting position (0.5 m beyond the other end of the mat) before turning around and completing the next pass. Participants continued in this manner until they completed three back and forth rounds (Egerton et al. 2014; Vallabhajosula et al. 2019). The spatiotemporal parameters were averaged over the six passes for each individual. Five spatiotemporal gait parameters analyzed included: cadence (number of steps per minute), stride length (distance between two successive points of the same foot during a step), stride length variability, stride time and stride time variability.

To analyze dual-task interference, the dual-task effects (DTE) were calculated on gait performance (Kelly et al. 2010; Plummer-D'Amato et al. 2012):

$$DTE = \left[\frac{(\text{dual task} - \text{single task})}{\text{single task}} \right] \times 100.$$

According to Yang et al. (2016), the sign's interpretation of the DTE depends on the parameter analyzed. For cadence and stride length, a negative value indicates that walking performance was worse during the dual than in the single task. On the contrary, for stride time, stride length variability and stride time variability, a positive value indicates worse performance during the dual compared to the single task.

Single-leg stance

The single-leg stance (SLS) was performed according to standard protocol. The SLS tasks required the participants, with the eyes open and hands on the waist, to stand on their dominant leg, while bending the non-dominant leg at a 90° angle for as long as they could. The tasks lasted from the time the participant lifted the foot off the ground to the time it was put back down. The duration, in seconds, was timed (Kärkkäinen et al. 2008).

Cognitive task protocol

Spelling words backwards was chosen as the CT. An investigator verbalized the five-letter words one by one, which the participants spelled backwards. A different set of words was chosen from a list of 100 unique words for each task performed by the participants. Spelling backwards is a challenging mental tracking task that has been previously described (Hollman et al. 2007, 2010).

Statistical analysis

GraphPad Prism 6.0 software (GraphPad, Inc., San Diego, California) was used to process the participants' characteristics, spatiotemporal gait parameters and SLS time.

Comparisons between tasks (single and dual tasks) as well between groups (HYG and HOG) were performed using mixed analysis of variance (ANOVA) and the effect size were measured and based on those provided by Cohen (1988) (small=0.01; medium=0.06; large=0.14). Unpaired *t* tests were utilized to test between-group differences of the participants' characteristics, DTEs for gait parameters, duration time of the SLS and SLS + CT and velocity during PPW and FPW. The association between IPAQ scores and the dual-task effect was tested using a Pearson correlation and correlation coefficients < 0.30 were considered weak, those between 0.30 and 0.70 were considered moderate and coefficients > 0.70 were considered strong. Statistical significance threshold was set at $p < 0.05$.

Results

Participants' characteristics are presented in Table 1 and the groups only differed significantly in age ($p < 0.001$). Of note, half of HOG were middle aged (45–65 years) and the other ten had an age range of 67–75 years. Both groups had similarly high self-reported physical activity levels as indicated by the mean metabolic equivalent task (MET)-min/week of over 3000 according to IPAQ. In fact, the MET-min/week of the HOG tended to be higher than the HYG (5276.2 versus 3699.3 (MET)-min/week; n.s.). Eleven participants in the HOG and 8 in the HYG had high physical activity, while 11 participants in the HYG and 8 in the HOG had moderate levels of physical activity. One participant in each group had a self-reported low physical activity according to the IPAQ. However, the association between IPAQ scores and the dual-task effects, of all gait parameters for PPW and FPW, was weak (< 0.30) and not significant ($p > 0.05$).

Table 1 Characteristics of healthy younger and older adults

	Younger	Older	<i>p</i>
Sex (<i>n</i> of M:F)	10M:10F	10M:10F	1.000
Age (years)	27.6 (3.5)	63.5 (11.3)	<0.001*
Height (m)	1.7 (0.1)	1.7 (0.1)	0.396
Weight (kg)	69.3 (15.8)	71.5 (16.2)	0.665
BMI (kg/m ²)	24.1 (3.8)	25.8 (4.3)	0.200
Dominant leg (<i>n</i>)	18R, 2L	14R, 6L	0.114
IPAQ (MET)-min/week	3699.3 (3285.4)	5276.2 (6840.9)	0.359

Mean (SD) reported unless stated otherwise

n number, *M* male, *F* female, *m* meters, *kg* kilogram, *kg/m²* kilograms per square meter, *BMI* body mass index, *IPAQ* International Physical Activity Questionnaire, *MET* metabolic equivalent of task, *min/week* minutes per week, *R* right, *L* left

*Statistically significant difference between the groups from unpaired *t* tests ($p < 0.05$)

In the HYG, the mean velocity of PPW was lower than FPW (12.13 versus 18.20 m/s; $p < 0.0001$), while for the HOG, the mean velocity of PPW was lower than FPW (12.92 versus 17.70 m/s; $p < 0.0001$). Decrements during dual versus single tasks were observed in all five gait parameters analyzed (Table 2). Compared to the single tasks, cadence and stride length were lower, stride time was longer, and stride length and time variability were higher during the PPW dual task ($p \leq 0.03$) and the FPW dual task ($p \leq 0.02$) (Table 2).

Regarding the effect of age, the DTE was greater in the HOG compared to the HYG during PPW in stride length ($p = 0.001$) and during FPW, in cadence ($p = 0.04$), stride length ($p = 0.02$) and stride time variability ($p = 0.04$) (Table 2). Also, HOG demonstrated shorter stride lengths compared to HYG during dual versus single tasks (PPW + CT: $p = 0.003$; FPW + CT: $p = 0.04$) (Fig. 1). Moreover, significant main effect of age*tasks was found for stride time during FPW tasks ($p = 0.04$) indicating that longer stride time was shown by HOG compared to HYG during dual versus single task (Fig. 1).

SLS duration was longer in HYG than HOG [109 s (90 s) versus 31 s (32 s), respectively; $p < 0.001$] as well as during SLS + CT [127 s (99 s) versus 56 s (97 s); $p = 0.03$]. Nonetheless, comparison of SLS duration between groups and tasks indicated no significant main effect of tasks ($p = 0.22$) or group*task interaction ($p = 0.84$).

Discussion

This study was unique for its comparisons of the effects of a mental tracking task on gait parameters during two different walking speeds through a dual-tasking experimental paradigm in younger and older adults. Studies evaluating gait parameters at different walking speeds and utilizing mental tracking tasks during dual tasking are limited, poorly understood and have variable methodology. In this study, spatiotemporal gait parameters and single-leg stance duration were evaluated during dual tasking. Decrements in all five spatiotemporal gait parameters were observed during the PPW and FPW dual compared to single tasks. Older age showed greater decrements in gait as evidenced by a shorter stride length and longer stride time and larger DTE for stride length (at PPW and FPW), cadence and stride time variability (at FPW). Also, HOG exhibited shorter times during SLS and SLS dual task when compared to the HYG. These changes were demonstrated in the older age group in spite of their active lifestyle self-reported in the IPAQ and inclusion of a lower age limit in the HOG group.

In this study, cadence decreased during the PPW and FPW dual compared to single tasks. The results of this study corroborate the previously reported findings in younger

Table 2 Comparisons between single and dual tasks (i.e., PPW vs. PPW + CT and FPW vs. FPW + CT) in the younger and older healthy adults

	PPW	PPW + CT	<i>p</i>	η^2	DTE (%)	<i>p</i>
Cadence (steps/min)						
Younger	107.42 (8.60)	106.77 (10.44)	0.021*	0.133	−0.62 (5.68)	0.09
Older	114.63 (8.06)	108.91 (9.90)			−4.74 (8.87)	
Stride length (m)						
Younger	1.35 (0.13)	1.34 (0.15)	<0.001*	0.281	−0.55 (6.00)	0.001**
Older	1.35 (0.11)	1.25 (0.16)			−7.66 (7.25)	
Stride length variability (%CV)						
Younger	2.71 (0.95)	3.66 (1.34)	<0.001*	0.339	58.54 (107.84)	0.42
Older	3.06 (1.20)	5.41 (3.23)			83.46 (85.57)	
Stride time (sec)						
Younger	1.12(0.09)	1.13(0.12)	0.032*	0.116	0.78 (5.54)	0.08
Older	1.05 (0.08)	1.11 (0.11)			5.70 (10.73)	
Stride time variability (%CV)						
Younger	2.50 (0.70)	3.42 (1.24)	0.009*	0.166	47.86 (70.19)	0.21
Older	2.59 (0.68)	6.65 (6.48)			111.64 (211.74)	
	FPW	FPW + CT	<i>p</i>	η^2	DTE (%)	<i>p</i>
Cadence (steps/min)						
Younger	131.72 (14.13)	123.76 (12.92)	<0.001*	0.471	−5.81 (6.12)	0.04**
Older	134.98 (16.44)	119.04 (7.80)			−10.91 (9.12)	
Stride length (m)						
Younger	1.65 (0.18)	1.55 (0.21)	<0.001*	0.673	−6.35 (5.59)	0.02**
Older	1.51 (0.16)	1.35 (0.19)			−11.17 (7.37)	
Stride length variability (%CV)						
Younger	2.64 (0.77)	3.51 (1.24)	0.010*	0.163	45.26 (72.96)	0.14
Older	4.10 (2.35)	7.63 (6.28)			169.51 (358.73)	
Stride time (sec)						
Younger	0.92 (0.10)	0.98 (0.10)	<0.001*	0.521	6.70 (7.16)	0.07
Older	0.90 (0.10)	1.01 (0.07)			13.64 (15.14)	
Stride time variability (%CV)						
Younger	3.28 (1.03)	3.79 (1.88)	0.017*	0.140	21.76 (61.54)	0.04**
Older	3.68 (2.25)	7.48 (6.85)			175.78 (321.46)	

Dual-task differences between groups are also reported. Mean (SD) reported

PPW preferred paced walk, FPW fast paced walk, CT cognitive task, *m* meters, % CV percent coefficient of variation, *min* minutes, *sec* seconds, η^2 partial eta squared (measure of effect size) of tasks from mixed ANOVA between tasks and groups, DTE dual-task effect

*Statistically significant main effects of paired tasks in the younger and older healthy adults ($p < 0.05$)

**Statistically significant between the groups from unpaired *t* tests ($p < 0.05$)

healthy participants as they performed dual tasks involving subtracting 7 from an initial 3-digit number while walking at a preferred pace (Lu et al. 2015) and middle-aged healthy participants (mean age: 44 years) while performing the Stroop test paired with regular walking (Lamoth et al. 2008). Similar findings have been reported in older healthy adults who performed walking dual tasks paired with a simple mental tracking task involving calculation such as serial subtractions by 3 from a number between 20 and 100 (Galletly and Brauer 2005) or a working memory task (verbal fluency) involving saying as many words as possible that start with a specific or alternate letter (Galletly and Brauer

2005; Simoni et al. 2013) compared to only walking. On the contrary, O’Shea et al. (2002) did not find any differences in cadence of old people between single and dual task when a mental tracking task (serial subtractions by 3) was paired with walking. Therefore, the change in cadence may be affected by the difficulty of the CT used in combination with walking.

The stride length significantly decreased and stride length variability significantly increased during PPW + CT and FPW + CT when compared to PPW and FPW, respectively. These findings are in agreement with those of Beauchet et al. (2005) where healthy young adults performed a

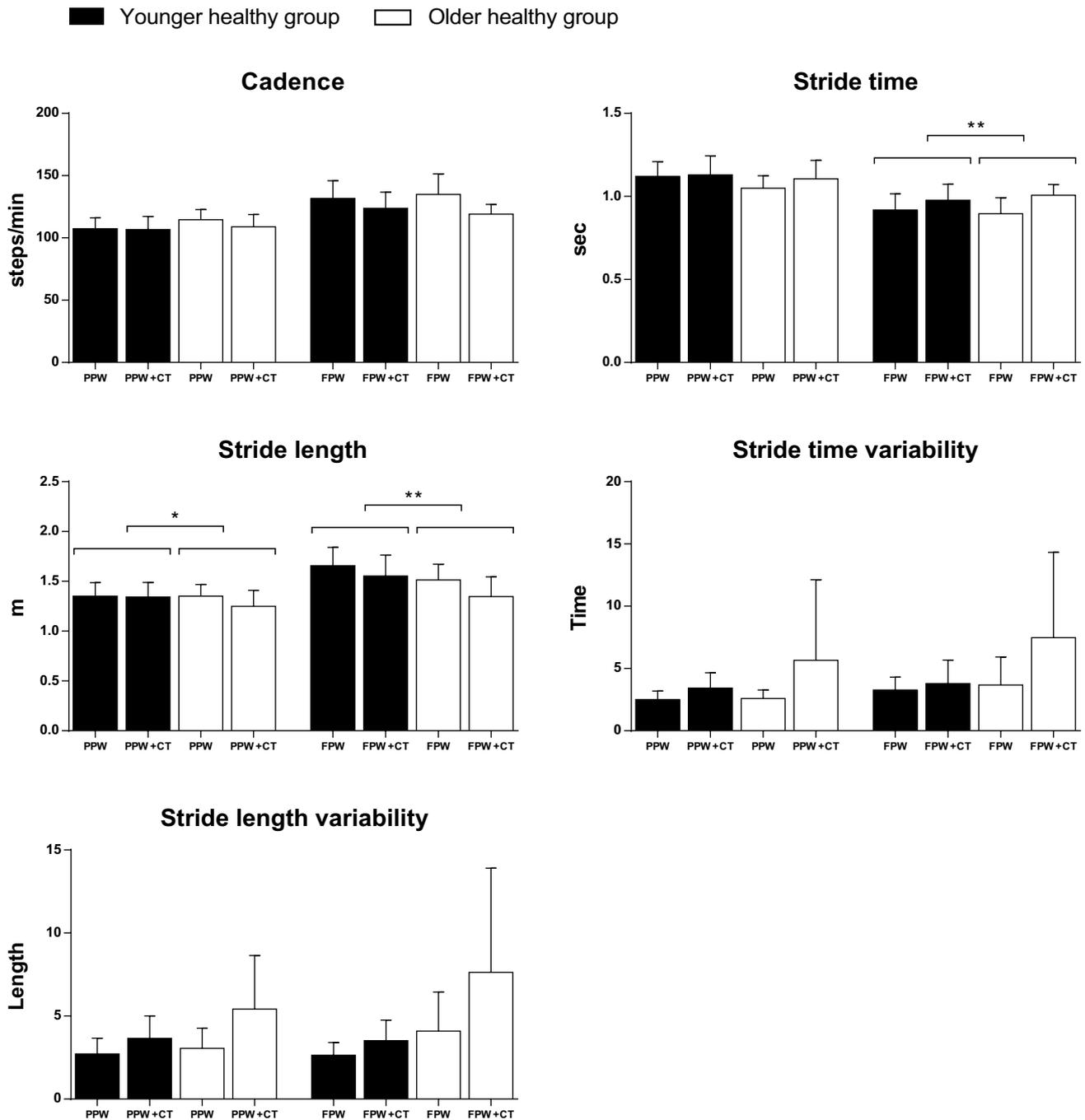


Fig. 1 Comparisons of gait parameters during single and dual tasks between the groups. Mean (SD) reported. Black bars=healthy younger group (HYG); white bars=healthy older group (HOG), *PPW* preferred paced walk, *FPW* fast paced walk, *CT* cognitive task, *steps/*

min steps per minute, *m* meters, *sec* seconds. *Statistically significant main effects of age*task interaction during PPW ($p < 0.05$). **Statistically significant main effects of age*task interaction during FPW ($p < 0.05$)

dual task involving walking and counting backwards. On the contrary, Dubost et al. (2008) reported no significant differences in stride length in young healthy adults during walking and enumerating animal names compared to just walking. It has been demonstrated that the difficulty of CT has an impact on gait parameters. During the simple CT,

counting forwards (Mirelman et al. 2014), the stride length did not change while walking at preferred speed in healthy young adults. However, during a more complex task that consisted of subtracting 7 from an initial 3-digit number (Lu et al. 2015) or saying alternate letters of the alphabet (Simoni et al. 2013), the stride length significantly decreased

in young adults during dual-task walking compared to just walking. The higher difficulty level of the CT used in the present study may explain the decrease in stride length during dual tasks. Similarly, a decrease in stride length has been reported in old adults when they performed a serial subtraction and naming animal species task while walking (Reelick et al. 2009). On the contrary, stride length was documented to be higher during dual tasks pairing PPW with serial subtractions (O’Shea et al. 2002; Galletly and Brauer 2005) and verbal fluency tasks with the letters “F” or “S” (Galletly and Brauer 2005) in older adults. Similarly, studies involving middle-aged healthy adults have reported an increase in stride length during walking and performance of the Stroop test (Lamoth et al. 2008) and increase in stride length variability during walking and a serial subtraction task (Delval et al. 2008). In agreement with these findings, our results showed an increase in stride length variability during dual tasks. Stride length variability was reported to be higher in older healthy adults during PPW dual task, independent of the CT, compared to just PPW (Reelick et al. 2009; Yogeve-Seligmann et al. 2010; McIsaac et al. 2015). A decrease in stride length and an increase in stride length variability during dual tasks may indicate cognitive and physical efforts that exceed the participants’ cognitive motor capabilities.

Mean stride time significantly increased during PPW and FPW dual compared to their respective single tasks. A higher stride time has been reported in healthy young adults during dual task pairing PPW with verbal fluency task (Yogeve-Seligmann et al. 2010), counting forwards (Mirelman et al. 2014), counting backwards (Beauchet et al. 2005) and serially subtracting 7 from an initial 3-digit number (Mirelman et al. 2014; Lu et al. 2015). Similarly, increase in stride time was also observed in old adults during walking at preferred pace, while performing a verbal fluency task compared to just walking at preferred pace (Yogeve-Seligmann et al. 2012). Moreover, our results showed higher stride time variability during dual compared to single task. Similar findings have been reported in young adults during PPW and counting backward from 50 (Beauchet et al. 2005) and in young and older adults during PPW and counting backward from 100 by 7 (Asai et al. 2013). On the contrary, in young adults, no differences in stride time variability were found during walking paired with serial subtraction by 7 from an initial 3-digit number (Mirelman et al. 2014), recalling words beginning with a predefined letter (Yogeve-Seligmann et al. 2010) or Stroop task (Plummer-D’Amato et al. 2011); however, a decrease in stride time variability was reported during serial subtraction by 7 from an initial 3-digit number and 2-back working memory task (Wrightson et al. 2016). Increased variability is predictive of higher risks of falls (Hamacher et al. 2011). Increased stride time and its variability indicate an increase in walking instability during dual tasking compared to performance of a single task.

Although the performance of gait parameters in both groups suffered were hampered during dual task, older adults appeared to be more affected due to group differences in shorter stride length and longer stride time and greater DTE of cadence, stride length and stride time variability. According to the shared resource capacity model, dual tasking seems to hamper older adults more than younger adults (Wrightson et al. 2016) indicating a more limited cognitive capacity of older adults during multitasking (Hollman et al. 2007). Moreover, attentional demands required to maintain balanced gait appear to be greater in older compared to younger people (Bridenbaugh and Kressig 2011; Sertel et al. 2017). Since, cognitive resources decline with age, older adults have reduced gait performance resulting in a higher risk of falls (Hollman et al. 2007).

The SLS duration is an effective tool for measuring balance dysfunction (Talarico et al. 2017). A study performed by Springer et al. (2007) and a recent meta-analysis performed by Bohannon and Tudini (2018) showed that time during standing on one leg is age dependent and decreases with older age. The present study corroborates these findings.

The similar self-reported physical activity levels of HYG and HOG were an unexpected result because older adults usually present lower levels of physical activity than younger adults (Chodsko-Zajko et al. 2009). Similar physical activity levels may explain the absence of age-related effects (between group differences) on some of the spatiotemporal gait parameters during dual tasks. Beurskens et al. (2014), Hollman et al. (2007) and Plummer-D’Amato et al. (2011) have also reported that age has a significant influence on step duration and step length during dual tasking. On the contrary, the meta-regression analysis performed by Al-Yahya et al. (2011) showed no association between age and the results of gait during dual task while performing verbal fluency task. Age, in conjunction with other factors such as physical activity and cognitive ability, may lead to decrements in performance during dual tasking.

In healthy older adults, the decrements in gait parameters during dual tasking may be used as a marker of early stages of cognitive decline and a marker of pre-dementia state (Montero-Odasso et al. 2012, 2014). Moreover, complex cognitive tasks, as spelling backwards, can reveal more about the cognitive status than simple cognitive tasks (Ehsani et al. 2019). Thus, the results for gait during dual tasking can be used as a diagnostic criteria for pre-dementia and could be used as a standard clinical assessment of older people (Smith et al. 2016) even if the other global measures of cognitive and physical function indicate otherwise (Hausdorff et al. 2008; Montero-Odasso et al. 2014; Verghese et al. 2014).

This study has some limitations. First of all, the present study did not consider the overlapping effects of language

word processing and verbalization (during spelling backwards) on walking as they may impact gait rhythm (Dault et al. 2003; Plummer-D'Amato et al. 2008). Third, gait asymmetry (e.g., of stance time, swing time) was not evaluated in this study, which could have affected the measurements. Lastly, although samples sizes were larger than many previous studies, n of 20 may not be generalizable to the larger population within the respective age ranges. In addition, a larger sample size would likely have shown more differences; based on the DTEs (Table 2) and using G*Power, sample sizes of 55 would have resulted in significant differences in all five variables during FPW and all but stride length variability during PPW.

Conclusions

In conclusion, we demonstrated that a dual task with a motor (walking at preferred and fast pace) and a mental tracking task (spelling five-letter words backwards) hampers important spatiotemporal gait parameters. Middle- and older aged participants had shortened stride length and lengthened stride time and worse DTE for cadence, stride length and stride time variability compared to younger participants. Also, fast paced walking showed more variability on gait parameters, suggesting reduced gait stability and, consequently, an increased risk of falls when walking more quickly than one's usual pace.

This study shed light on how a broader spectrum of gait parameters in physically active middle-aged and older adults was impacted during dual tasking. These findings are clinically relevant as they highlight the impact of age on gait during dual tasking irrespective of physical activity levels and those who are middle aged. The results of this study may inform the current evaluative and rehabilitation protocols of assessing and rehabilitating cognition and motor control to utilize dual tasking. Dual tasking paradigm can be easily incorporated in practice for early detection of mild cognitive impairment and motor deficits as well as to strengthen the link between cognition and motor control. Improved motor ability (e.g., increased gait velocity) and mental functions are linked to better functional capabilities, reduced risk of falls and better quality of life. Future studies should aim to determine the feasibility of certain dual task protocols in clinical settings that require minimal physical exertion and time commitment while taking into consideration different walking speeds and participants' physical activity level.

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Compliance with ethical standards

Conflicts of interest The authors declare that they have no conflicts of interest.

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