Walking modality, but not task difficulty, influences the control of dual-task walking

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Walking modality, but not task difficulty, influences the control of dual-task walking

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Research Highlights:

- We examined the effect of walking modality (overground and treadmill walking) on dual-task walking performance
- Stride time variability is higher during overground walking compared to treadmill walking
- The direction of the dual-task cost is dependent on walking modality
- There is no difference in the perceived difficulty of the dual task between the two walking modalities

Abstract

During dual-task gait, changes in the stride-to-stride variability of stride time (STV) are suggested to represent the allocation of cognitive control to walking [1]. However, contrasting effects have been reported for overground and treadmill walking, which may be due to differences in the relative difficulty of the dual task. Here we compared the effect of overground and treadmill dual-task walking on STV in 18 healthy adults. Participants walked overground and on a treadmill for 120 s during single-task (walking only) and dual-task (walking whilst performing serial subtractions in sevens) conditions. Dual-task effects on STV, cognitive task (serial subtraction) performance and perceived task difficulty were compared between walking modalities. STV was increased during overground dual-task walking, but was unchanged during treadmill dual-task walking. There were no differences in cognitive task performance or perceived task difficulty. These results show that gait is controlled differently during overground and treadmill dual-task walking. However, these differences are not solely due to differences in task difficulty, and may instead represent modality dependent control strategies.

Keywords: Gait, Cognition, Dual-task, Treadmill walking, Overground walking

Introduction

The cognitive control of walking is typically examined using a dual-task paradigm, wherein participants simultaneously walk and perform a cognitively demanding task [2]. The stride-to-stride variability of stride time (STV), which is suggested to represent the automaticity of gait [3], is frequently used to investigate the dual-task effect on walking [4,5]. However, the dual-task effects on STV in healthy adults are controversial, with both increases [4] and reductions [5,6] in STV reported during dual-task walking.

One possible cause of this discrepancy is the use of both overground and treadmill walking protocols. Walking modality (e.g. overground or treadmill) has been suggested to influence dual-task gait performance by altering control strategies [7]. Treadmill walking may require less cognitive control than overground walking because it provides external control of the walking pattern [7]. Previous accounts of control differences between walking modalities have reported modality-dependent effects on walking kinetics and muscle activation patterns [8,9]. Additionally, the relative difficulty of dual-task walking may differ between modalities. According to the dual-process account, dual-task difficulty influences the allocation of cognitive control [6,10]. An easier dual task would allow the walker to allocate control away from the walking task to the cognitive task, reducing walking variability and/or improving cognitive task performance. Conversely, a more difficult dual task would require the walker to allocate cognitive control to both cognitive and walking tasks, increasing walking variability [10]. Changes in the control of dual-task gait would thus be expected to occur with concomitant changes in perceived task difficulty. However, differences in dual-task difficulty between walking modalities have not been compared in the literature.

Dual-task gait performance is suggested to be a useful clinical marker of both cognitive impairment and future fall risk [1]. To interpret and apply dual-task effects from the laboratory to clinical and natural settings, it is thus important to understand the factors influencing dual-task gait performance. Therefore, the aim of this study was to examine whether walking modality influenced the control of dual-task gait, and whether, in accordance with the dual-process account, these effects were due to differences in the relative task difficulty.

Method

Following institutional ethical approval, 18 healthy adults (two females, mean age 21.7 $\pm$ 2.2 years) gave written informed consent and participated in the study. Initially, participants performed a cognitive task (serial subtractions in sevens) whilst standing. Subsequently, participants performed 240 s of both overground and treadmill walking, in a counter balanced order. Participants walked in silence for 120 s (single task) and then walked for 120 s whilst performing the cognitive task (dual task) in both walking modalities. Preferred treadmill walking speed was determined during familiarisation using an established method [5]. Participants were asked to walk overground at the same speed as their preferred treadmill speed. During overground walking, participants walked continuously along a 12 m walkway, with a 1-m turning zone at each end.

Temporal gait parameters were recorded using three body-worn gyroscopes (OPAL, APDM, Portland, USA) which transmitted wirelessly to a PC where they were recorded using the Mobility Lab software package (version 1.2, APDM, Portland, USA). Stride time (s), STV (coefficient of variation of stride time, %) and stride velocity (a measure of gait speed, $m.s^{-1}$) were recorded, using a previously established technique [11], during single and dual-task walking. STV and stride velocity during turning in the overground condition were excluded from analysis [12]. The number of correct and incorrect answers in the cognitive task were recorded during both the single task (standing) and dual-task walking. To control for a speed accuracy trade-off, where participants may have attempted to perform as many subtractions as possible without focusing on their accuracy, cognitive task performance was calculated using the following equation:

$$(Number\ of\ correct\ answers - number\ of\ errors)$$

Equation 1. Cognitive task performance calculation

The dual-task cost on STV and cognitive task performance were calculated using the following equation [13]:

$$\left(\frac{Dual\ task\ value - Single\ task\ value}{Single\ task\ value}\right) * 100$$

Equation 2. Dual-task cost calculation

Perceptions of task difficulty were recorded after each dual-task condition (treadmill and overground) using Borg's CR10 scale [14].

Because data were not normally distributed, Wilcoxon signed rank tests were used to compare the effect of walking modality on STV and stride velocity during single and dual-task walking and cognitive task performance, the dual-task cost on STV and cognitive task performance and perceived task difficulty during dual-task walking. Single sample Mann Whitney U-tests were used to examine whether the dual-task cost on STV and cognitive task performance were significantly different from 0. Statistical analyses were performed using the JASP software package (Version 0.8.00). Statistical significance was set at p<0.05. Cohen's d (d) was used as measure of effect size.

Results

The mean±SD for all variables during dual-task walking across both walking modalities are presented in Table 1.

Table 1. here please

There was no difference in stride velocity between treadmill and overground walking for single-task walking (mean difference (MD) <0.1 $m.s^{-1}$, T=41.0, p=0.905, d=0.1). During dual-task walking, there was also no difference between the walking modalities in stride velocity (MD<0.1 $m.s^{-1}$, T=38.0, p=0.621, d<0.1). STV was higher during overground single-task walking compared to treadmill single-task walking (MD=1.2%, T=153.0, p<0.001, d=1.0). During dual-task walking, STV was also higher during overground compared to treadmill walking (MD=1.5%, T=171.0, p<0.001, d=1.3).

The dual-task cost on STV was lower during treadmill walking than overground walking (MD=19.2%, T=152.0, p=0.002, d=0.8, Figure 1). Mann Whitney U-tests revealed that the dual-task cost on STV was significantly different than 0 for overground walking ($U_{(17)}$=147.0, p=0.006), but not for treadmill walking ($U_{(17)}$=70.0, p=0.844).

Figure 1. here please

There was no difference in cognitive task performance during dual-task walking between the two walking modalities (MD=1.1, T=68.0, p=0.705, d=0.1). There was also no difference in the dual-task cost on cognitive task performance between the walking modalities (MD=5.9%, T=61.0, p=0.478, d=0.2, see Figure 2). Neither the dual-task cost on cognitive task performance during overground ($U_{(17)}$=47.0, p=0.098 or treadmill ($U_{(17)}$=60.0, p=0.698) walking were significantly different to 0.

Figure 2. here please

There was also no significant difference in perceived task difficulty between walking modalities during dual-task walking (overground=4$\pm$2, treadmill=4$\pm$2, MD<1, T=61.0, p=0.478, d=0.1).

Discussion

The aim of the present study was to examine the effect of walking modality on the control of dual-task gait, and whether these changes were due to differences in task difficulty as predicted by the dual-process account [10]. STV was higher during overground walking than during treadmill walking, indicating that walking modality influenced STV differently. During dual-task walking, the dual-task costs on STV increased during overground walking, whilst it did not change during treadmill walking. There was no difference in cognitive task performance and no difference in the perceived task difficulty between the walking modalities. These results show that healthy adults adopt different performance strategies during dual-task walking on a treadmill and during walking overground. These differences in performance strategies do not result from one task being more difficult than the other. Instead, these results suggest that walkers may adopt different control strategies across modalities.

Changes in STV are suggested to represent alterations in the automaticity of the walking pattern [3], where lower STV represents an automatic walking pattern requiring minimal top-down control [1]. Within this framework, the results of this study indicate that treadmill and overground walking require different levels of top-down control. In addition, the simultaneous performance of a cognitive task appears to have very different effects on the cognitive control strategies across the walking modalities: during treadmill walking, STV was not altered during dual-task gait, whilst during overground walking it was increased. These data replicate a previous study which revealed a similar effect in older adults [7], and may help to explain the discrepancies in the literature regarding the effect of dual-task walking on STV in healthy adults [6,15].

A common explanation for reductions in STV during dual-task treadmill walking is that dual-task costs are dependent on task difficulty [6]. The dual-process account [10] posits that 'improvements' in dual-task gait would occur when cognitive control is diverted away from gait toward an easy cognitive task. Conversely, the simultaneous performance of a more difficult cognitive task would reduce performance. However, here there were no differences in perceived task difficulty, or cognitive task performance. These results indicate that differences in cognitive control strategies during dual-task walking may not be solely dependent on task difficulty. Furthermore, reductions and increases in STV may not necessarily represent improvements or decrements in dual-task gait, rather they represent different cognitive control strategies in response to different task constraints. Participants were asked to walk at the same speed as their previously determined preferred treadmill speed. Data from decerebrate animal models indicate that top-down control is not required to produce regular stepping during treadmill walking [16]. There is, however, a well-established relationship between cognitive function and overground walking speed [17]. Although speculative, it is possible that the maintenance of walking speed during overground walking requires greater top-down control, resulting in the differences in STV reported here.

In conclusion, stride time variability was increased during overground dual-task walking but unchanged during treadmill dual-task walking. For the first time, we have shown that these differences are not due to differences in task difficulty. Instead, these results suggest that cognitive control strategies may differ across walking modalities. Therefore, the influence of walking modality on cognitive control must be considered when interpreting dual-task gait effects.

Conflict of Interest

There are no personal or financial conflicts of interest for any of the authors.

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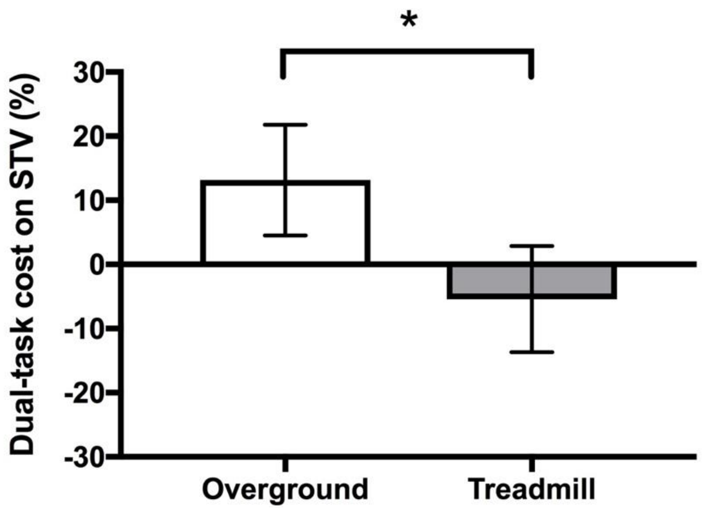

Figure 1. Mean STV dual-task cost on STV during overground and treadmill dual-task walking. * represents significantly greater dual-task cost on STV during treadmill dual-task walking than during overground walking (p<0.05). Error bars represent 95% CI of the mean.

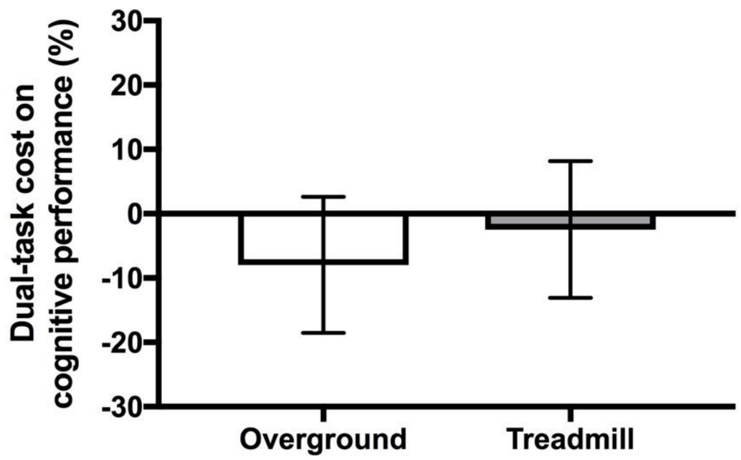

Figure 2. Mean dual-task cost on cognitive task performance during overground and treadmill dual-task walking. Error bars represent 95% CI of the mean.

Table 1. Mean±SD STV (%), stride velocity ($m.s^{-1}$), and total cognitive task performance, number of correct answers and errors, during both single and dual tasks

	Overground		Treadmill	
	Single task	Dual task	Single task	Dual task
Stride Velocity ($m.s^{-1}$)	1.4±0.1	1.3±0.1	1.3±0.1	1.3±0.1
Stride time variability (%)	2.6±1.3	2.9±1.3	1.2±0.3*	1.1±0.3*
Cognitive task performance	34±12 †	31±14	34±12 †	32±11
Correct Answers	*35±11 †*	*33±13*	*35±11 †*	*34±11*
Errors	*1±1 †*	*1±2*	*1±1 †*	*1±2*

*Significantly lower STV during treadmill walking compared to overground walking
† Only one single task measurement recorded