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(Article begins on next page)

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Alberto Nascimbeni, Marco Minchillo, Adriana Salatino, Ursula Morabito, Raffaella Ricci

ABSTRACT

Gait is an attention-demanding task even in healthy young adults. However, scant evidence exists about the attentional load required at various walking speeds. The aim of this study was to investigate motor–cognitive interference while walking at spontaneous, slow and very slow speed on a treadmill while carrying out a backward counting task, in a group ($n = 22$) of healthy young participants. Cognitive performance was also assessed while sitting. Higher DT cost on the cognitive task was found at spontaneous and very slow walking speed, while at slow walking speed the cognitive task was prioritized with higher DT cost on the motor task. The attentional allocation during DT depends on walking speed with gait prioritization at spontaneous and very slow speed that likely represent more challenging motor conditions.

1. Introduction

Gait is an attention-demanding task in elderly and neurological patients [1] and, to a lesser extent, in healthy young individuals [2,3], as demonstrated by studies on cognitive–motor interference using dual task (DT) conditions. Cognitive–motor interference refers to the phenomenon in which carrying-out simultaneously a cognitive and a motor task interferes with the performance of one or both tasks. The overload of attentional resources during DT may disrupt both cognitive performance and gait in individuals with slower walking speed (WS) [4] and higher gait variability [5]. Furthermore, higher gait variability has been related to increased fall risk [6]. However, there is scant research about the possible different attentional load imposed by gait at different WS on the treadmill [7,8]. In particular, very slow WS might require greater attention, due to reduced automaticity and higher cortical demands with increased interference during DT [9,10]. The aim of this study was to investigate motor–cognitive interference at spontaneous, slow and very slow WS on a treadmill in healthy young participants. We chose to focus on these walking speeds because there is scant literature on this topic that may have clinical implications. We hypothesized that as gait velocity decreased, the attentional load would increase, resulting in greater DT interference.

2. Methods

Twenty two young healthy volunteers (7 men and 15 women, mean age 26.9 ± 6.3 years) participated to the study. Walking on a treadmill was carried out in the single task condition at 100%, 60% and 20% of their spontaneous walking speed (WS), previously calculated for each participant during 10 min walking on the treadmill. The DT conditions consisted of walking at the same three velocities while backward counting by three, starting from 300. The participants repeated the backward counting in single task, while sitting. Each subject underwent seven experimental conditions. Each condition lasted 1 min. The order of conditions was randomized across participants and each subject underwent a different task order. The participants were asked not to prioritize either task over the other. A footswitches-based statistical gait analysis system (STEP 32, DEM Italia, Leinì, Turin, Italy) was employed. Footswitches closing strength was 3 N and the sampling rate was 2 kHz. Gait data were offline statistically processed by the system software. The examined gait parameters were: stride time (ST), coefficient of variation of stride time (CoV) and double support percentage (DS) of stride cycle. The parameters values were calculated as means between the two sides. CoV was calculated as the percentage of the quotient between

Table 1
Median values and relative interquartile range of gait parameters at 100%, 60% and 20% of spontaneous walking speed (WS).

Gait parameter	100% WS		60% WS		20% WS	
	Single	DT	Single	DT	Single	DT
ST	1.10 (0.10)	1.10 (0.15)	1.40 (0.20)	1.45 (0.20)	2.70 (0.60)	2.73 (0.70)
CoV	1.45 (0.70)	1.00 (0.80)	2.00 (1.10)	2.00 (0.60)	4.00 (3.10)	4.81 (1.80)
DS	20.43 (5.50)	20.15 (4.75)	25.48 (5.30)	27.55 (7.55)	42.18 (9.85)	42.68 (8.25)

Single = single task; DT = dual task; ST = stride time; CoV = coefficient of variation of stride time; DS = double support percentage of stride time.

standard deviation and stride time mean (CoV = [SD/ST mean] $\times$ 100). The cognitive task performance was recorded and offline evaluated. Only correct calculations (i.e. number of correct responses) were considered in the analysis. Dual task cost on both gait and cognitive parameters was also calculated using the formula [(Single-task–Dual-task)/Single-task*100] [11]. The study received approval by the local Ethical Committee and the participants gave their written informed consent.

2.1. Statistical analysis

Since some of the data were not normally distributed (according to Kolmogorov–Smirnov test), statistical analyses were carried out using the nonparametric paired-sample Sign Test, with Bonferroni correction for multiple comparisons ($P < 0.05$). Separate analyses were performed to test the effects of 'task' (single, DT) and 'velocity' (100%, 60%, and 20% of WS) on each gait parameter (ST, CoV, DS) and on the relative DT costs. Separate analyses were also conducted to assess the effect of condition (single task, DT at 100%, 60%, and 20% of WS) on backward counting and on the relative DT cost.

3. Results

The average spontaneous WS was 1.13 ± 0.32 m/s. Gait parameters and cost median values are reported in Tables 1 and 2, respectively. The analyses did not show any significant difference between single and DT condition at different WS for any of the gait parameters. However, DT cost on CoV parameter was significantly (Bonferroni correction $P < 0.05/3 = 0.017$) higher at 60% WS than 100% WS ($Z = 2.46$, $P = 0.014$).

The statistical analysis of cognitive performance showed significant (Bonferroni correction $P < 0.05/6 = 0.008$) differences between single task and DT at 100% WS ($Z = 3.06$, $P = 0.002$), single task and DT at 20% WS ($Z = 3.62$, $P = 0.0002$), and DT at 20% and 60% WS ($Z = 2.91$, $P = 0.003$). The median values and relative interquartile range of the correct calculations carried out by the participants were: in single task = 33.50 (11.00), at 100% WS = 31.00 (14.00), at 60% WS = 33.00 (11.00) and at 20% WS = 30.00 (6.00). To summarize, participants showed better cognitive task performance during single task and DT at 60% WS than during DT at 100% and 20% WS. Consistently, the DT cost on cognitive performance was significantly (Bonferroni correction $P < 0.05/3 = 0.017$) higher at 100% than 60% WS ($Z = 2.62$, $P = 0.009$) and at 20% than 60% WS ($Z = 2.91$, $P = 0.004$).

4. Discussion

Attentional allocation in healthy young subjects, with WS constrained by a treadmill, depends on gait velocity. During walking at spontaneous or very slow WS, attentional resources are preferentially allocated to the motor task as indexed by higher DT cost on the cognitive performance. This strategy may be explained by gait prioritization during challenging motor conditions [1,12]. On the other hand, walking at slow speed, does not interfere with the cognitive task but rather increases DT cost on gait variability. This finding, suggesting an attentional shift from an easier motor task to the cognitive processing, might mirror the spontaneous strategy to decrease WS when carrying out a cognitive task during gait to reduce the attentional resources to the motor component and facilitate cognition. Our results also indicate that walking at very slow WS is an attention-demanding task possibly due to lower gait automaticity and higher cortical control with changes in muscular activation pattern [9].

Findings of our study are consistent with a previous work [11] showing reduced DT cognitive cost (on a Stroop Task) at slower than spontaneous WS. Prioritization of the cognitive task, at this speed, was not observed when the task was less attention demanding (i.e. counting backwards by one) than that used in our study. Szturm [13], employing a visual–spatial task and treadmill walking, found a decrease of cognitive performance at both slow (70%) and spontaneous WS and an increase of gait variability in both conditions. However, the different kind of cognitive tasks, may hinder the comparison with the results of our study. Finally, very few studies have investigated DT at very slow WS. In particular higher DT cost in stroke patients with more severe lower limb impairment and very slow WS has been observed [10].

The main limitation of this study is the possibility of learning effect at individual level. However, the fact that the order of conditions was randomized across subjects might have minimized this risk at group level.

Table 2
Median values and relative interquartile range of cost for each gait parameter and cognitive performance at 100%, 60% and 20% of spontaneous walking speed (WS).

COST	100% WS	60% WS	20% WS
ST	0.00 (0.00)	0.00 (3.57)	8.31 (19.99)
CoV	0.00 (33.33)	−14.56 (58.50)	−34.27 (85.52)
DS	0.23 (10.19)	−2.09 (8.02)	−0.10 (15.96)
Cognitive	8.96 (18.08)	1.22 (15.54)	10.94 (12.62)

ST = stride time; CoV = coefficient of variation of stride time; DS = double support percentage of stride time; Cognitive = backward counting task.

5. Conclusion

Attentional allocation during DT depends on WS in healthy young subjects walking on a treadmill. Higher DT cognitive cost is evidenced at spontaneous and very slow WS, but not at slow WS, while higher motor cost, expressed as an increase of CoV, is evidenced at slow WS. Gait is prioritized by attention in more challenging motor conditions.

Authors contribution

Alberto Nascimbeni contributed to the conception and design of the study, article drafting and revising and to the approval of the final version. Marco Minchillo, Adriana Salatino, Ursula Morabito contributed to the acquisition of data, or analysis and interpretation of data and to the approval of the final version. Raffaella Ricci contributed to the article drafting and critically revising and to the approval of the final version.

Conflicts of interest statement

The authors declare that there are no conflicts of interest.

References

[1] Yogev-Seligmann G, Hausdorff J, Giladi N. The role of executive function and attention in gait. Mov Disord 2008;23:329–41.

[2] Beauchet O, Dubost O, Herrmann F, Kressig RW. Stride-to-stride variability while backward counting among healthy young adults. J Neuroeng Rehabil 2005;2:26.

[3] Regnaux JP, Robertson J, Smail DB, Daniel O, Bussel B. Human treadmill walking needs attention. J Neuroeng Rehabil 2006;3:19.

[4] Al-Yahya E, Dawes H, Smith L, Dennis A, Howells K, Cockburn J. Cognitive motor interference while walking: a systematic review and meta-analysis. Neurosci Behav Rev 2011;35(3):715–28.

[5] Dubost V, Annwiler C, Aminian K, Najafi B, Hermann FR, Beauchet O. Stride-to-stride variability while enumerating animal names among healthy young adults: result of stride velocity or effect of attention-demanding task. Gait Posture 2008;27:138–43.

[6] Hausdorff JM, Rios D, Edelberg HK. Gait variability and fall risk in community-living older adults: a 1-year prospective study. Arch Phys Med Rehabil 2001;82:1050–6.

[7] Kline JE, Poggensee K, Ferris DP. Your brain on speed: cognitive performance of a spatial working memory task is not affected by walking speed. Front Hum Neurosci 2014;8:288.

[8] Abbud GAC, Li KZH, De Mont RG. Attentional requirements of walking according to the gait phase and onset of auditory stimuli. Gait Posture 2009;30:227–32.

[9] Den Otter AR, Geurts ACH, Mulder T, Duysens J. Speed related changes in muscle activity from normal to very slow walking speeds. Gait Posture 2004;19:270–8.

[10] Plummer-D'Amato P, Altmann LJP. Relationships between motor function and gait-related dual-task interference after stroke: a pilot study. Gait Posture 2012;35:170–2.

[11] Patel P, Lamar M, Bhatt T. Effect of type of cognitive task and walking speed on cognitive-motor interference during dual-task walking. Neuroscience 2014;260: 140–8.

[12] Mersmann F, Bohm S, Bierbaum S, Dietrich R, Arampatzis A. Young and old adults prioritize dynamic stability control following gait perturbations when performing a concurrent cognitive task. Gait Posture 2013;37(3):373–7.

[13] Szturm T, Maharjan P, Marotta JJ, Shay B, Shrestha S, Sakhalkar V. The interacting effect of cognitive and motor task demands on performances of gait, balance and cognition in young adults. Gait Posture 2013;38:596–602.