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Attentional costs of walking are not affected by variations in lateral balance demands in young and older adults

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ABSTRACT

Increased attentional costs of walking in older adults have been attributed to age-related changes in visuomotor and/or balance control of walking. The present experiment was conducted to examine the hypothesis that attentional costs of walking vary with lateral balance demands during walking in young and older adults. Twenty young and twenty older adults walked on a treadmill at their preferred walking speed under five conditions: unconstrained normal walking, walking on projected visual lines corresponding to either the participant's preferred step width or 50% thereof (i.e. increased balance demand), and walking within low- and high-stiffness lateral stabilization frames (i.e. lower balance demands). Attentional costs were assessed using a probe reaction-time task during these five walking conditions, normalized to baseline performance as obtained during sitting. Both imposed step-width conditions were more attentionally demanding than the three other conditions, in the absence of any other significant differences between conditions. These effects were similar in the two groups. The results indicate that the attentional costs of walking were, in contrast to what has been postulated previously, not influenced by lateral balance demands. The observed difference in attentional costs between normal walking and both visual lines conditions suggests that visuomotor control processes, rather than balance control, strongly affect the attentional costs of walking. A tentative explanation of these results may be that visuomotor control processes are mainly governed by attention-demanding cortical processes, whereas balance is regulated predominantly subcortically.

1. Introduction

Limited ability to adjust walking to task and environmental demands increases fall risk in elderly persons [1]. An important aspect of walking adaptability is the ability to cope with variations of attentional demands associated with performing secondary tasks while walking [1,2]. An age-related increase in the attentional demands of walking may hamper an individual's ability to respond to environmental hazards with potentially serious consequences. Indeed, such age-related changes are associated with less safe gait, poor mobility, increased dependence in activities of daily living and particularly increased fall risk [3].

The interaction between walking and attention has most commonly been assessed using dual-task paradigms in which walking is performed simultaneously with a secondary cognitive task [4]. Competition for limited attentional resources between the primary and secondary task may result in interference or decrement in performance of either one or both tasks when compared with their baseline single-task performances. Lundin-Olsson et al. [3] showed that older adults who are not able to continue walking while talking are more prone to falling than those who can perform the two tasks simultaneously. More recent studies [5–7] support increased dual-task interference with aging, suggesting that walking is more attentionally demanding in older than in young adults.

Increased attentional costs of walking among older adults may be attributed to subtle brain impairments or disorders in the coordination of sensory and motor information required for performing complex abilities, such as balance regulation during walking. Previous research revealed that in older adults both

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cognitive impairments [8] and elevated visuomotor demands [9–12] are associated with increased attentional costs of walking. Few studies [13,14], however, have specifically addressed how balance control affects the attentional costs of walking, especially in older adults. Pertinent evidence comes primarily from experiments with base-of-support manipulations, showing that attentional costs are higher during walking than during standing or sitting [9,10,13,14]. Although balance requirements may change over the gait cycle, inconsistent results have been reported regarding the attentional costs for specific phases in the gait cycle [13–15]. However, balance demands were never manipulated systematically during the gait cycle as a whole, which precludes drawing firm conclusions about the effect of balance control on the attentional costs of walking. In the present study, we focused on lateral stability manipulations because walking is less passively stable in mediolateral direction than in fore-aft direction [16]. Active sensorimotor control required for lateral balance during walking may be expected to elevate the attentional costs of walking.

In particular, we examined the effect of variations in lateral balance demands on attentional costs of walking in both young and older adults. Balance demands were manipulated by means of two levels of prescribed step width (SW; preferred vs. narrower than preferred, imposed by means of visual lines projected onto the walking surface) and a lateral stabilization device (involving two levels of mechanical stabilization [17]). With these manipulations, we created conditions with higher and lower balance demands, respectively. The attentional costs associated with these conditions were assessed with vibrotactile stimulus-response reaction times (RT) [9,10]. We expected that higher balance demands (as evoked by walking with a narrow base of support) would increase the attentional costs of walking, particularly in older adults. Likewise, we expected that lower balance demands (as evoked by lateral stabilization) would reduce the attentional costs of walking, again particularly in older adults.

2. Material and methods

2.1. Participants

Twenty young adults (female/male: 12/8) and 20 healthy older adults (female/male: 12/8) participated in the experiment (Table 1). Participants had no self-reported cardiovascular or cardiopulmonar problems, orthopedic conditions, uncorrected visual or auditory impairments, neurological disease, or other conditions limiting mobility; they did not use walking aids and the Mini Mental State Exam score for the older participants exceeded 23 (range 24–30). All participants provided written informed consent before participation. The departmental ethics committee approved the experiment.

Table 1
Participants' demographic and clinical characteristics per group.

	Young adults (f/m: 12/8)	Older adults (f/m: 12/8)	Group comparisons	
			Statistics	*p*-value
Age (year)	23.2 ± 3.3	72.9 ± 4.6	t_{38} = 39.13	<0.001
Height (cm)	174.5 ± 9.6	170.9 ± 10.2	t_{38} = 1.15	0.26
Weight (kg)	64.6 ± 10.8	66.6 ± 10.2	t_{37} = 0.60	0.56
CWS (km/h)	4.2 ± 0.6	3.7 ± 0.7	t_{38} = 2.43	0.02
FRD (cm)	35.2 ± 7.6	29.4 ± 6.1	t_{38} = 2.64	0.01
Baseline RT (ms)	233.5 ± 25.0	297.3 ± 31.8	t_{38} = 7.05	<0.001

Notes: values are mean ± SD. CWS, comfortable walking speed; FRD, functional reach distance; RT, reaction time; and f/m, female/male.

2.2. Experimental set-up

The experimental set-up was designed to induce higher and lower balance demands, using two separate manipulations: prescribed SW and lateral stabilization. A force-platform instrumented dual-belt treadmill (Motekforce Link, Amsterdam/Culemborg, The Netherlands) equipped with a projector allowing projection of visual lines onto the belt's surface was used to measure and impose SW in the prescribed conditions (Fig. 1A). In the lateral stabilization conditions, an external stabilizer [17] (Fig. 1B) was used to enhance lateral stability. Two spring-like rubber cords were attached to a frame fastened to the waist and anchored to ball-bearing trolleys that moved freely in for-aft direction within a horizontal rail parallel to the ground, positioned at either side of the participant. The height of the rail was adjusted to the participant's waist height. Cords with two different levels of stiffness (low stiffness: 760 Nm^{-1} and high stiffness: 1613 Nm^{-1}, see [17]) were used, with the high-stiffness level providing larger stability.

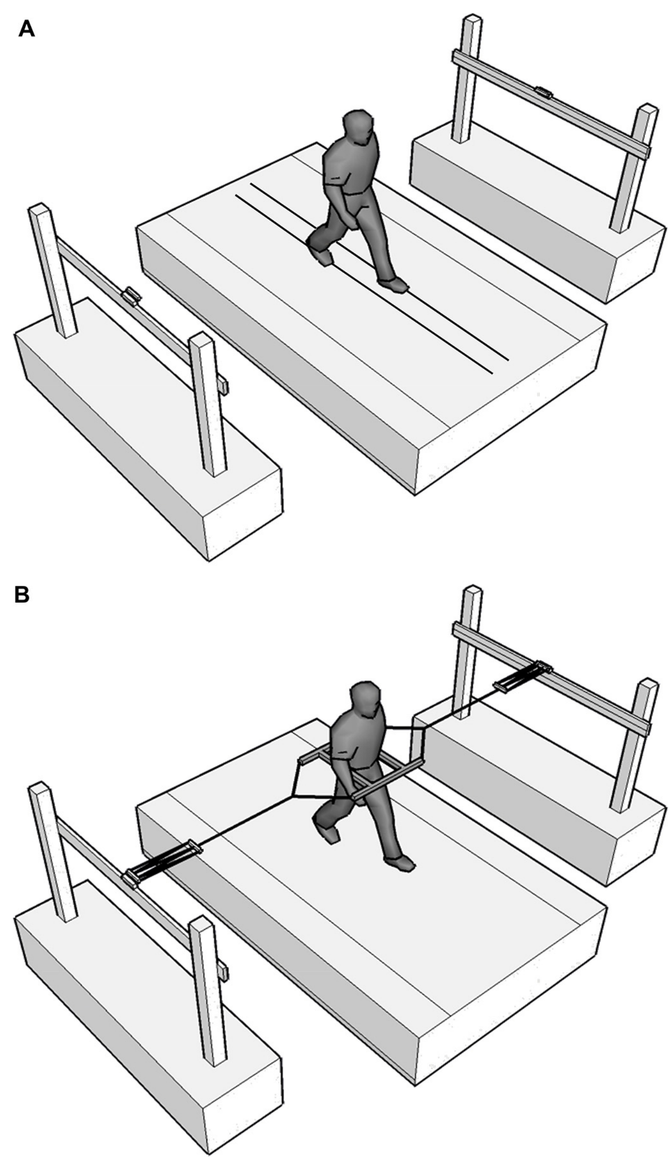

Fig. 1. Schematic of the experimental conditions to vary lateral balance demands. (A) Walking on visual lines projected onto the treadmill belt; (B) Walking with external lateral stabilizer with a spring-like cord attached to the light-weight frame fastened to the waist belt on one end and on the other end to the ball-bearing trolley.
Figure adapted with permission from J Biomech 2013;46:2109–14.