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Age effects on the control of dynamic balance during step adjustments under temporal constraints

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ABSTRACT

This study investigated the age effects on the control of dynamic balance during step adjustments under temporal constraints. Fifteen young adults and 14 older adults avoided a virtual white planar obstacle by lengthening or shortening their steps under free or constrained conditions. In the anterior–posterior direction, older adults demonstrated significantly decreased center of mass velocity at the swing foot contact under temporal constraints. Additionally, the distances between the 'extrapolated center of mass' position and base of support at the swing foot contact were greater in older adults than young adults. In the mediolateral direction, center of mass displacement was significantly increased in older adults compared with young adults. Consequently, older adults showed a significantly increased step width at the swing foot contact in the constraint condition. Overall, these data suggest that older adults demonstrate a conservative strategy to maintain anterior–posterior stability. By contrast, although older adults are able to modulate their step width to maintain mediolateral dynamic balance, age-related changes in mediolateral balance control under temporal constraints may increase the risk of falls in the lateral direction during obstacle negotiation.

1. Introduction

Falls are a common and often devastating problem in older adults because of their frequency and consequences (Rubenstein, 2006). Tripping or slipping over an obstacle is one of the most frequently reported causes of falls (Campbell et al., 1990; Tinetti & Speechley, 1989). Successful avoidance of an obstacle requires visually guided anticipatory modulation of the ongoing walking pattern and anticipatory balance control. A previous systematic review reported that older adults are at greater risk of contacting obstacles under time-constrained conditions (Galna, Peters, Murphy, & Morris, 2009).

Step adjustments under temporal constraints may provide a challenge to dynamic balance control, potentially causing a loss of balance. If an obstacle suddenly appears during walking, a long-step strategy or a short-step strategy can be used (Chen, Ashton-Miller, Alexander, & Schultz, 1994). In a long-step strategy, the obstacle is crossed using a lengthened crossing step. In a short-step strategy, the pre-crossing step is shortened and the obstacle is crossed on the next step. A sudden lengthening of the crossing step results in a loss of balance in the lateral direction (Weerdesteyn, Nienhuis, Mulder, &

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Duysens, 2005), while a sudden shortening of the pre-crossing step leads to falling without contacting an obstacle (Chen et al., 1994).

Temporal pressure can influence balance control during volitional stepping (Yiou, Hussein, & Larue, 2012; Yiou, Hussein, & LaRue, 2014), gait initiation (Caderby, Yiou, Peyrot, Begon, & Dalleau, 2014), and obstacle negotiation (Nakano, Fukaya, Kanai, Akizuki, & Ohashi, 2015). Moreover, older adults show increased risk of mediolateral (ML) imbalance during leg flexion under temporal constraints compared with young adults (Hussein, Yiou, & Larue, 2013). Thus, the ability to maintain dynamic balance may degrade in older adults when negotiating obstacles under temporal constraints. However, the effects of age on the control of dynamic balance during step adjustments under temporal constraints remain unclear.

The aim of this study was to examine the effects of age on the control of dynamic balance during step adjustments under temporal constraints. To achieve this, we compared balance control parameters in older adults with young adults with or without temporal constraints. We hypothesize that age will affect the control of dynamic balance under temporal constraints but not in the absence of temporal constraints.

2. Methods

2.1. Participants

Fourteen young adults (YA; five female, nine male; age, 21.9 ± 2.2 years; height, 167.2 ± 8.8 cm; body mass, 60.6 ± 11.3 kg; body mass index, 21.6 ± 2.8 kg/m^2) and 14 older adults (OA; five female, nine male; age, 77.1 ± 5.5 years; height, 160.1 ± 8.8 cm; body mass, 56.8 ± 9.4 kg; body mass index, 22.0 ± 2.3 kg/m^2) volunteered for this study. Young participants were recruited from university and graduate students. Older participants were recruited from the local community. The inclusion criteria were (1) age $\geqslant$65 years, (2) independent in walking without walking equipment, and (3) no fall history within the last 6 months. Older participants were excluded if they had any history of serious orthopedic, cardiovascular, or neurological diseases or dysfunction, or any pain that might affect walking. All participants completed informed consent procedures approved by the local ethics committee.

2.2. Apparatus

Our protocol replicated the protocol of Moraes, Allard, and Patla (2007). A liquid crystal display monitor (41.8 × 55.6 cm; ProLiteE-2473HDS-B; Iiyama, Tokyo, Japan) was embedded in a walkway (5.4 × 0.9 m) (Fig. 1) with a piece of tempered glass placed over it so that participants could step over it normally. A virtual white planar obstacle measuring 4 cm (depth) × 39 cm (length) was projected onto the middle of the monitor. The size of the obstacle was identical for all participants. A mat switch (operating force >60 N; OM-CVP623; Ojiden, Osaka, Japan) measuring 152 mm (depth) × 588 mm (length) × 4.4 mm (thickness) was connected to the monitor, and the obstacle was projected onto the monitor when participants stepped on the switch. Kinematic data were measured using an eight-camera motion analysis system (Oxford Metrics Group, Vicon Nexus, Oxford, UK) with a 100-Hz sampling rate.

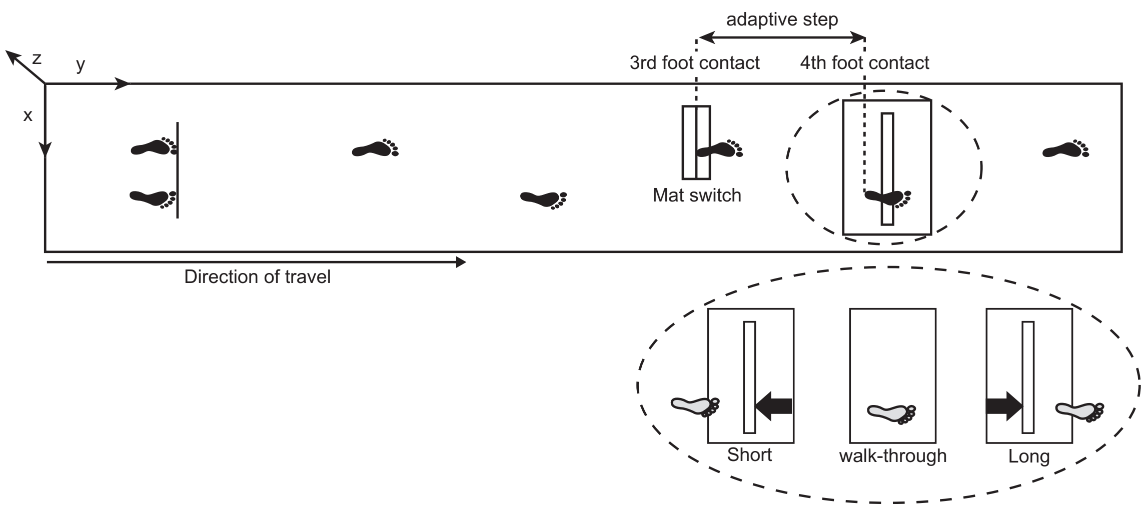

Fig. 1. Schematic of the experimental setup. Experimental setup showing virtual white planar obstacle and a red arrow projected on the monitor.