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Short communication

Effects of narrow base gait on mediolateral balance control in young and older adults

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ABSTRACT

The aim of this study was to examine the effect of narrowing step width on mediolateral (ML) center of mass (COM) kinematics and margin of stability (MOS) in young and older adults. Fourteen young and 18 healthy older adults were asked to walk on a treadmill at preferred speed, stepping on projected lines at their predetermined preferred step width (PSW) and at a 50% narrowed step width (NSW). Linear trunk accelerations were recorded by an inertial sensor, attached at the level of the lumbar spine and foot placement was determined from force sensors in the treadmill. Mediolateral peak-to-peak COM displacement, COM velocity and MOS within strides were estimated. Mean ML-COM displacement and velocity, which were significantly higher in older compared to young adults, were significantly reduced in the NSW condition while the variability of ML-COM velocity was increased in the NSW condition. A significant interaction effect of step width and age was found for ML-COM velocity, showing larger decreases in older adults in the NSW condition. Walking with NSW reduced the ML-MOS significantly in both groups while it was smaller in the older group. Although reductions of ML-COM displacement and velocity may occur as direct mechanical effects of reduced step width, the larger variability of ML COM velocity in the older adults suggests active control of ML COM movements in response to the reduced base of support. Given the effects on MOS, narrowing step width might challenge ML-balance control and lead to less robust gait especially in older adults.

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1. Introduction

Mediolateral (ML) gait stability requires regulating the center of mass (COM) position relative to the lateral limits of the base of support (BOS). From this perspective, the ML margin of stability (MOS), which considers the ML-COM position and velocity relative to the lateral border of the BOS, can provide important information (Hof et al., 2005). Based on the simplifying assumptions of the inverted pendulum model for balance control (Hof et al., 2005; Winter, 1995), a smaller ML-MOS would indicate lower robustness to deal with sideward perturbations and hence a higher risk of instability, although empirical evidence to support this assumption is lacking (Bruijn et al., 2013). In addition, larger kinematic variability may increase the probability of exceeding the MOS and increase fall risk (Toebes et al., 2012). Perturbations of gait stability often elicit increased step width (SW) to maintain or increase the ML-MOS (Hak et al., 2012), but as a trade-off increasing SW entails energetic costs (Donelan et al., 2001).

Age-related balance impairments lead to an increased fall risk (Hausdorff et al., 2001; Tinetti and Kumar, 2010). In line with the above, older adults, especially older adults at risk of falling, often adopt an increased SW as a compensatory strategy (Maki, 1997; Schrager et al., 2008), while a narrow SW, among older adults, indicates increased risk of sideward falls (Ko et al., 2007) compared to falls in other directions. In young adults, walking with narrow steps reduced the MOS (Young and Dingwell, 2012). However, in older adults, a reduced ML-COM displacement and velocity were observed when walking with narrow steps (Schrager et al., 2008), which might have preserved the ML-MOS, although this was not calculated. Such a reduction of ML-COM displacement and velocity when walking with narrow steps might arise as a direct mechanical effect of the narrower SW, since narrower stepping would decrease the moment induced by the ground reaction force and consequently reduce ML body sway (Hof et al., 2007). However, it may also reflect a strategy to more tightly control the COM over the narrower BOS.

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We aimed to investigate the effect of narrowing SW on ML-balance control in terms of ML-COM kinematics and ML-MOS in young and older adults. We hypothesized that both young and older adults would show a decreased ML-MOS with narrow SW, in spite of reduced ML-COM displacement and velocity.

2. Methods

2.1. Participants

Eighteen healthy, community-dwelling older adults (ten females; mean age 73, SD 4 years; height 172, SD 10 cm; mass 63, SD 6 kg) and fourteen young adults (nine females; mean age 23, SD 3 years; height 174, SD 10 cm; mass 66, SD 10 kg) participated in this study. The local ethics committee approved the protocol (#2014-32) and participants gave written, informed consent before participation.

2.2. Experimental protocol

Participants walked on a split-belt treadmill (Motekforce Link, Amsterdam, The Netherlands) with two embedded force platforms. After a familiarization and determining their preferred walking speed (Mazaheri et al., 2014), they walked for 3 min to calculate their preferred SW. Then, they walked for 2.5 min under two SW conditions in which the distance between the two lines projected on the treadmill was set symmetrically relative to the midline of the treadmill at their preferred SW (PSW) or at 50% of their preferred SW (NSW). The participants were instructed to align the middle of their shoe with the line. During both trials, 3D linear accelerations of the trunk were recorded by an inertial sensor (Dynaport Hybrid, McRoberts B.V., The Hague, The Netherlands) attached at the level of the lumbar spine. A safety harness was used to support body mass in case of an impending fall.

2.3. Data collection and analysis

Ground reaction forces were recorded at 1000 samples/s. Subsequently, force data were low-pass filtered at a cut-off frequency of 5 Hz and anterior–posterior center-of-pressure (COP) data were used to calculate left and right heel strike (HS) and toe-off (TO) instants (Roerdink et al., 2008).

SW was calculated as the distance between the ML COP during left and right single-support phases (e.g., from left TO to left HS for right single-support). Mean and standard deviation (SD) of step time were calculated based on the intervals between heel strikes.

The inertial sensor was measured at 100 samples/s. Data were low-pass filtered at 20 Hz. Misalignment of the sensor relative to the vertical and direction of progression was corrected (Rispens et al., 2014).

Assuming that the inertial sensor movement equals COM movement, time-series of ML-acceleration were integrated to estimate ML-COM velocity and position (Floor-Westerdijk et al., 2012), which were both high-pass filtered with a cut-off frequency of 0.1 Hz to avoid drift. Then, the peak-to-peak ML-displacement and velocity were calculated within a stride and the mean and SD of these parameters were calculated over 120 strides.

Finally, the ML-position and velocity of the sensor were used to estimate the time-series of the ML-extrapolated COM position (ML-xCOM) (Hof et al., 2005), using a leg length of 53% of total body height (Drillis et al., 1964). Assuming symmetric gait, the peak-to-peak displacement of ML-xCOM within each stride was subtracted from the concomitant SWs averaged within each stride and divided by two to obtain an estimate of the ML-MOS (Hof et al., 2005).

2.4. Statistics

There were no violations of normality and homogeneity of variance assumptions, as checked by Shapiro–Wilk and Levene's tests. To test whether SW affects the means and SD of ML-COM displacement and velocity, ML-xCOM and ML-MOS in young and older adults, two factor (conditions [NSW, PSW] × age [young, older])

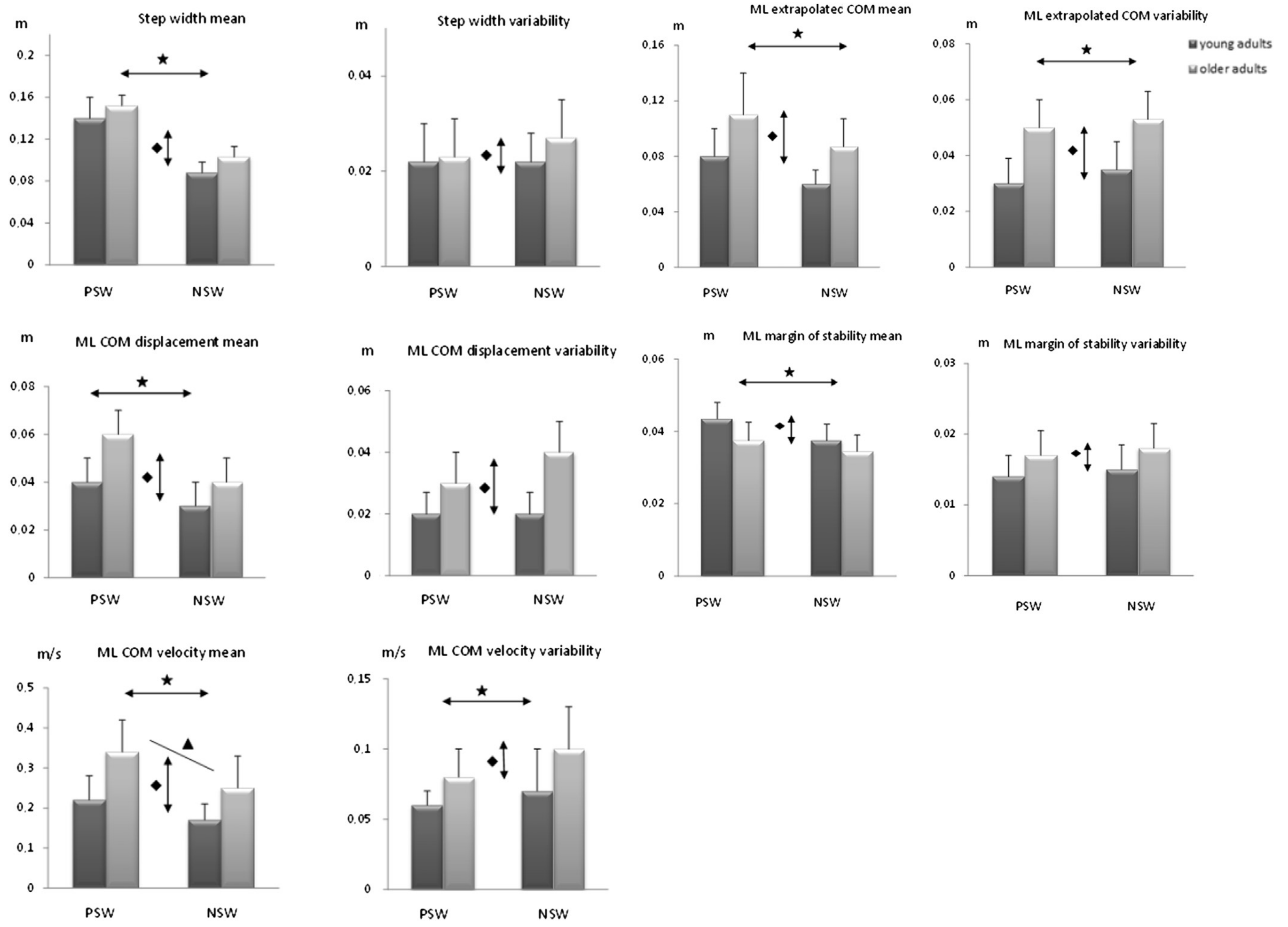

Fig. 1. The effect of preferred step width (PSW) and narrow step width (NSW) on ML-COM displacement and velocity, ML-xCOM and ML-MOS in young and older adults. The stars, diamonds and triangles indicate significant effects of step width, age and interactions of step width and age, respectively. The error bars represent standard deviation of mean.

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