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Hip abductor neuromuscular capacity: A limiting factor in mediolateral balance control in older adults?

Mina Arvin [a], Jaap H. van Dieën [a,*], Gert S. Faber [a], Mirjam Pijnappels [a], Marco J.M. Hoozemans [a,b], Sabine M.P. Verschueren [c]

[a] MOVE Research Institute Amsterdam, Department of Human Movement Sciences, VU University Amsterdam, Amsterdam, The Netherlands
[b] CORAL – Centre for Orthopaedic Research Alkmaar, Orthopaedic Outpatient Department, Medical Centre Alkmaar, Alkmaar, The Netherlands
[c] Department of Rehabilitation Sciences, Faculty of Kinesiology and Rehabilitation Sciences, KU Leuven, Leuven, Belgium

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ABSTRACT

Background: Mediolateral balance impairment is an important cause of falling in older adults. We aimed to investigate whether hip abductor muscular strength and/or position sense are limiting factors in mediolateral balance control.

Methods: Sixteen community-dwelling older adults performed three different mediolateral weight-shifting tasks, by tracking (1) a sinusoidally moving visual target, "visual-MELBA"; (2) a sinusoidally translating platform without explicit visual feedback, "mechanical-MELBA"; and (3) an unpredictable platform translation, "sudden-platform-translation." Balance performance was quantified for each task and correlated with hip abductor position sense, isometric strength, and peak hip abduction/adduction moments and moment rates.

Findings: Participants with better balance performance showed higher and faster hip abduction/adduction moment production during the tasks. Isometric hip abductor strength was significantly correlated with accuracy of tracking the visual target, while hip abductor position sense was associated with the bandwidth over which the mechanical target could be tracked and with a smaller delay between CoM movement and the sudden-platform movement.

Interpretation: Hip abductor muscles play an important role in mediolateral balance control. Accurate balance performance appears limited by lower hip abductor strength when explicit visual information on balance reduces the need for hip abductor proprioception, while proprioceptive acuity may limit balance performance when no explicit enhanced feedback is presented and required weight shifts have to be inferred from "normal" sensory information.

1. Introduction

On estimate, 30% of community-dwelling older adults fall at least once per year (Milat et al., 2011). Incorrect weight shifting is the most common cause of falling, and standing is one of the three classes of activities during which most falls in older adults occur (Robinovitch et al., 2013). Balance impairment, particularly in mediolateral (ML) direction, is suggested to be an important risk factor for such falls (Hilliard et al., 2008; Lord et al., 1999; Tinetti et al., 1988), and community-dwelling older adults are less able to actively control ML displacement of the center of mass (CoM) than young adults (Cofre Lizama et al., 2014).

ML-balance in bipedal stance is mainly controlled by a hip loading–unloading strategy through modulation of hip abductor muscle activity (Winter et al., 1993). An age-related reduction in hip abduction–adduction strength and torque production rate (Johnson et al., 2004; Kim et al., 2011) may negatively affect ML-balance control (Chang et al., 2005). Besides adequate muscle strength, balance control requires adequate integration of visual, vestibular, and somatosensory information (McCloskey, 1978). Hip abductor afference appears to play a role in this, since hip abductor vibration causes ML sway (Cofre Lizama et al., 2016; Roden-Reynolds et al., 2015). Although both the motor and the sensory capacity of the hip abductor musculature likely contribute to ML-balance control, it can be questioned whether these capacities limit balance performance in challenging situations.

We investigated whether hip abductor motor and sensory capacities limit balance control during predictable and unpredictable ML weight shifting in older adults. We correlated muscle strength and joint position sense with performance on weight-shifting tasks. As a visually guided task, we used a recently developed "MedioLateral Balance Assessment" tool (MELBA), in which participants track a visual target at increasing frequencies with ML movements of the CoM (Cofre

* Corresponding author at: VU University Amsterdam, Van der Boechorststraat 9, 1081 BT Amsterdam, the Netherlands.
E-mail address: j.van.dieen@vu.nl (J.H. van Dieën).

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Lizama et al., 2014). We additionally used a mechanical version of MELBA, without explicit visual feedback, in which target movements were imposed through platform translations that participants had to follow by shifting their CoM, again gradually increasing the frequency of target movements. Both of these tasks were continuous and predictable as target movements were sinusoidal. To compare, we also tested performance after transient unpredictable platform translations.

Because of the presence of explicit, enhanced visual feedback in visual-MELBA, proprioceptive information would be less important for balance (Cofre Lizama et al., 2016) and performance might consequently be limited by hip abductor strength. Hence, we hypothesized that people with higher isometric abductor strength will perform better on the visual-MELBA. Omitting explicit visual feedback, as in mechanical-MELBA and the unpredictable-platform-translation, makes proprioceptive information more important (Cofre Lizama et al., 2016), hence in these tasks, hip abductor proprioception might limit performance before hip strength does so. Therefore, we hypothesized hip proprioceptive acuity to be correlated to performance in mechanical-MELBA and after sudden-platform-translation.

2. Methods

2.1. Participants

Sixteen community-dwelling older adults (12 females and 4 males with a mean age of 68.3 (SD 4.8) years, a mean body height of 165.6 (SD 7.0) cm, and a mean body mass of 68.1 (SD 12.6) kg) participated in this study. Potential participants were excluded if they had a history of musculoskeletal disorders within the last 6 months, any pathology or previous surgery involving lower extremity joints or low back, or any neurological disorders including vestibular or visual problems and postural instability. The local ethics committee of KU Leuven approved the procedure. Participants signed informed consent before participation.

2.2. Experimental design

A novel mediolateral balance assessment task (MELBA) (Cofre Lizama et al., 2014), which consists of tracking a visual target with the body CoM, was used. To challenge various sensory and motor capacities, we selected (1) predictable weight shifting, tracking a sinusoidally moving visual target with explicit visual feedback, henceforth called "visual-MELBA"; (2) predictable weight shifting, by standing as still as possible on a sinusoidally translating platform without explicit visual feedback, henceforth called "mechanical-MELBA"; and (3) reactive unpredictable weight shifting to regain upright stance after a sudden-transient platform translation to right or left, henceforth called "sudden-platform-translation". Body height was measured to standardize stance width during all tasks. Maximum hip abductor muscle strength and hip joint position sense (JPS) were assessed as measures of neuromuscular capacity.

The experiment always started with the visual- and the mechanical-MELBA (the order of the visual- and mechanical-MELBA was randomized between participants), followed by sudden-platform-translation. Four trials of visual-MELBA and mechanical-MELBA tasks were performed by each participant, of which the first one was used to get familiar with the task. For sudden-platform-translation, participants were given one practice trial before the measurements. Subsequently, eight trials were performed randomly ordered, yielding a total of four left and right translations.

2.2.1. Visual-MELBA

The visual-MELBA task has been described previously (Cofre Lizama et al., 2014). In short, participants were asked to stand with arms crossed, with a stance width of 11% of body height and a 14° angle between the longitudinal axes of the feet, while their CoM position (red sphere of 9 cm diameter) was projected on a screen (2×1.5 m size) (Fig. 1). The projected target (white sphere of 11 cm diameter) moved sinusoidally in ML-direction, with an amplitude of 50% of stance width, while its movement frequency increased over time (Cofre Lizama et al., 2014). The target signal comprised 2 blocks of 20 s at 0.1 and 0.2 Hz, 1 block of 10 s at 0.3 Hz, and 13 blocks of 5 s at 0.4–1.6 Hz (with 0.1 Hz increments per block). The total duration of the task was 115 s. The participants were instructed to track the target by ML-CoM movement as accurately as possible, by moving their entire body.

2.2.2. Mechanical-MELBA

The participants were asked to stand on a CAREN platform (Motekforce Link, Amsterdam, The Netherlands). The setup was the same as in Fig. 1, except that the representation of the CoM and the visual target were not projected. The target now was the mediolaterally moving platform; the subject was instructed to stand as still as possible to follow the platform translation. The target signal was constructed with the same frequency changes as the visual-MELBA, but the maximum amplitude of the platform movement, which was 50% of stance width, was decreased by 2% to 64% over the range from 0.4 to 1.6 Hz, in view of the maximum acceleration of the CAREN platform.

2.2.3. Sudden-platform-translation

Participants were instructed to stand still in the same setup as used for MELBA and to regain upright stance as quickly as possible after a perturbation, without stepping. After a random interval of minimally 5 s, the platform suddenly translated toward the left or right (Fig. 1). The

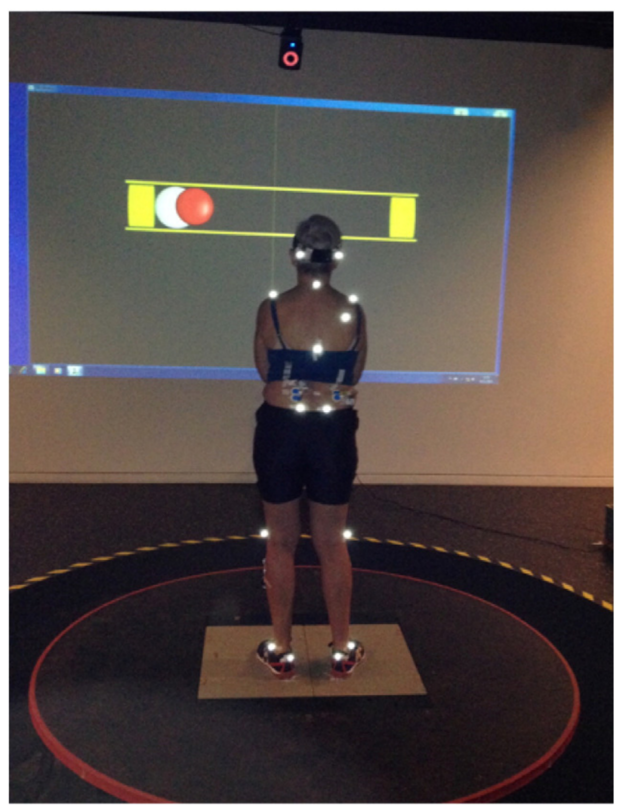

Fig. 1. The measurement setup for the weight-shifting tasks. The visual-MELBA is presented here on the screen (white sphere indicating the mediolaterally moving target to be tracked by the red sphere representing the body CoM). The mechanical-MELBA and sudden-translation tasks were assessed without any screen projection, but with the platform moving mediolaterally.