Gait & Posture 42 (2015) 79–84

Contents lists available at ScienceDirect

Gait & Posture

journal homepage: www.elsevier.com/locate/gaitpost

Mediolateral balance and gait stability in older adults

L. Eduardo Cofré Lizama [a,b], Mirjam Pijnappels [a,**], Sietse M. Rispens [a], N. Peter Reeves [c], Sabine M. Verschueren [d], Jaap H. van Dieën [a,e,*]

[a] MOVE Research Institute Amsterdam, Faculty of Human Movement Sciences, VU University Amsterdam, The Netherlands
[b] Department of Medicine (Royal Melbourne Hospital), The University of Melbourne, Melbourne, Australia
[c] College of Osteopathic Medicine, Michigan State University, USA
[d] Department of Rehabilitation Sciences, Faculty of Kinesiology and Rehabilitation Sciences, Katholieke Universiteit Leuven, Leuven, Belgium
[e] King Abdulaziz University, Jeddah, Saudi Arabia

ARTICLE INFO

Keywords:
Aging
Balance
Gait
Stability
Ecological validity

ABSTRACT

Early detection of balance impairment is crucial to identify individuals who may benefit from interventions aimed to prevent falls, which is a major problem in aging societies. Since mediolateral balance deteriorates with aging, we proposed a mediolateral balance assessment (MELBA) tool that uses a CoM-tracking task of predictable sinusoidal and unpredictable multisine targets. This method has shown to be reliable and sensitive to aging effect, however, it is not known whether it can predict performance on common daily-life tasks such as walking. This study aimed to determine whether MELBA is an ecologically valid tool by correlating its outputs with a measure of mediolateral gait stability known to be predictive of falls.

Nineteen community-dwelling older adults (72 ± 5 years) tracked predictable and unpredictable target displacements at increasing frequencies with their CoM by shifting their weight sideward. Response delay (phase-shift) and amplitude difference (gain) between the CoM and target in the frequency domain were used to quantify performance. To assess gait stability, the local divergence exponent was calculated using mediolateral accelerations with an inertial sensor when walking on a treadmill (LDE_{TR}) and in daily-life (LDE_{DL}) for one week. Pearson product-moment correlation analyses were performed to determine correlations between performance on MELBA tasks and LDE.

Results show that phase-shift bandwidth for the predictable target (range above −90°) was significantly correlated with LDE_{TR} whereas phase-shift bandwidth for the unpredictable target was significantly correlated with LDE_{DL}. In conclusion MELBA is an ecologically valid tool for mediolateral balance assessment in community-dwelling older adults who exhibit subtle balance impairments.

1. Introduction

Falls have a high incidence in healthy elderly, with 30% of people over 65 falling at least once every year, and falls are even more common among elderly with chronic diseases and disabilities [1]. This poses a major health problem for our aging society in which more than 15% of the population worldwide will be over 65 years old by 2050 [2]. Most older people exhibit some degree of balance impairment, which can increase the risk of falling [3]. Therefore detecting balance impairments at early stages in this population is crucial to identify people at risk of falling and ultimately of paramount importance for healthy aging.

Balance impairment and its association to fall risk have been studied using clinical and laboratory measures of balance control. Several measures of postural sway (i.e. spontaneous sway of the center of pressure) have shown that impairment of balance in the mediolateral (ML) direction is predictive of falls [4]. Unfortunately, most of the current clinical balance tests do not emphasize ML balance capacities and were shown to exhibit ceiling effects. In line with this, Pardasaney and co-workers (2013) suggested that for the community-dwelling older adults, new balance assessment tools should be of greater complexity to improve sensitivity [5].

* Corresponding author at: MOVE Research Institute Amsterdam, Faculty of Human Movement Sciences, VU University Amsterdam, van der Boechorststraat 9, 1081 BT, The Netherlands. Tel.: +31 20 5988501.
** Corresponding author at: MOVE Research Institute Amsterdam, Faculty of Human Movement Sciences, VU University Amsterdam, van der Boechorststraat 9, 1081 BT Amsterdam, The Netherlands. Tel.: +31 20 5988501; fax: +31 20 59 88529.
E-mail addresses: m.pijnappels@vu.nl (M. Pijnappels), j.van.dieen@vu.nl (J.H. van Dieën).

http://dx.doi.org/10.1016/j.gaitpost.2015.04.010
0966-6362/

In this context, we recently proposed a ML balance assessment tool (MELBA) in which subjects track a visually presented target with ML movements of their Center of Mass (CoM) [6]. MELBA was shown to be reliable and sensitive to subtle balance impairments in healthy elderly not detected by conventional posturography and clinical measures of balance [6]. Responsiveness (bandwidth) of the balance control system is assessed in terms of the response delay (phase-shift) and amplitude difference (gain) between the CoM and the target along predictable and unpredictable ML trajectories. Impairments of ML balance control likely affect gait, which is the activity during which most falls occur [7]. However, the association between ML balance control, as assessed with MELBA, and stability of gait is as yet unknown.

Gait stability has been quantified using the maximum Lyapunov exponent, or more appropriately the local divergence exponent (LDE) [8,9]. The LDE quantifies the sensitivity of the gait kinematics to continuous small perturbations present due to external perturbations and neuromuscular noise with greater (positive) values indicating "less stable" kinematics [10]. The LDE has been suggested to be the most suitable measure of gait stability available at present [11]. Estimates of the LDE of gait kinematics obtained during walking on a treadmill and during walking in daily-life are both predictive of fall risk [9,12,13]. Although both walking contexts assess physical capacities, daily-life walking may also include behavioral and environmental determinants of fall risk [14]. Furthermore, the LDE has been shown to be sensitive to induced impairments of balance through galvanic stimulation of vestibular afferents [15] and through external mechanical perturbations [16].

Therefore, we hypothesized that measures of balance control obtained with MELBA are associated with measures of ML gait stability in walking on a treadmill and during daily-life. Such associations would demonstrate MELBA's predictive ability regarding gait stability and hence its ecological validity.

2. Methodology

2.1. Participants

Nineteen healthy older adults (7 women and 12 men, age: 72 ± 5 years; height: 1.73 ± .09 m; weight: 76.6 ± 15 kg) with no history of falls over the previous 12 months participated in this study. Participants were excluded if they presented any musculoskeletal or neurological condition or used medications that could affect balance. Participants had mini mental state examination scores ≥25 out of 30 [17] and clinical balance assessment that revealed maximum or close to the maximum scores above the cut-off scores for the highest category defined for each test [6].

This study was approved by the Ethical Committee of the Faculty of Human Movement Sciences, VU University (2011-48M) and the Medical Ethical Committee of the VU University Medical Center Amsterdam (2010/290), in accordance with the ethical standards of the declaration of Helsinki. All participants were informed of the experimental procedures and signed informed consent prior to the experiment.

2.2. Task and procedure

2.2.1. MELBA – mediolateral balance assessment

Each participant performed a series of ML-CoM tracking tasks, while standing barefoot and with the arms crossed in a quiet and low-intensity lit room (Fig. 1). Body CoM was calculated with a 9-markers frontal plane model (forehead, shoulder, anterior-superior iliac spines, knees and ankles) tracked with an Optotrak Certus system (NDI, Waterloo, Ontario, Canada). Gender specific CoM calculations were performed using scaling of anthropometric data

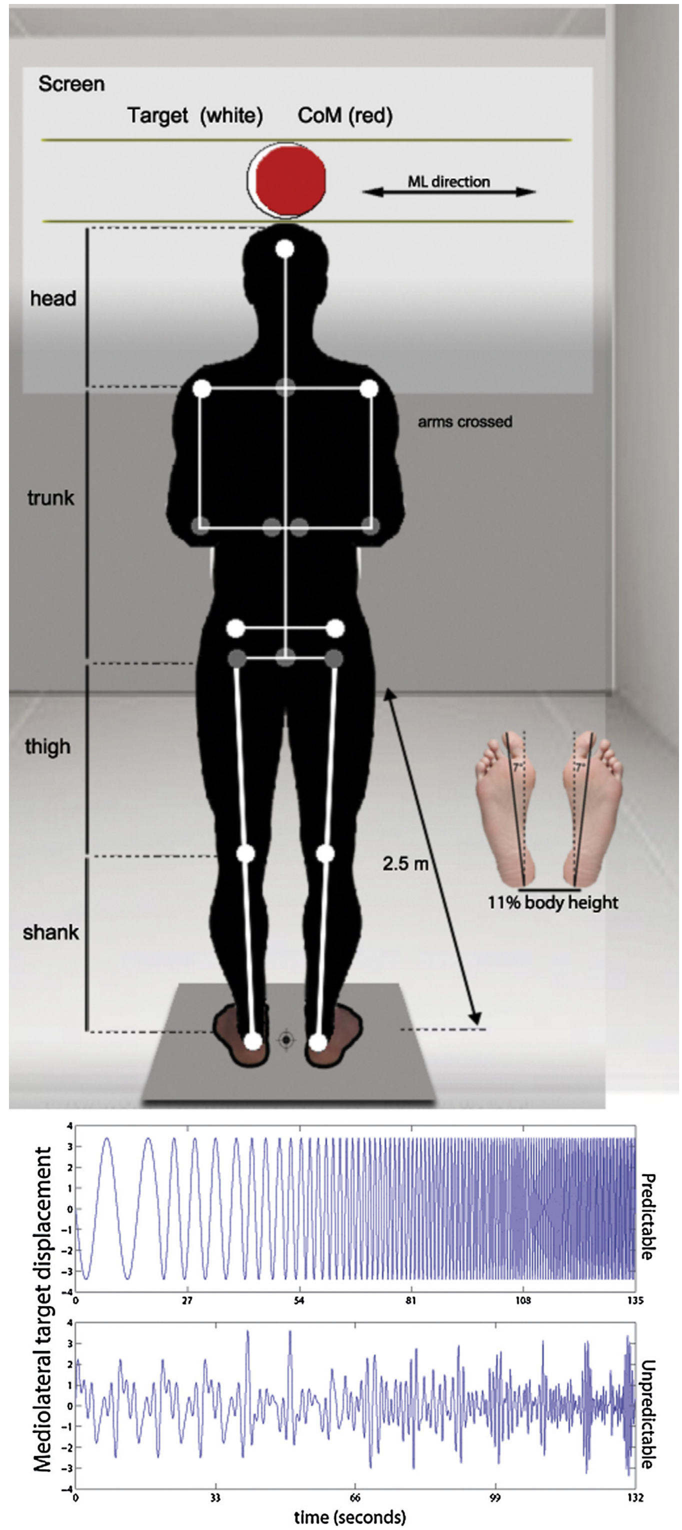

Fig. 1. Set-up and model for Center of Mass (CoM) calculation showing a silhouette with superimposed makers (white dots) and estimated joint centers (gray dots). The displays of the CoM feedback (red sphere) and the target (white sphere) are also presented. Insertion at the right bottom depicts stance width and angle. The target mediolateral (ML) displacement patterns (predictable and unpredictable) are shown at the bottom panel [7]. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of the article.)

and inertial parameters described by de Leva [18]. D-flow 3.10.0 software (Motek Medical, Amsterdam, The Netherlands) was used to produce target signals as well as to record (60 samples/s) and display target and CoM data on a screen 2.5 m in front of the