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Effect of altered surfaces on postural sway characteristics in elderly subjects

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ABSTRACT

Mobility is essentially based on successful balance control. The evaluation of functional strategies for postural stability is requisite for effective balance rehabilitation and fall prevention in elderly subjects. Our objective was to clarify control mechanisms of different standing positions reflecting challenges of typical everyday life situations. For this purpose, elderly subjects stood on different surfaces resulting in a change of the biomechanical constraints. Sway parameters out of time and frequency domain were calculated from center-of-pressure (COP) excursions. Besides the classic quantification of the amount of sway variability, we investigated the temporal organization of postural sway by means of nonlinear time series analysis. Limb load symmetry was quantified via foot pressure insoles. We found task dependent motor outputs: (1) asymmetrical loading in all conditions; (2) altered amount and structure of COP movements with dissimilar changes in medio-lateral and anterior–posterior direction; (3) changes of the motor output affect several time scales especially when standing on a balance board or with one foot on a step. Our results indicate that elderly subjects preferred forcefully one limb which supports a step-initiation strategy. Modifications of the postural sway structure refer to the interaction of multiple control mechanisms to cope with the altered demands. The identification of postural strategies employed in daily activities augments the ecological validity of postural control studies.

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1. Introduction

We are living in complex environments which consistently challenge us to adapt the control of our body position to new situations. Balance control is a primary requirement for successful mobility (Era et al., 1997). It allows us to be active within our community and is an important component of activities of daily living (Frank & Patla, 2003). It is a well-known phenomenon that elderly subjects are more likely to have balance disorders which is associated with a higher risk of falling (Horak, 2006; Ganz, Bao, Shekelle, & Rubenstein, 2007; Maki & McIllroy, 1996; Piirtola & Era, 2006; Salzman, 2010). Falls often occur during routine daily activities rather than during high-risk activities like climbing a ladder (Nevitt, Cummings, & Hudes, 1991). They lead to injury, loss of independence and a diminished quality of life (Jackowski, 2008). A main rehabilitation goal after a fall is the return to a good postural stability. Frank and Patla (2003) criticize that balance training in sterile environments (like a laboratory) does not simulate challenges usually encountered in the community. A traditional method to evaluate balance performance is to study the ability to stand quietly on the level ground with or without surface translations. For instance, the Romberg test (Romberg, 1853), which is a classical stability assessment, demands subjects to stand as still as possible. Variations of the classical setting, resulting in different motor outputs, comprise, e.g., foot placement like stance width (e.g., Kirby, Price, & MacLeod, 1987), sensory condition like eyes closure (e.g., Prieto, Myklebust, Hoffmann, Lovett, & Myklebust, 1996), secondary task manipulation like cognitive task (e.g., McNevin & Wulf, 2002). Seldom, stance on a surface different from the level ground is analyzed. However, common real world situations often demand standing on various surfaces. Hence, there is a need to study postural control in everyday situations to improve the ecological validity of posturography (Visser, Carpenter, vander Kooij, & Bloem, 2008). In this context, it could be shown that standing on a ramp affects fast and slow mechanisms of balance control and alters electromyographic activities of the ankle muscles in young healthy adults (Mezzarane & Kohn, 2007; Sasagawa, Ushiyama, Masani, Kouzaki, & Kanehisa, 2009). In a more practical setting Simeonov, Hsiao, and Hendricks (2009) found that visual cues can improve balance control on sloped surfaces of construction workers on roofs. In the present study, we evaluate

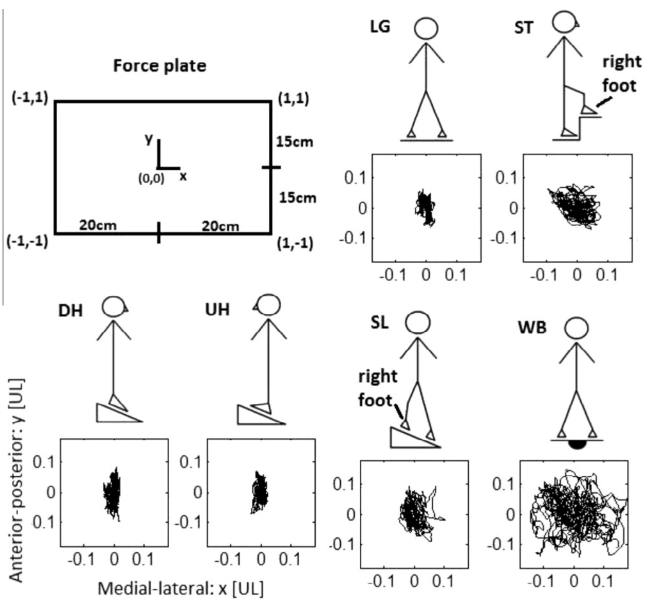

Fig. 1. Top left: Schematic force plate showing the units of the calculated COP position. Top right, bottom: Schematic image of each surface condition with an exemplary COP pattern of one subject (LG = level ground, ST = step, DH = downhill, UH = uphill, SL = slope, WB = wobbling board).