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Adaptive feedback potential in dynamic stability during disturbed walking in the elderly

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ABSTRACT

After perturbation of the gait, feedback information may help regaining balance adequately, but it remains unknown whether adaptive feedback responses are possible after repetitive and unexpected perturbations during gait and if there are age-related differences. Prior experience may contribute to improved reactive behavior.

Fourteen old (59–73yrs) and fourteen young (22–31yrs) males walked on a walkway which included one covered element. By exchanging this element participants either stepped on hard surface or unexpectedly on soft surface which caused a perturbation in gait. The gait protocol contained 5 unexpected soft trials to quantify the reactive adaptation. Each soft trial was followed by 4–8 hard trials to generate a wash-out effect. The dynamic stability was investigated by using the margin of stability (MoS), which was calculated as the difference between the anterior boundary of the base of support and the extrapolated position of the center of mass in the anterior-posterior direction.

MoS at recovery leg touchdown were significantly lower in the unexpected soft trials compared to the baseline, indicating a less stable posture. However, MoS increased ($p<0.05$) in both groups within the disturbed trials, indicating feedback adaptive improvements. Young and old participants showed differences in the handling of the perturbation in the course of several trials. The magnitude of the reactive adaptation after the fifth unexpected perturbation was significantly different compared to the first unexpected perturbation (old: $49\pm30\%$; young: $77\pm40\%$), showing a tendency ($p=0.065$) for higher values in the young participants.

Old individuals maintain the ability to adapt to feedback controlled perturbations. However, the locomotor behavior is more conservative compared to the young ones, leading to disadvantages in the reactive adaptation during disturbed walking.

1. Introduction

The incidence of falls for the elderly population increased in accordance with the consequential fall-related injuries (Blake et al., 1988; Tinetti et al., 1988; King and Tinetti, 1995). Especially after unexpected perturbations like tripping, old subjects show a decreased recovery performance compared to young ones leading to a higher occurrence of falls (Thelen et al., 1997, 2000; Grabiner et al., 2005; Pijnappels et al., 2005; Karamanidis and Arampatzis, 2007). The reduced ability of the elderly population to regain balance can be attributed to an age-related decrease in muscle strength, tendon stiffness (Schultz, 1995; Grabiner et al., 2005; Karamanidis et al., 2008) and a reduced rate of force development (Vandervoort and McComas, 1986). Furthermore, impairments in motor performance are not only dependent on changes in peripheral structures, but as well on the central nervous system changes due to age-related degeneration of motor cortical regions or neurotransmitter systems (Seidler et al., 2010).

However, recovery performance can be modified by adaptations in a predictive and/or feedback based manner. Possible adjustments affect, for example the magnitude of the base of support (prior as well as after the perturbation), the horizontal velocity of the center of mass and the position of the center of mass (Bhatt et al., 2005, 2006; MacLellan and Patla, 2006; Arampatzis et al., 2011). It is believed that supraspinal structures account for predictive locomotor adjustments (Earhart et al., 2002; Morton and Bastian, 2006) and determine the required feedforward motor control which is based on available knowledge about the movement. Humans are able to improve their dynamic stability in a predictive manner, counteracting an expected perturbation by ongoing adaptive adjustments based on prior experience (Marigold and Patla, 2002; Pai et al., 2003; van der Linden et al., 2007). Predictive adjustments may help to avoid or to reduce the

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