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Light touch compensates peripheral somatosensory degradation in postural control of older adults

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ABSTRACT

The present study aimed to investigate the sensitivity of detecting lower limb passive motion and use of additional sensory information from fingertip light touch for the postural control of older adults in comparison with young adults. A total of 11 older and 11 young adults (aged 68.1 ± 5.2 and 24.2 ± 2.2 years, respectively) underwent two tasks. We evaluated their sensitivity to passive ankle joint movement while seated in the first task. Participants then stood quietly on a force plate in a semi-tandem stance, for 30 s under two fingertip contact force conditions (no touch and light touch limited to 1 N). The results showed that the threshold of passive ankle displacement and body sway is higher in older adults than in young adults. The body sway reduced for both older and young adults with the addition of light touch at the fingertips. The maximum cross-correlation coefficient and time lags between body sway and fingertip light touch center of pressure was similar between both groups, suggesting that older adults used light touch to reduce body sway, similar to young adults. A higher threshold in detecting passive ankle joint movement may contribute to the increased body sway observed in older adults. These deficits may be compensated by additional sensory cues that would provide enhanced information used to control the upright stance.

1. Introduction

Sensory feedback about the relationship established between adjacent body segments and the relationship between the whole-body configuration and the surrounding environment is crucial for maintaining upright stance. To provide useful information about body dynamics in space, sensory stimuli received from different sources (e.g., visual, vestibular, and somatosensory systems) (Nashner, 1981) need to be integrated in the central nervous system (CNS). Based on this information, appropriate muscle activation is produced to achieve or maintain a desirable body posture. Therefore, postural control requires appropriate sensory integration and an intricate relationship between the sensory and motor systems (Horak & Macpherson, 1996).

The findings of several previous studies indicate that older adults present poorer postural control performance (i.e., larger body sway) than young adults (Lord & Ward, 1994; Maki & McIlroy, 1996; Sturnieks, St George, & Lord, 2008; Woollacott & Shumway-Cook, 1990). Despite other possible factors, poorer postural control performance is associated with an impaired ability to obtain accurate afferent cues from the body periphery (Blaszczyk, Lowe, & Hansen, 1994; Collins, De Luca, Burrows, & Lipsitz, 1995; Lord &

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Menz, 2000; Prioli, Cardozo, de Freitas Junior, & Barela, 2006; Prioli, Freitas Junior, & Barela, 2005). For instance, Toledo and Barela (2010, 2014) recently demonstrated that less accurate detection of passive motion around the ankle joint was associated with larger sway in older adults during the upright stance. Assuming that in an upright stance, the human body behaves as a single-segment inverted pendulum (Winter, Prince, Frank, Powell, & Zabjek, 1996), information around the ankle is critical to detect any whole-body deviation from its desirable position. Therefore, if older adults need larger displacement to detect passive motion in their ankles, their greater sway could be directly related to less accurate lower limb proprioceptive cues (Toledo & Barela, 2010).

In a situation in which available sensory cues are not accurate, creating less precise estimation of body dynamics, an alternative strategy would be to enhance information by providing alternative sensory cue sources. For instance, several studies demonstrated that information from fingertip contact to a rigid surface provides sensory cues that can be used as an additional source of somatosensory information to attenuate body sway in upright stance in newly walking infants (Barela, Jeka, & Clark, 1999; Metcalfe et al., 2005), children (Barela, Jeka, & Clark, 2003), young adults (Holden, Ventura, & Lackner, 1994; Jeka & Lackner, 1994, 1995), and in individuals with vestibular dysfunction (Lackner et al., 1999), peripheral neuropathy (Dickstein, Shupert, & Horak, 2001), anterior cruciate ligament injury (Bonfim, Grossi, Paccola, & Barela, 2008), and stroke (Cunha, Alouche, Araujo, & Freitas, 2012). The premise of this approach is that fingertip contact to a rigid surface provides information about arm position and body sway, leading to anticipatory muscle activity to revert and/or maintain a more stable upright stance, consequently, reducing the body sway magnitude (Jeka & Lackner, 1994, 1995; Jeka, Schoner, Dijkstra, Ribeiro, & Lackner, 1997).

A few studies investigated the effects of light touch on body sway of older adults (Baccini et al., 2007; Reginella, Redfern, & Furman, 1999; Tremblay, Mireault, Dessureault, Manning, & Sveistrup, 2004). Although they employed different methodology, the studies revealed that older adults were able to reduce body sway by touching a stationary surface. Baccini and colleagues (2007) showed that by lightly contacting (applying forces up to 1 N) a rigid surface, older adults reduced their body sway compared to a non-contact condition; the effect of light touch was even larger compared to that observed in young adults. Similarly, Tremblay and colleagues (2004) also observed a reduction in body sway in older adults, although they did not control the amount of applied force on the touching surface. The use of fingertip cues from contacting a surface to reduce body sway magnitude in older adults was even observed when cues from the lower limbs were distorted (Reginella et al., 1999). Despite the important and promising findings from these studies (Baccini et al., 2007; Reginella et al., 1999; Tremblay et al., 2004), however, there are many questions related to how older adults use light touch on a surface to reduce postural sway, which remain to be examined. First, the relationship between changes in the applied fingertip forces and body sway has not been assessed in older adults. In young adults, changes in applied forces preceded (approximately 300 ms) the corresponding body sway, indicating that changes in applied forces at the fingertip are used to anticipate changes in body sway (Jeka & Lackner, 1995). Second, the aforementioned studies that investigated the effect of light touching in older adults (Reginella et al., 1999; Tremblay et al., 2004) did not limit the applied force to 1 N. Thus, it is uncertain whether the light touch provided a sensory or mechanical effect. Therefore, although contacting a surface to reduce the magnitude of body sway has been established in older adults, the mechanism underlying the use of such contact for body stabilization still requires further investigation.

Despite the possible questions related to the use of enhanced somatosensory cues from the fingertip contact by older adults, Baccini and colleagues (2007) suggested that tactile cues obtained from contacting a rigid surface might counterbalance detrimental deterioration of sensory information from the lower extremities, which can compromise postural performance in older adults. Results from Tremblay and colleagues (2004) corroborated with this hypothesis, since they demonstrated that for older adults fingertip contact to a stationary surface is useful for controlling body sway, even when proprioceptive cues from the lower limbs were distorted. The use of additional sensory cues, such as the ones provided by lightly touching a rigid surface to improve upright stance performance, is important because previous findings indicate that body sway in older adults is influenced by less accurate motion detection around the ankle (Lord, Clark, & Webster, 1991; Lord & Menz, 2000; Toledo & Barela, 2010; Winter et al., 1996). Thus, older adults might enhance sensory information by additional cues coming from lightly touching a rigid surface to compensate impairments in their lower limb proprioception acuity. Assuming that light touch and motion detection around the ankle joint do not share the same functioning mechanisms (i.e., receptors responding to different stimuli and having different thresholds), the CNS might take advantage of using cues coming from both sources, i.e., light touch and motion around the ankle joint, to improve postural control performance. However, if cues from the motion around the ankle joint are degraded with age, the CNS would obtain less accurate information about body dynamics, e.g. sway position and velocity. Thus, contacting a surface would be sufficient to compensate for such sensory degradation to maintain a performance level similar to young adults.

Despite evidence that older adults can use light touch to reduce body sway (Baccini et al., 2007; Tremblay et al., 2004), and its possible behavioral role in compensating for deteriorated proprioceptive cues from lower limbs, this direct relationship has not been examined yet. Therefore, the main aim of the present study was to examine whether possibly less accurate detection of passive motion of ankle joint would account for larger sway of older adults. In addition, this study also examined the use of light touch by older adults to determine if it might be sufficient to overcome possibly less accurate cues coming from the lower limbs. We hypothesized that older adults would be less sensitive to passive motion detection in the lower limb joint and in postural control when compared to young adults. However, such deterioration of lower limb sensitivity in older adults would be compensated by sensory cues from the fingertip contacting a rigid surface to reduce postural sway.