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Light touch leads to increased stability in quiet and perturbed balance: Equivalent effects between post-stroke and healthy older individuals

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ABSTRACT

Cerebral damage provoked by stroke may lead to deficits of quiet balance control and of the recovery of body equilibrium following an unanticipated postural perturbation. In this investigation we aimed to evaluate the effect of light touch (LT) of an earth-fixed surface on balance stability in individuals with post-stroke hemiparesis, taking performance of age-matched healthy participants as reference. Evaluations were made in conditions of full and no visual information. Analysis of quiet balance showed that LT induced higher balance stability, with reduced amplitude and velocity of postural sway. Evaluation of the effect of LT on automatic postural responses was made in the task of recovering body equilibrium following a mechanical perturbation of balance leading to fast forward body sway. Results showed that LT led to reduced amplitude of center of mass displacement following the perturbation, in addition to reduced amplitude and velocity of center of pressure under the feet, and lower activation of the lower legs muscles. Those effects of LT were observed in both the post-stroke and control groups, and did not interact with vision availability. Our results indicated then that individuals who suffered a cerebral stroke can stabilize perturbed and non-perturbed postural responses by lightly touching a stable surface to a similar extent of healthy older individuals.

1. Introduction

Neural impairment resulting from cerebral stroke may induce several deficits in upright balance control. In quiet standing, stroke has been shown to lead to decreased balance stability as revealed by greater amplitude (Corriveau, Hebert, Raiche, & Prince, 2004; de Haart, Geurts, Huidekoper, Fasotti, & van Limbeek, 2004; Dickstein & Abulaffio, 2000) and velocity (Yu, Jung, & Cho, 2012) of body sway. In reactive responses to unanticipated perturbations, research has shown delayed (Di Fabio, Badke, & Duncan, 1986; Ikai, Kamikubo, Takehara, Nishi, & Miyano, 2003; Marigold & Eng, 2006a; Marigold, Eng, & Inglis, 2004) and weaker (Fernandes, Coelho, Martinelli, & Teixeira, 2018; Garland, Ivanova, & Mochizuki, 2007; Ikai et al., 2003) muscular responses (mainly in the paretic leg) in comparison with neurologically healthy individuals. Beyond deficits in motor components of postural responses to maintain or recover stable balance, stroke may lead also to important alterations of sensory processing leading to postural instability. Niam, Cheung, Sullivan, Kent, and Gu (1999) found that increased postural sway due to stroke was observed only in individuals with impaired ankle proprioception. This result suggests that processing deficits of proprioceptive information signaling postural sway (Duclos, Maynard, Abbas, & Mesure, 2015) is also critical to balance control.

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Consistent with the interpretation of the particularly relevant role of proprioceptive processing for body balance control, additional results have shown more evident decrement of postural stability only when vision is suppressed (Bensoussan et al., 2007; Marigold & Eng, 2006b; Roerdink, Geurts, de Haart, & Beek, 2009) or in experimental conditions involving manipulation of vision and other sources of sensory information used for body balance control (Bonan et al., 2004; Marigold, Eng, Tokuno, & Donnelly, 2004; Oliveira et al., 2011). This increased visual dependence for maintenance of stable quiet balance in post-stroke individuals may be associated with impaired processing of proprioceptive afference, leading to limited sensory sources available for balance control when vision is unavailable.

A procedure that has been revealed to be effective to increase stability of body balance is providing additional sensory information relevant for postural sway through fingertip light touch (LT) of an earth-fixed surface. Results have indicated that LT leads to increased balance stability both in quiet (Chen & Tsai, 2015; Holden, Ventura, & Lackner, 1994; Jeka & Lackner, 1994, 1995; Johannsen, Lou, & Chen, 2014; Rabin, DiZio, & Lackner, 2006) and dynamic (Dickstein & Laufer, 2004; Kodesh, Falash, Sprecher, & Dickstein, 2015) balance. When one touches a stable surface, postural oscillation leads to variation of pressure on the highly sensitive cutaneous receptors on the fingertip's skin (Johnson & Hsiao, 1992). This is thought to provide the control system with augmented sensory information relevant for balance control (Jeka & Lackner, 1994, 1995). Consistent with that notion, different studies have shown that LT stabilizes body balance in a more evident way when balance-related sensory information is altered, like in conditions of experimental manipulation of vision (Baccini et al., 2007; Jeka & Lackner, 1994; Sozzi, Do, Monti, & Schieppati, 2012) or ankle proprioception (Lackner, Rabin, & DiZio, 2000), and also in patients with impaired tactile information from the feet soles (Dickstein, Shupert, & Horak, 2001) or from the vestibular system (Bernard-Demanze et al., 2015; Lackner et al., 1999). These investigations have indicated that LT can partially compensate for the absence or lack of reliable information from other sensory sources signaling body sway to the central nervous system.

An issue of particular interest for the current study is whether LT could lead to improved balance control also in individuals who suffered a stroke, with potential deficits of proprioceptive information processing (Duclos et al., 2015; Niam et al., 1999). Preliminary information on this issue has been provided by showing that LT either with the paretic or the nonparetic hand induces improvement of quiet balance stability, as indicated by lower amplitude and velocity of the center of pressure (CoP) under the feet (Cunha, Alouche, Araujo, & Freitas, 2012). Cunha et al.'s results also showed that LT led to balance stabilization in conditions of either full vision or no-vision, with a proportional reduction of balance sway between the visual conditions. Those results suggest that post-stroke individuals are able to use the additional haptic information provided by LT to diminish body balance sway in the task of keeping quiet upright balance. Regarding unanticipated balance perturbations, on the other hand, preliminary results have provided inconsistent evidence that LT could also modulate postural responses in neurologic individuals. Dickstein, Peterka, and Horak (2003) evaluated the effect of LT of a stable bar on automatic postural responses to sudden backward displacements of the support base at different velocities in individuals with profound feet sensory neuropathy. Results suggested that LT led to reduced initial rate of CoP displacement at the lowest platform velocity, but that effect was not reproduced in larger perturbations induced by higher velocities of platform translations. Additionally, postural responses were evaluated mainly based on CoP displacement, which does not represent a direct index of postural stability in situations of perturbed stance, as it is the case of CoM analysis. No further studies have addressed the effects of LT on stabilization of reactive postural responses in neurologic individuals. Thus, the extent to which stroke survivors could improve body balance recovery following an unanticipated perturbation by lightly touching an earth-fixed surface is an issue open to investigation.

In the current research, we aimed to assess the effect of LT on body balance control of individuals who suffered a cerebral stroke, having performance of healthy age-matched individuals as reference of normal behavior. The study was conducted in two steps. In the first one, we aimed to confirm in our participants the capacity to use LT to stabilize postural sway in quiet balance, as has been demonstrated previously in healthy older (Albertsen, Temprado, Berton, & Heuer, 2014; Baccini et al., 2007) and post-stroke (Cunha et al., 2012) individuals. In the main second step, we evaluated in the same groups the effect of LT on automatic postural responses for balance recovery following an unanticipated mechanical perturbation. In both quiet and perturbed balance evaluations we tested the effect of LT in conditions of full vision and no-vision. We hypothesized that LT leads to adaptive responses in quiet and perturbed balance for both post-stroke and healthy individuals, with the perspective that LT might reduce differences of postural control between those groups. As post-stroke individuals have been shown to be more vision-dependent than healthy individuals (Bonan et al., 2004; Corriveau et al., 2004; Manor et al., 2010), LT was expected to affect postural responses to a greater extent in the former when vision is suppressed.

2. Methods

2.1. Participants

Ten chronic hemiparetic post-stroke (5 females), age range 46–76 years (M = 64.70 years, SD = 11.21), and ten healthy (7 females), age range 45–76 years (M = 64.91 years, SD = 7.83), individuals volunteered for this study. Selection of both post-stroke and healthy control participants was made from a public hospital database, with all of them living in the same region. Post-stroke participants were selected following clinical evaluation and cerebral image analysis by the hospital's neurologists. Inclusion criteria for hemisphere damage participants were the following: time range following stroke from 6 months to 3 years, mild to moderate functional disability based on the modified Rankin scale (score $<$ 3) (Wilson et al., 2002), behavioral manifestation of hemiparesis, absence of neurologic or orthopedic diseases other than those induced exclusively by the stroke, absence of damage to the cerebellum or brain stem (based on magnetic resonance imaging evaluation), and scores 1–2 in the modified Ashworth's spasticity scale (Ansari,