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Research article

Precueing time but not direction of postural perturbation induces early muscular activation: Comparison between young and elderly individuals

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HIGHLIGHTS

- Precue of time of stance perturbation leads to shorter response latency.
- Direction precue of stance perturbation does not modulate muscular responses.
- The effects of precueing were similar between the young and the elderly.

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ABSTRACT

In this study, we evaluated the effect of precueing characteristics of an impending perturbation to upright stance on reactive responses of distal leg muscles. Young and older individuals were compared in a task of recovering stable upright stance following rotation of the supporting platform to induce anterior or posterior body sway. Directions of the supporting platform rotation were randomized across trials. Immediately before postural perturbation participants were cued about direction and/or time of platform rotation, or performed the task under directional and temporal uncertainty of the impending perturbation. Results showed that precueing time of perturbation led to earlier muscular activation onset, while precueing perturbation direction did not modulate either latency or magnitude of muscular activation. Those effects were similar between age groups. Our findings suggest that awareness of the perturbation time favored shorter response latencies in both the young and older individuals.

1. Introduction

Uncertainty about the nature of an upcoming perturbation to upright stance has been shown to lead to poor reactive postural responses in both young [1] and older [2] individuals. The effect of uncertainty on reactive postural responses suggests that muscular activation to restore stable upright stance following balance perturbation is mediated by higher order processing. Evidence of higher order processing involvement in reactive postural responses has been reported in studies showing cortical activation occurring prior to the initiation of compensatory postural adjustments during voluntary body oscillation [3] and prior to expected mechanical perturbations [4–7]. The existence of this central mediated mechanism is also supported by experimental data showing that contextual cues about the kind and time of perturbation affect the pattern of postural responses [4–7]. From those findings, anticipatory cortical activation has been proposed to prime neural centers

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responsible for the control of reactive postural response [4,5]. However, a review of literature on the effect of direction and timing precueing of an impending postural perturbation has shown contradictory results regarding reactive muscular activation.

Diener et al. [8] reported lack of effect of direction precueing in stance perturbation by means of rotation of the supporting platform, inducing forward or backward sway. Results showed that precueing direction of the forthcoming perturbation did not lead to shorter response latency. In a further test of the effect of precueing parameters of stance perturbation on reactive postural responses, Gilles et al. [9] induced sideways or forward sway through horizontal forces applied to the pelvis. Although they found that directional precueing through repeated perturbations of the same kind led to changes in timing and amplitude of muscle responses, no reduction of latency of muscular responses onset was observed. These preliminary studies suggest a lack of effect of direction precueing on early muscular activation in the recovery of body balance. On the other hand, there is some evidence that precueing time of perturbation can shorten the latency of muscular responses onset. McChesney et al. [10] evaluated the effect of stance perturbation by anteroposterior translations of the supporting platform. The effect of directional or directionally neutral precueing provided at a constant time before platform motion were compared against no precueing. Results showed that both direction and directionally neutral precueing led to earlier muscular responses as compared to no precueing. As in both precued conditions time of perturbation onset was cued, it becomes apparent that awareness of the onset time of an impending perturbation, rather than awareness of perturbation direction, led to shorter latency of muscular activation. The conjecture that precueing the onset time of a postural perturbation is critical for generating earlier and more well-adapted responses may also underlie results by Jacobs et al. [4] and Mochizuki et al. [5–7], suggesting a beneficial effect of precueing amplitude of an impending perturbation on postural responses. As precueing was provided at a constant time before perturbation, that procedure may have improved the reactive postural response by precueing time of the impending perturbation rather than precueing its spatial parameters. In line with this possibility, prior awareness of the time of an upcoming motion of the base of support has been shown to decrease the magnitude of activation of the ankles' periarticular muscles [4,5,11]. From these results, it can be thought that modulation of reactive postural responses occurs in conditions that the exact time of perturbation can be foreseen.

In this scenario of contradictory evidences concerning the hypothesis of the central inputs capability of priming the neuromuscular system through precueing spatial/temporal characteristics of an impending perturbation, it might be argued that the effect of precueing on muscular responses could be observed more sharply in older adults. It has been shown that aging leads to increased activation of cortical areas associated with processing of sensory information and intersensory integration when performing voluntary movements [12]. Behavioral studies on balance control have shown that elderly's quiet stance stability is more disturbed by a simultaneous performance of a cognitive task than the young [13–15]. Moreover, it has been shown that more difficult postural tasks lead to increased use of attentional resources in the elderly [16,17]. These results indicate greater penetrability of higher order processing into postural control in the elderly than in young individuals. From this assumption, it could be expected that higher order processing associated with awareness of characteristics of an impending balance perturbation affects to a greater extent older than young individuals.

In the present investigation we aimed to test the effects of precueing direction or time of balance perturbation on early reactive muscular responses, comparing the effects between young and elderly individuals. For this purpose, we evaluated lower leg muscular activation in response to rotation of the support base to assess the earliest postural responses observed in the lower leg muscles [20]. Because of the short latency of these responses, they can be considered as the most direct indication of the hypothetical presetting of neural structures regulating reactive responses by means of precueing. Based on the notion that postural responses require more attentional control in the elderly, we hypothesized that the muscular reactions are more sensitive to precueing of an impending balance perturbation in the elderly than in young individuals.

2. Materials and methods

2.1. Participants

Participated of this study physically active individuals: 16 (8 women) university students, age range 19–27 years (M = 22.06 years, sd = 3.75), and 15 (12 women) elderly, age range 64–86 years (M = 74.3 years, sd = 6.92). Inclusion criteria were no history of neurological, sensorial or musculoskeletal disease potentially affecting postural control, as self-declared by the participants. Cognitive function was evaluated in the elderly participants through the mini-mental state examination [18]. Participants provided informed consent to participate in the study. Experimental procedures were approved by the local ethical committee.

2.2. Apparatus and task

The task was recovering stable upright body balance following rotation of the supporting platform. Initial posture was quiet stance on a moving force platform (NeuroCom PRO Balance Master System). Participants were barefoot, keeping the feet parallel shoulder-width apart, with the arms in parallel to the trunk. The subjects gazed at a monitor screen positioned 1.5 m away at the eyes height. Stance perturbation was generated by rotating the supporting platform, provoking dorsal or plantar flexion of the ankles. These postural perturbations induced posterior or anterior body sway, respectively. Amplitude of rotation was 10° with average velocity of 50°/s. Participants were instructed to resist the perturbation without moving the feet, and to refrain from making anticipatory movements. Gaze was kept at the monitor screen during testing, as visually supervised by one of the experimenters. Activation of the tibialis anterior (TA) and gastrocnemius medialis (GM) muscles of the right leg was recorded by using surface electromyography (EMG, EMG System®). Myoelectrical signals were captured by using self-adhesive gel-filled bipolar Ag–AgCl electrodes.

2.3. Experimental design and procedures

Each age group was evaluated in four experimental conditions, resulting from the combination of precueing the direction and onset time of platform rotation. For precueing direction of platform rotation, visual cues were presented through vertical arrows. Black 8 × 11-cm (height × width) arrows were presented on a white background on the monitor screen. Upward arrow signaled that the ensuing platform rotation would lead to ankle dorsal flexion inducing backward body sway, while downward arrow signaled that the ensuing platform rotation would lead to ankle plantar flexion inducing forward body sway. Following a verbal warning, visual precueing was displayed for 2 s. After disappearance of the signaling arrow, a black 2-cm diameter circle was shown on the monitor screen. Participants gazed at the circle while waiting for the ensuing platform rotation. For pure precueing of direction of platform rotation, precueing was provided in the context of timing uncertainty: the foreperiod between the end of precueing presentation and initiation of platform rotation was variable across trials. That