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Age-related changes in postural control to the demands of a precision task

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ABSTRACT

Optimal sensorimotor integration is needed to maintain the precision of a visuomotor postural task. Furthermore, cognitive resources have been suggested to be involved in maintaining balance, especially in older adults. This study investigated how older and younger adults differed in employing sensorimotor strategies in a dual-task situation. Older (age 65–84 years) and younger adults (age 19–30 years) performed a visually-based, postural tracking task in different body orientations (from 0° to 45°), which necessitated slightly different task goals. On some trials, participants performed a concurrent silent arithmetic task with the visuomotor tracking task. The results demonstrated that sensorimotor control declined with age. Older adults showed greater medial–lateral center of pressure variability compared to younger adults in the precision task. Younger adults displayed a trend to decrease anterior–posterior variability, but older adults exhibited an opposite trend when the body orientation changed from 0° to 45°. The addition of a dual-task situation decreased overall postural variability in both age groups. Age-related changes in postural control may degrade the flexible coordination of the sensory feedback and motor execution. This study suggested that medial–lateral stability may be more sensitive to this age-related decline and may be closely associated with postural instability and falls.

1. Introduction

When crossing a busy intersection, an individual's attention can be drawn to the traffic light, approaching cars, fellow pedestrians, or occupied in a conversation with a companion. The ability to cross the street safely and efficiently is fundamental to independent living in older adults, especially to those who live in urban settings. In this complex situation, older adults require the flexibility to allocate attention between maintaining posture and the secondary task (e.g., talking, scanning the busy street for threats, or tracking visual targets) to adapt quickly to surroundings. Thus, the coordination between vision, posture and secondary tasks comprises a common element in our daily life activities.

Postural control depends on the integration of information from visual, proprioceptive, and vestibular systems. Conflicts among these sensory systems challenge the postural control system to integrate correct orientation in space and determine

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the appropriate motor response. A common method for studying visuomotor adaptation is to alter visual feedback. For example, a large body of research has been conducted using prism glasses to impose lateral translation or angular deviation while participants are performing goal-directed tasks. This manipulation introduces a temporal reorganization of visual and proprioceptive recalibration during the course of adaptation (Baraduc & Wolpert, 2002; Jakobson & Goodale, 1989; Roby-Brami & Burnod, 1995). Investigations of visuomotor control in balance have shown that aging deteriorates the ability to perform goal-directed movements (Dault, de Haart, Geurts, Arts, & Nienhuis, 2003; Freitas & Duarte, 2012; Hatzitaki & Konstadakos, 2007). The coordination between vision and posture has been examined by a visual tracking task that requires participants to maintain a real-time visual feedback of the center of pressure (COP) within a reference. Dault, Yardley, & Frank, (2003) found that younger adults, but not older adults, had decreased COP variability with augmented visual feedback. The authors suggested that when younger participants stood in front of a computer screen with COP feedback, they used a "tighter" control strategy through rapid alternations in the direction of ankle moments. Older adults, however, were not able to adapt sway control to the required task as a result of motor and sensory deficits with aging. When asking participants to maintain their COP within a fixed target that was presented on the computer screen (e.g., visual feedback tasks used in Dault et al. (2003)), individuals controlled the real-time COP cursor in both the mediolateral (ML) and anteroposterior (AP) directions in order to achieve the task goal. This was performed while participants stood and looked straight ahead to the screen. One question that remained to be addressed was how the posture system organizes ML and AP control for the postural precision task under different head orientations (i.e., head is rotated to the side). The task would likely become more challenging because COP movement in the ML direction from the force platform would be converted into movement in the AP direction on the COP feedback cursor and vice versa. When the head is turned sideways, conflict between visual feedback and proprioceptive cues challenge the postural control system, requiring adjustments in the central nervous system (CNS) integration process to determine the correct orientation in space and the appropriate motor response in maintaining the precision goal (Redfern, Yardley, & Bronstein, 2001). Therefore, changing head orientations is one way to generate different postural precision demands. The first objective of this study was to investigate the pattern of postural organization used by younger and older adults in both the ML and AP directions during visual tracking tasks. Examining such visuomotor rearrangement during postural control will shed light on the neural process involved in sensorimotor coordination as well as identify age-related changes in postural control.

One approach to study the effect of head orientations on postural control is to instruct the participants to maintain their head straight forward (0°) or turned to the side (90°) (Balasubramaniam, Riley, & Turvey, 2000; Riley, Balasubramaniam, & Mitra, 1998; Stoffregen, Smart, Bardy, & Pagulayan, 1999). However, a decline in functional movement is one of the most significant alterations that occur with aging (Bemben, 1999). Aging is a normal biological process associated with changes in the elasticity of connective tissues, and results in a significant decrease in flexibility (Campanelli, 1996). Therefore, pathological and degenerative changes in aging can decrease the cervical spine range of motion (Tousignant, Smeesters, Breton, Breton, & Corriveau, 2006). It has been suggested that the loss of normal cervical lordosis leads to limited neck movements, especially neck rotation (Maigne, 2000). Furthermore, turning the head 90° to the side does not appear to be a functional posture used in our daily lives. Bennett, Schenk, and Simmons (2002) examined the mean active range of motion of the cervical spine required to perform 13 daily functional tasks in healthy young adults. The functional tasks included tying shoes, backing up a car, washing hair in the shower, and crossing the street. Specifically, they found that the greatest rotation of the cervical spine was in the task of backing up a car, which is less than 90° (67.6° ± 11.8°) without trunk motion. As a result, the present study involved a task where participants rotated their head from 0° to a maximum of 45° to the side.

The complexity of postural control is further exacerbated by the fact that people often engage in secondary task performance while maintaining balance. Consequently, it is important to take into consideration the interaction between the postural task and secondary task performance. In an earlier study, we used a dual-task paradigm to examine the extent to which postural control is influenced by visual and cognitive task performance in younger and older adults (Yeh, Cluff, & Balasubramaniam, 2014). During the delayed visual feedback task, we found that compared to younger adults, older adults had increased reliance on visual feedback for postural control even though the visual feedback was delayed by several hundreds of milliseconds (Yeh et al., 2014). In addition, our results revealed that performing a secondary task decreases postural sway variability in younger but not older adults. Seemingly automatic tasks like standing may require additional cognitive resources in late adulthood due to general decreases in sensorimotor (Wade & Jones, 1997) and cognitive-attention function (Lacour, Bernard-Demanze, & Dumitrescu, 2008; McDowd, 1997), thereby contributing to increases in postural sway when older adults maintain standing balance while they are engaged in other tasks. The second aim of this study was to investigate whether a secondary task altered postural control during a postural precision task.

The primary hypothesis was that postural performance as measured by COP variability would be greater in older adults compared to younger adults especially in the ML direction (cf. Rogers & Mille, 2003). There are a growing number of studies suggesting that increased sway variability does not necessarily reflect compromised balance. Rather, sway variability may reflect the characteristics of exploratory behavior (Carpenter, Murnaghan, & Inglis, 2010; Murnaghan, Horslen, Inglis, & Carpenter, 2011; Riley, Mitra, Stoffregen, & Turvey, 1997). In the present study, however, increased sway variability reflected a decrement in balance control since our task goal was to maintain the COP feedback cursor within a fixed target.

A secondary hypothesis was that the assembly of postural organization in ML and AP COP variability would respond negatively to the precision demands of the postural task when body orientation changed from 0° to 45°. Specifically, the COP variability (SD) in the ML and AP was expected to vary systematically with body orientation, with ML increasing and AP decreasing when body orientation changed from 0° to 45°. This was because in the 0° (head forward) condition, the task