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Effects of visual focus and gait speed on walking balance in the frontal plane

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ABSTRACT

We investigated how head position and gait speed influenced frontal plane balance responses to external perturbations during gait. Thirteen healthy participants walked on a treadmill at three different gait speeds. Visual conditions included either focus downward on lower extremities and walking surface only or focus forward on a stationary scene with horizontal and vertical lines. The treadmill was positioned on a platform that was stationary (non-perturbed) or moving in a pattern that appeared random to the subjects (perturbed). In non-perturbed walking, medial–lateral upper body motion was very similar between visual conditions. However, in perturbed walking, there was significantly less body motion when focus was on the stationary visual scene, suggesting visual feedback of stationary vertical and horizontal cues are particularly important when balance is challenged. Sensitivity of body motion to perturbations was significantly decreased by increasing gait speed, suggesting that faster walking was less sensitive to frontal plane perturbations. Finally, our use of external perturbations supported the idea that certain differences in balance control mechanisms can only be detected in more challenging situations, which is an important consideration for approaches to investigating sensory contribution to balance during gait.

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1. Introduction

Many studies have been completed to better understand the sensory contributions to balance in standing (e.g., Goodworth & Peterka, 2010; Horak & Macpherson, 1996; Peterka, 2002), but less is known about the contribution of sensory feedback to balance in gait. One reason may be that describing walking balance is complicated by the number of variables affecting sensory feedback. For example, changes in visual focus (Hollands & Marple-Horvat, 2001; Lackner & DiZio, 1988; Patla & Vickers, 2003) and gait speed will have an impact on how sensory feedback is used. Also, during gait, the base of support changes with every step and the type of surface walked upon (Marigold & Patla, 2008; Menz, Lord, St George, et al., 2004); and changes in base of support and surface characteristics are known to affect sensory contributions to standing balance (Day, Steiger, Thompson, & Marsden, 1993; Goodworth & Peterka, 2010). Therefore, to enhance our knowledge of sensory contributions to walking balance, the current study investigates how changes in head position and gait speed influence balance responses to perturbations.

While several feedback systems may contribute to walking balance, it has been shown that visual feedback is particularly strong. Visual stimulation can dominate over proprioceptive feedback and is critical to adjust specific gait mechanics (Graci, Elliot, & Buckley, 2009; Iosa, Fusco, Morone, & Paolucci, 2012; Lackner & DiZio, 1988). Occluding different portions of the visual field, including peripheral vision, has a significant effect on gait mechanics (Graci et al., 2009; Marigold & Patla, 2008). Other studies have shown that visual stimulation can evoke body sway and increased variability during gait, especially in the frontal plane (McAndrew, Dingwell, & Wilken, 2010; O'Connor & Kuo, 2009).

Although natural visual scanning can include looking forward at stable environmental cues or looking down at the surface and feet, the relative importance of each is not well known. In particular, when balance is perturbed with a moving surface, a person may be more stable when focusing their vision downward because they can see where to place their feet relative to the surface for optimal foot placement. Foot placement in gait forms the base of support and anchoring for balance control (Osaki, Kunin, Cohen, & Raphan, 2007; Pijnappels, Bobbert & van Dieen, 2005). Also, individuals tend to look down more when walking over uneven terrain (Rietdyk & Drifmeyer, 2010) and exhibit decreased performance when the lower visual field is occluded (Marigold & Patla, 2008). In contrast, a person may be more stable if he/she focuses forward because he/she can receive visual feedback that is congruent with gravity. Stationary visual cues aligned with gravity are known to enhance balance during gait (McAndrew et al., 2010; O'Connor & Kuo, 2009) and standing in the frontal (Goodworth & Peterka, 2010; Oie, Kiemel, & Jeka, 2002) and sagittal plane (Peterka, 2002).

Another factor that can influence balance during gait is speed. There has been conflicting evidence regarding which gait speed is most stabilizing. Different relationships between gait speed and fall risk exist, with some studies showing no relationship between the two variables (Feltner, MacRae, & McNitt-Gray, 1994; Gehlsen & Whaley, 1990) and others showing that faster walking is associated with a decreased risk of falling (Lord, Lloyd, & Li, 1996; Wolfson, Whipple, Amerman, & Tobin, 1990), consistent with suggestions from Craik, Herman, and Finley (1976) and Murray (1967). In contrast, researchers have shown that gait variability is lowest (presumably most controlled) at normal walking speeds (Oberg, Karsznia, & Oberg, 1993) and others have reported that slow walking is most stable using measurements of "local dynamic stability" (Dingwell & Marin, 2006) and induced tripping in the sagittal plane (Bhatt, Wening, & Pai, 2005; Pavol, Owings, Foley, & Grabiner, 1999). Therefore, further investigation into the role of gait speed on balance is valuable; and the interaction with visual feedback may be especially important in the frontal plane because control in the frontal plane is more influenced by sensory feedback than the sagittal plane (Bauby & Kuo, 2000; O'Connor & Kuo, 2009).

In the current study, we use three gait speeds to address the question of whether visual feedback of a stable visual scene congruent with gravity is better for frontal plane balance than visual feedback of one's own lower extremities and surface. We apply continuous external perturbations to elicit reactive balance responses as stability is generally defined as the ability of a system to respond to perturbations (Dingwell & Marin, 2006; Reeves, Narendra, & Cholewicki, 2007). The different gait speeds also allow us to determine (a) if head position influences balance more at one gait speed compared to