Human Movement Science 35 (2014) 121–130

Contents lists available at ScienceDirect

Human Movement Science

journal homepage: www.elsevier.com/locate/humov

# Effects of aging on whole body and segmental control while obstacle crossing under impaired sensory conditions ☆

Alison C. Novak [a], Nandini Deshpande [b,*]

[a] Toronto Rehabilitation Institute, Toronto, ON, Canada
[b] School of Rehabilitation Therapy, Queen's University, Kingston, ON, Canada

ARTICLE INFO

*Article history:*
Available online 18 April 2014

*PsycINFO classification:*
2320
2330
2860

*Keywords:*
Aging
Obstacle crossing
Kinematics
Locomotion
Sensorimotor

ABSTRACT

The ability to safely negotiate obstacles is an important component of independent mobility, requiring adaptive locomotor responses to maintain dynamic balance. This study examined the effects of aging and visual–vestibular interactions on whole-body and segmental control during obstacle crossing. Twelve young and 15 older adults walked along a straight pathway and stepped over one obstacle placed in their path. The task was completed under 4 conditions which included intact or blurred vision, and intact or perturbed vestibular information using galvanic vestibular stimulation (GVS). Global task performance significantly increased under suboptimal vision conditions. Vision also significantly influenced medial–lateral center of mass displacement, irrespective of age and GVS. Older adults demonstrated significantly greater trunk pitch and head roll angles under suboptimal vision conditions. Similar to whole-body control, no GVS effect was found for any measures of segmental control. The results indicate a significant reliance on visual but not vestibular information for locomotor control during obstacle crossing. The lack of differences in GVS effects suggests that vestibular information is not up-regulated for obstacle avoidance. This is not differentially affected by aging. In older adults, insufficient visual input appears to affect ability to minimize anterior–posterior trunk movement despite a slower obstacle crossing time and walking speed. Combined with larger

☆ The findings were partially presented at 1st Joint World Congress of ISPGR and Gait & Mental Function Conference, Norway in June 2012.

* Corresponding author. Address: Louise D Acton Building, 31 George Street, Queen's University, Kingston, ON K7L 3N6, Canada. Tel.: +1 613 533 2916; fax: +1 613 533 6776.
*E-mail address:* nandinijd@yahoo.com (N. Deshpande).

http://dx.doi.org/10.1016/j.humov.2014.03.009
0167-9457/

medial–lateral deviation of the body COM with insufficient visual information, the older adults may be at a greater risk for imbalance or inability to recover from a possible trip when stepping over an obstacle.



## 1. Introduction

The ability to safely negotiate obstacles is an important component of independent and safe mobility, requiring adaptive locomotor responses to maintain dynamic balance. It follows that planning, organization and generation of appropriate motor responses to facilitate dynamic equilibrium is required for successful task completion. Such control necessitates sensory information from the visual, somatosensory and vestibular systems. Failure in one or more of these systems or their integration can place unique constraints on the postural control system (Horak, 2006).

Aging results in generalized decline in individual sensory functions and the ability of the central nervous system to integrate sensory information through reweighting the gain of the individual systems (Mozolic, Hugenschmidt, Peiffer, & Laurienti, 2012). Lord and Dayhew (2001) have identified reduced visual depth perception and contrast sensitivity as one of the strongest risk factors for multiple falls in community-dwelling older adults. The proactive or anticipatory control afforded by an intact visual system provides a plausible explanation why, as it allows for the type and extent of balance threats to be recognized early for appropriate modifications to the ongoing behavior (Frank & Patla, 2003; Mohagheghi, Moraes, & Patla, 2004). Physiological changes in the vestibular system (i.e., loss of vestibular nerve fibers, loss of vestibular hair cells) also occur with aging and may reduce the capacity to correctly detect head and trunk position and motion in space, limiting the ability to maintain a stable reference frame from which to generate postural responses (Pozzo, Levik, & Berthoz, 1995; Shumway-Cook & Woollacott, 2007).

Deterioration in sensory function is proposed to reduce the ability to compensate for missing or conflicting sensory inputs for maintaining balance (Mozolic et al., 2012). Subsequently, older adults demonstrate decline in balance control during standing and require longer duration to complete mobility tasks when sensory input is manipulated (Deshpande, Novak, & Patla, 2006; Horak, Nashner, & Diener, 1990; Novak & Deshpande, 2011). During goal directed locomotion in an uncluttered environment, Deshpande and Patla (2007) have shown that compared to young adults, the ability of the older adult to down regulate sub-optimal vestibular input is affected despite availability of normal vision. The effects of aging on a possible reweighting of vestibular information for more challenging locomotor tasks, such as obstacle crossing, however, are not known.

To achieve successful obstacle avoidance, the body's center of mass (COM) has to be controlled within a narrow base of support defined by a single limb in contact with the ground, as the contralateral leg swings concurrently over the obstacle. To accommodate this challenge, older adults adopt a slower more conservative strategy compared to their younger counterparts, reflected by reductions in crossing velocity (Chen, Ashton-Miller, Alexander, & Schultz, 1991). Despite this, the maladaptive aspects of the conservative strategy, such as shortened landing distances, lack of adaptation in trunk range of motion (ROM) and COM displacement within a narrow base of support could potentially place older persons at risk for imbalance when stepping over an obstacle (Hahn & Chou, 2004; Lowrey, Watson, & Vallis, 2007). To date only one study has investigated visual–vestibular interaction on locomotor adaptations during obstacle crossing in healthy young adults (McFadyen, Bouyer, Bent, & Inglis, 2007). The authors reported a complex visual control but a lack of differences with deteriorated vestibular input, suggesting that vestibular information was not up-regulated for obstacle crossing when compared to level walking. In addition, study of the segmental control during obstacle crossing (i.e., individual control of the head and trunk segments) demonstrates significant deviations in frontal plane motion caused by deteriorated vestibular information, with little effect on sagittal plane