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Full Length Article

Older adults exhibit altered motor coordination during an upper limb object transport task requiring a lateral change in support

Andrew H. Huntley [a], John L. Zettel [a], Lori Ann Vallis [a,b,*]

[a] Human Health and Nutritional Sciences, University of Guelph, Canada
[b] Schlegel-UW Research Institute for Aging, Kitchener, ON, Canada

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ABSTRACT

Investigating an ecologically relevant upper limb task, such as manually transporting an object with a concurrent lateral change in support (sidestepping alongside a kitchen counter), may provide greater insight into potential deficits in postural stability, variability and motor coordination in older adults. Nine healthy young and eleven older, community dwelling adults executed an upper limb object transport task requiring a lateral change in support in two directions at two self-selected speeds, self-paced and fast-paced. Dynamic postural stability and movement variability was quantified via whole-body center of mass motion. The onset of lead lower limb movement in relation to object movement onset was quantified as a measure of motor coordination. Older adults demonstrated similar levels of stability and variability as their younger counterparts, but at slower peak movement velocity and increased task duration. Furthermore, older adults demonstrated asymmetrical motor coordination between left and right task directions, while younger adults remained consistent regardless of task direction. Thus, older adults significantly modulated movement speed and motor coordination to maintain similar levels of stability and variability compared to their younger counterparts.

1. Introduction

The ability of an older adult to complete activities of daily living (ADL) is central for independence. Unfortunately, the execution of many complex ADLs may place an older adult at a higher risk of falling. The events preceding a fall are diverse; one being incorrect weight transfers as a common cause of falls in both community dwelling older adults (Berg, Alessio, Mills, & Tong, 1997) and older adults residing in long term care facilities (Robinovitch et al., 2013). Previous literature has shown that carrying an object, reaching, or leaning are related to a substantial proportion of falls (Nachreiner, Findorff, Wyman, & McCarthy, 2007). A reduced ability to maintain lateral balance is related to falls during quiet sway (Maki, Holliday, & Topper, 1994) and has been used to differentiate between low and high fall risk older adults (Williams, McClenaghan, & Dickerson, 1997). Overall, older adults may be at increased risk of instability and ultimately falling when performing movements involving the lateral plane of motion (Rogers & Mille, 2003), although at present we do not know if stability is further challenged when concurrently performing a secondary upper body motor task.

Studies that have focused on reaching and postural control in older adults have primarily done so with a fixed base of support (BOS). These include clinical tasks like the functional reach (FR) balance test in healthy older adults (Jonsson,

* Corresponding author at: Human Health and Nutritional Sciences, University of Guelph, 50 Stone Road East, Guelph, Ontario N1G 2W1, Canada.
E-mail address: lvallis@uoguelph.ca (L.A. Vallis).

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Henriksson, & Hirschfeld, 2003), as well as clinical populations such as stroke (Smith, Hembree, & Thompson, 2004) and Parkinson's disease (Behrman, Light, Flynn, & Thigpen, 2002) patients. Lateral FR balance tests have also been investigated in older adults (Takahashi et al., 2006). Experimental paradigms have also assessed balance in older adults when reaching forward, both within an arm's length (Bleuse et al., 2006) and beyond (Paizis, Papaxanthis, Berret, & Pozzo, 2008). However, to our knowledge no studies to date have examined reaching to transport an object with a lateral change in support in an ecologically valid setting. This type of task is directly related to many activities of daily living (e.g. transferring an object in a kitchen along the countertop that requires a side step) and thus may provide improved insight into day-to-day balance control in a population with an increased falls risk due to age.

Furthermore, studies examining reaching in older adults with a fixed base of support rarely measure dynamic postural stability. The majority of FR tests rely on the displacement between the start and end points of the reaching limb (Bennie et al., 2003; Weiner, Duncan, Chandler, & Studenski, 1992). Past work has also reported details about the center of mass (COM) and center of pressure (COP) relationship (Wernick-Robinson, Krebs, & Giorgetti, 1999), and providing measures of COP to infer stability limits (Jonsson et al., 2003), although none of these specifically quantify the control of the COM or COP in relation to the BOS. Other reaching studies have examined aging effects on anticipatory postural adjustments made preceding the reach (Bleuse et al., 2006), and have reported COM and COP displacement values (Paizis et al., 2008) as a balance assessment measure. COP trajectory smoothness, calculated from normalized jerk (the 4th derivative of displacement) of the COP in both anterioposterior and mediolateral directions has also been used to infer postural stability in older adults when performing a reaching task (Huang & Brown, 2013). While these measures may provide valuable information about how an older adult is executing a given task, they do not account for how an individual controls COM or COP relative to the BOS, and may not fully quantify balance control when a lateral change in support is involved in the task. Previous work by Hof, Gazendam, and Sinke (2005) proposed a model of Time-to-Contact (TTC) to quantify whole body stability during complex, dynamic tasks. In brief, the TTC measure quantifies the time it would take for the COM to travel beyond the BOS. It can be utilized in single or dual stance support as it is dependent on simultaneously capturing the BOS in addition to the COM, and has been shown to be an important control parameter of the central nervous system (Hasson, Van Emmerik, & Caldwell, 2008).

While quantifying stability is important when assessing balance control during a given task, variability is also a discerning measure. Huang and Ahmed (2011) have shown that older adults can exhibit a "trade-off" of maneuverability in favour of stability during complex tasks; stability may be prioritized to maintain balance, but this prioritization may result in their inability to safely adapt to any ongoing task to environmental constraints. Quantifying variability in addition to stability during the execution of complex tasks ensures that any trade-offs between these factors is captured. Details regarding this trade-off is critically important; if an individual cannot adapt task performance to altered or changing environmental and/or task circumstances, they may place themselves at risk of being unable to successfully react to a perturbation to the system that was not planned for, which ultimately could lead to a destabilizing event and loss of balance.

The primary purpose of the current study was to examine age related changes in stability and variability of balance control when performing a dynamic, change in support task that is representative of a functional activity of daily living. Our chosen task involved moving an object, located at standard countertop height off the ground, 1 m to the right or left, thus requiring one complete lateral step to complete the task. We hypothesized that whole body stability would be decreased in older adults compared to their younger counterparts at both the initiation of the lateral step and the completion of the first lateral step when required to reach and then transport an object between locations. Furthermore, we hypothesized that older adults would demonstrate higher inter-trial variability compared to young adults, indicating a greater inconsistency in the execution of this complex motor action. A secondary purpose of this study was to determine the effect of instructed task-speed on stability and variability, as falls by older adults have been reported to occur when older adults report feeling rushed or are in a rush to complete a task (Nachreiner et al., 2007). Therefore, we hypothesized that older adults would have decreased stability and increased variability when performing the task at a fast-pace.

2. Methods

2.1. Participants

Participants were recruited from the University of Guelph and surrounding community. In total, nine healthy young adults (5 females and 4 males) and eleven community dwelling healthy older adults (5 females and 6 males) volunteered to take part in the current experimental protocol (see Table 1 for subject characteristics). All participants completed the Falls Efficacy Scale (FES; Table 1) (Kempen et al., 2008) to characterize fear of falling and the Waterloo Handedness Questionnaire (Bryden, Pryde, & Roy, 2000), to ensure all participants were right handed. Furthermore, all participants were self-reported right leg dominant, free of any self-reported neuromuscular or skeletomuscular diseases, and did not take medication that would affect executive function, cognition, or motor control. All community dwelling, healthy older adults who participated in this study had never experienced a fall. In compliance with University ethics guidelines for the current study, all older adults completed the Mini Mental Status Exam (MMSE) (Cockrell & Folstein, 2002). The MMSE was strictly used to ensure competency in giving informed consent for the current study; a score of 25 or less was used as the exclusion criteria. This study was approved by the University of Guelph human Research Ethics Board.