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Manual Tracking Impairs Postural Stability in Older Adults

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Title: Manual Tracking Impairs Postural Stability in Older Adults

Short Title: Manual Tracking and Postural Stability

Abstract:

Introduction: Older adults show increased postural sway and a greater risk of falls when completing activities with high cognitive demands. While dual-task approaches have clarified an association between cognitive processes and postural control, it is unclear how manual ability, which is also required for the successful completion of cognitively-demanding tasks (e.g. putting a key into a lock), affects this relationship.

Methods: Kinematic technology was used to explore the relationship between postural sway and manual control in healthy younger and older adults. Participants remained standing to complete a visual-motor tracking task on a tablet computer. Root Mean Square tracking error measured manual performance, and a balance board measured deviations in Centre of Pressure as a marker of postural sway.

Results: Older adults displayed poorer manual accuracy and increased postural sway across all testing conditions.

Conclusions: Cognitive capacity can interact with multiple task demands, and in turn affect postural sway in older adults. Improving our understanding of factors that influence postural control will assist falls-prevention efforts and inform clinical practice.

Keywords: Posture; Stability; Falls; Older Adult; Kinematics; Motor Control

Introduction

Falling is commonplace in the older adult community, with 35% of people aged 65-years and over experiencing at least one fall per year (Department of Health, 2009). This can have serious personal implications for the faller (e.g. reduced quality of life, loss of confidence, fear of future falls) – 80% of women, for example, would actually prefer death over the loss of autonomy that can result from a serious fall (Salkeld et al., 2000). The UK National Health Service also bears the substantial cost of services that frequent falls incur, such as funding emergency responses, inpatient care, surgical interventions as well as rehabilitation. There are, therefore, many reasons that the risk factors associated with falling are a topic of key interest, both in the health and social care sectors. Prevention and early intervention strategies can be better informed by our knowledge of what causes some older people to fall more often than others.

Extensive research has identified a series of risk factors underlying falls (e.g. Gale et al., 2016), and we know many of the neuro-muscular functions that play an important role in an individual's ability to maintain stable posture, and thereby prevent the likelihood of a fall. One example is the relationship between cognition (i.e. the mental processes involved in the acquisition and manipulation of information in order to produce an appropriate motor response) and postural control. Studies using 'dual task' paradigms have found that when older adults are faced with completing a cognitively-demanding task, they are more likely to show signs of impaired balance (e.g. Huxford et al., 2006). Older adults are also more likely to be at risk of a fall when carrying out activities with a high cognitive load (Mignardot et al., 2014). What is currently unclear, however, is the extent to which manual control (the positional manipulation of hands during a task) might also contribute to instability, particularly when performing a task that requires a combination of cognitive, motor and postural processes. Daily activities involving the completion of concurrent tasks, often demand cognitive resources, while at the same time requiring a person to produce accurate manual control (e.g. inserting, and then turning, a key inside a lock). Given that older people naturally experience a decline in motor performance (Raw et al., 2012a; Raw et al., 2012b; Raw et al., 2014; Raw et al., 2016.), it is important that we understand the extent to which manual tasks can affect postural stability. This knowledge will contribute to the body of evidence that currently informs falls prevention and rehabilitation schemes across the health and social care sectors.

Understanding Falls

Recurrent falls in older adults are often a manifestation of impaired postural control (Woollacott and Shumway-Cook, 2002), as indexed by 'Centre of Pressure' (COP) measures of postural sway (Lin et al., 2008; Kouzaki and Shinohara, 2010). Nonetheless, the mechanisms that underlie impairments in postural control are currently unclear; and it is highly likely that falls are multifactorial, resulting from a number of specific issues ranging from personal history (i.e. number of previous falls), physiological strength (e.g. extent of muscle wastage), drug intake (e.g. use of sedative medication) and visual disturbances (Department of Health, 2009). Furthermore, falls occur more often in people with reduced cognitive capacity (Rubenstein, 2006; Muir et al., 2012), and a growing body of evidence has consistently reported a relationship between cognition and falls – including studies using behavioural, electroencephalography, transcranial magnetic stimulation and imaging methods (e.g. Papegaaij et al., 2014). For example, Papegaaij et al. (2014)

identify that imaging data suggests that supraspinal structures of the brain (e.g. frontal, parietal, and motor cortices) are involved in, and thus important for, the control of posture (e.g. Papegaaij et al., 2014). Age-related cognitive decline has been documented in such supraspinal cortical areas related to posture (Kouzaki and Masani, 2012, Papegaaij et al., 2014), suggesting a relationship between an individuals' cognitive abilities and their likelihood to fall as a consequence of poor postural control.

The relationship between cognitive function and postural control has been explored predominantly with the use of 'dual task' paradigms (Woolacott and Shumway-Cook, 2002), where cognitive and postural tasks are carried out concurrently. One idea has been to use secondary cognitive tasks to improve postural control; shifting an individual's attention away from their postural stability and using this distraction to reduce sway. Note that this approach uses simple cognitive tasks (that introduce little additional cognitive load) but has been shown to lead to more stable posture in healthy younger and older populations (Melzer et al., 2001; Huxford et al., 2006) as well as some clinical groups (e.g. stroke patients; Hyndman et al., 2009). When the cognitive demands of the task are increased, however, older adults in particular show increased COP displacements, indicating a reduced capacity to maintain a stable posture (for example, Huxford et al., 2006; Liu-Ambrose et al., 2009; Hsu et al., 2012; Schaefer et al., 2014). Not only does an increased cognitive load often yield greater postural sway in older adults, it can also impede performance of the cognitive task itself (for example, Maylor et al., 2001; Huxford et al, 2006).

Older adults' reduced ability to avoid excessive postural sway when performing a cognitively-demanding secondary task highlights the importance of cognition in controlling balance in daily activities. Unsurprisingly then, some studies have identified a relationship between falls history and performance within dual-task settings involving posture and cognition (Makizako et al., 2010; Mignardot et al., 2014). Some literature has found that cognitive tasks can either benefit or attenuate balance control, depending whether task difficulty is low or high, respectively (Riley et al., 2003). It is not clear, however, whether an individual will attempt to maintain performance on a cognitive task at the cost of balance or vice versa. There is some evidence for 'posture first' control strategies, where older adults will neglect other tasks that are competing for cognitive resources in order to prevent a loss of postural control (Lundin-Olson et al., 1997; Lion et al., 2013). In contrast a 'posture second' tactic has sometimes been observed which is particularly problematic since this places the individual at a risk of falling through their prioritisation of the secondary task over the maintenance of a stable stance (Huxford et al., 2006; Harley et al., 2009; Yogev-Seligmann et al., 2012; Holtzer et al., 2014).

There is no doubt that many of the cognitive tasks used within dual-task experiments map onto the type of activities that older adults undertake whilst standing upright (e.g., recalling items on a shopping list whilst standing in a supermarket aisle). However, many real life concurrent tasks involve less abstract cognitive processes: a simple example would be when an older adult must allocate visual attention and control their hand in order to use a key to open their front door. There are anecdotal reports of older adults falling in these kind of circumstances, where additional fine visual-motor demands are required (e.g., putting the key in the lock or opening a garden gate). It is therefore surprising that there has been a lack of investigations (none as far as we are aware), into the impact of the sensorimotor processing associated with precision manual control on postural stability. This may be due in large part to the technical difficulties involved in measuring performance on a manual task, while concurrently assessing postural stability in a community setting (i.e. where reasonable numbers of representative older adults can be tested; in contrast to the generally high performing older participants capable of attending research laboratories). Regardless of why there is a paucity of studies, it is disappointing that the relationship between manual and postural control is not better understood, given the numerous activities of daily living that involve the synergistic linking of these processes. It is especially important to determine the impact of performing visual-motor control functions on postural stability, and in turn, the possible relationship between such tasks and the likelihood of falling, especially since we already know that a significant decline in motor skill is expected as people get older (Raw et al., 2012a).

In order to examine the above-mentioned issues, the present study examined the relationship between postural sway and visual-manual task performance in healthy young individuals, and a group of community dwelling older adults. We exploited recent technology emerging from our multidisciplinary laboratories that can be used to obtain objective measurements of posture concurrently with precise markers of manual control (Flatters et al., 2014). Primarily, we aimed to identify whether dual-task interference occurs for older adults when performing a manual control task. We also looked for patterns of 'task prioritisation' to see whether varying the visuomotor task difficulty would differentially impair postural stability, thus determining the extent of compensatory trade-offs that occur between separate tasks conducted concurrently in older people.

Method

Participants in the Standing Condition

Eighty-two participants were split into two groups on the basis of age, where 40 people were classed as 'young' (mean age = 23.4, SD = 4.14; all participants ≤35 years; 2:1 Female:Male), and 42 people were classed as 'older' (mean age 75.5, SD 8.55; all participants ≥65 years; 6:1 Female:Male). The young adults were mainly recruited from a university student population, whereas the older group comprised of individuals who were living independently at the time of the study and who were recruited to the study through social groups at local community centres. Both groups of participants were assessed for normal or corrected to normal vision using a Snellen eye chart, with a minimum score of 6/12 (20/40) eyesight required for participation. To confirm that older adult participants were in good health, a detailed medical history was obtained from the older adult group by the research team, including falls history and current medication. 12 older participants in the standing group reported having had a fall in the last 2 years. Care must be taken when interpreting such reports, however, since there is no way to verify/validate these reports, and we cannot be sure that some individuals forgot that they had a minor trip over this period. Even if we accept the reports, the reason underlying a fall and the severity of each fall can vary hugely (e.g. even a young hill walker may trip when tired and walking on a rugged path). To measure how much concern the group had about falling we used the Falls Efficacy Scale – International (FES-I) a scale using a four point rating system (2 representing no concern to 4 representing high concern) over a series of 16 questions (so scores could range from 16-64). The median FES-I score for the older standing group was 23 (min = 16; max = 44), with the majority of participants (N = 33) having low or moderate concern over falling (as defined by Yardley et al. 2005). The Addenbrooke's Cognitive Examination Revised (Mioshi et al., 2006) was administered to measure cognitive capabilities with a mean score of 85. Two older adult participants did not wish to complete certain elements; one declined to complete the ACE-R and the other declined to provide a medical history.

Participants in the Seated Condition

Two separate groups of Younger and Older participants (independent of the standing groups) were tested to provide a measure of tracking performance when seated: 80 participants were in the Older Adult Seated Group (mean age = 75.6 years, SD 9.1; 2:1 Female:Male) and 231 participants formed the Younger Adult Seated Group: (mean age: 20.2 years, SD = 3.5; 2:1 Female:Male). The older adults had no reported history of neurological disease, motor disorders or ophthalmological deficits, but no detailed medical history was taken.

Ethics

Ethical approval was provided by the University of Leeds Research Ethics Committee (reference number 11-0098, dated 20/5/2011), in accordance with the British Psychological Society Ethical guidelines and the Declaration of Helsinki.

Procedure and Apparatus

Visuomotor Control Task

A visuomotor control task was created using ‘KineLab’ (Culmer, et al., 2009), easily-accessible kinematic software which is installed on a Toshiba digitizing tablet portable computer (Toshiba Portégé, 14″ screen: 260 × 163 mm, 1,280 × 800 pixels, 32 bit colour, 60 Hz refresh time) and captures a sophisticated series of outcome measures. The tablet’s screen provides a horizontal surface (in landscape orientation) similar to writing with a pen and paper using a stylus as an input device. The testing lectern for the laptop was measured and adjusted for participant height; the lower lip of the lectern was the same height as the participant’s elbow. Participants interacted with the tablet using a handheld stylus (stylus length = 150mm; nib length =1mm) held by their dominant hand. This approach to capturing high-quality objective data for the measurement of manual control has been developed through earlier work of our research team, where the software has been found capable of distinguishing objectively and reliably between poor and proficient motor performance in populations of all ages (i.e. from children to older adults; e.g. Raw et al., 2012; Flatters et al., 2011). For the task in the present study, participants were asked to keep the handheld digitised stylus on a green dot (dot diameter = 10mm) which moved around the screen along an invisible figure-of-eight path (Figure 1). The dot progressively increased in speed from a slow (i.e. time to complete one figure-of-eight = 16sec), to medium (i.e. time to complete one figure-of-eight = 8sec) and then a fast pace (i.e. time to complete one figure-of-eight = 4sec). Each of the speed conditions repeated for three figure-of-eights, before the next speed began (i.e. total of nine figure-of-eights to track). Tracking error was analysed as a marker of manual control, by calculating the Root Mean Square positional Error (RMS; mm, sampled at 60Hz) between the moving target and the handheld stylus throughout the task.

- Insert Figure 1-

Concurrent Postural Stability Measures

A Nintendo Wii balance board (a valid tool for assessing standing balance; Clark, et al., 2010) with a sampling frequency of 60Hz, linked to a laptop via a Bluetooth connection, was used to capture the deviation in COP. Data were collected on a Toshiba laptop through a customised postural sway program (Flatters et al., 2014) using LabVIEW (National Instruments) script. We measured path length of COP over time (mm) for use as our marker of postural sway. Before beginning the measurement of postural sway, each participant was checked for appropriate shoes (defined as comprising flat soles with support provided around the foot via straps or laces). A height-adjustable metal lectern was used to support the tablet laptop; the height of which was adjusted for each participant (NB. the lower side of the lectern was approximately the same height as the participant's elbow; see Figure 2 for an image of the full task set-up). Postural stability was examined by splitting the experiment into three 'tests' (i) the participants stood on the board with their hands by their sides and their eyes closed for 30sec; (ii) the participants stood on the board once again, but this time they were asked to concentrate on a static circular target on the tablet computer screen (dot diameter = 10mm) for a further 30sec; (iii) the participants were required to concurrently maintain their stance while performing the visuomotor control task. The third and final test was repeated under two different stance conditions, firstly with the feet firmly together, and secondly with the feet apart (NB. participants were asked to stand with feet ‘comfortably separated’ and arms by their sides)[1]. As no differences in COP were observed between the stance conditions, results for each participant have been collapsed across the two types of stance.

The whole process, including all three tests (i.e. standing with eyes closed, standing while fixating on a dot, standing while completing the visuomotor control task) was repeated twice, with each round taking approximately 3min. Participants were asked to remain as still as possible and not speak during the timed trials, but these instructions did not request that participants prioritised either task during the testing. No explicit instruction was given to participants with regards to their arm positioning during the task, though participants were asked to use their preferred hand. The researcher who was present to oversee the testing sessions, noted that the majority of participants rested their non-preferred hand by their side for the completion of the visuomotor task, while the preferred hand was held so that the arm hovered above the tablet PC (i.e. to avoid skin contact with the screen; see Figure 1).

- Insert Figure 2-

[1] The order of these three tests (i.e. standing with eyes closed, standing while fixating on a dot, and standing while completing the visuomotor control task) was not counterbalanced; hence all participants underwent the testing conditions in the same order. We did not feel it necessary to vary the order of tests between participants because there is no evidence to suggest that standing for two sets of 30sec was likely to interfere with manual task performance.

Data Analysis

The three outcome measures of interest were:

1. Centre of Pressure (CoP; mm) for Postural Sway: Determined according to the digitally recorded path length (mm) from the balance board. More movement when standing on the balance board led to higher path length scores that indicated greater postural sway.

2. Root Mean Square Tracking Error for Manual Control (RMS; mm): When the concurrent visuomotor control task was performed, RMS tracking error (the distance between the moving target and the handheld stylus, sampled at 60Hz) was measured. This was calculated for each trial, separated across the different speed conditions (slow, medium and fast). Higher RMS tracking error scores reflected the stylus being further away from the moving target during trials, and hence indicated poorer manual control.

3. Proportional Dual Task Costs (pDTC): A secondary measure was calculated to take account of the baseline sway for each individual in each age group (Quiet Standing with eyes open, COP_{QS}). This controls for sway that was present in all conditions, in order to evaluate the relative increase in sway caused by the secondary task. The pDTC measure was calculated separately for each participant when manually tracking targets at each speed ($_{spd}$) as follows:

   $$pDTC_{spd} = (CoP_{spd} / CoP_{QS}) -1 / 100$$

   The pDTC calculations produce a score on a scale anchored to 0 (indicating no difference in sway compared to quiet standing) whereby positive pDTC values indicate more sway relative to quiet standing (100% would indicate a path length twice as long as baseline) whereas negative values would indicate reduced sway compared to quiet standing.

Mean COP Path Length,RMS Tracking Error and pDTC were calculated for each participant in each age group. Formal statistical analyses were performed on these data using separate mixed ANOVAs.. Greenhouse-Geisser estimates of sphericity (ε) are reported where degrees of freedom (DF) have been adjusted (unadjusted DF values are given throughout for ease of interpretation).

Results

Participant Characteristics

Standing participants (N = 82) completed all of the testing conditions, twice each. No adverse clinical events occurred during the experimental period. For technical reasons, tracking data failed to record some of the visuomotor control task conditions for four of the older adults, and these were therefore absent from the statistical analysis. The postural sway data did not record for two of the older adults in some of the conditions, and so these data were also excluded from the analysis. There were no technical difficulties reported for the Seated group, and all 80 of the Older Adults and the 231 Younger adults were able to take part in the testing conditions.

Postural Sway Results

No-Visuomotor Task Conditions (Standing Condition)

The difference in postural sway between the young and older adult groups in the first two no-visuomotor task conditions (i.e. standing with eyes closed, standing while fixating on a dot; Figure 3) was analysed using the CoP movement data (mm) from the balance board. A mixed condition (eyes closed, eyes fixated) x age group (young, old) ANOVA revealed a significant main effect of condition ($F(1, 74) = 68.22$, $p<0.001$, $\eta^2_p = 0.48$) and a significant main effect of age group ($F(1, 74) = 10.58$, $p<0.01$, $\eta^2_p = 0.13$), with all participants showing greater sway when standing with their eyes closed, and older adults displaying greater postural sway both with their eyes closed and when standing while fixating on a visual target. There was also a small but significant condition × age group interaction, ($F(1, 74) = 5.04$, $p < 0.05$, $\eta^2_p = 0.6$), driven by a larger increase in postural sway for the older group when their eyes were closed.

- Insert Figure 3 -

Visuomotor Task Condition (Standing Condition)

For the data collected in the test where participants were required to complete a visuomotor control task while maintaining a stable stance on the balance board, statistical analyses were performed firstly on COP Path Length and pDTC measures of postural sway, and then on RMS Tracking Error for the examination of manual control.

The COP Path Length data for each age group across all tracking speeds is shown in Figure 4a. A tracking speed (slow, medium, fast) x age group (young, old) mixed ANOVA identified a main effect of tracking speed, ($F(2, 148) = 22.27$, $p<0.001$, $\eta^2_p = .23$, $\varepsilon = .56$), and age group, ($F(1, 74) = 26.47$, $p < 0.001$), on postural sway (but no interaction; $F(2, 148) = 1.46$, $p=0.236$, $\eta^2_p = .019$) whereby faster tracking and older age led to greater sway. The Proportional Dual Task Costs (pDTC) relative to quiet standing (Figure 4b) were calculated to take account of the baseline sway for each age group (standing eyes open). There was still a significant increase in postural sway for faster target speeds ($F(2, 148) = 21.78$, $p<0.001$, $\eta^2_p = .23$, $\varepsilon = .56$), and older adults exhibited greater proportional increase in sway during dual-task conditions (i.e. when completing a visuomotor task at the same time as standing still; $F(1, 74) = 17.23$, $p< 0.001$, $\eta^2_p = .19$); but again there was no interaction ($F(2, 148) = .795$, $p=.387$, $\eta^2_p = .011$, $\varepsilon = .56$) .

Analysis of the tracking data from the visuomotor control task (as indexed by the RMS Error; mm) varied between age groups and tracking speed conditions (Figure 4c). A tracking speed (slow, medium, fast) x age group (young, old) mixed ANOVA showed a significant effect of target speed on participant performance error ($F(2, 148) = 2925.13$, $p<0.001$, $\eta^2_p = .98$, $\varepsilon = .91$) and a significant effect of age group, (F

(1, 74) = 27.86, p <0.001, η^2_p= .27), with older adults reliably producing more error than young adults across all speeds of target tracking. In this case there was also a significant interaction between tracking speed and age group (F (2, 148) = 9.45, p<0.001, η^2_p= .11, ε = .91) indicating that older adults were more affected than the young group, by the increasing demands of a concurrent visuomotor task – the older the participant, the harder it was to keep up with the faster pace of the moving dot.

Task Prioritisation (Standing Versus Seated Condition)

To determine whether participants were prioritising manual control over postural stability in the visuomotor task (i.e. whether tracking performance was affected by standing still on the balance board), we examined tracking data from a different Seated group of younger and older participants who completed the same visuomotor control task while in a Seated position. A mixed model tracking speed (slow, medium, fast) x stance group (between group: standing, seated) x age group (between group: young, old) ANOVA showed a significant main effect of tracking speed, with motor accuracy decreasing with heightened task demands (mean RMS for the slow speed condition = 7.95mm, SD = 0.23; mean RMS for the fast speed condition = 25.34mm, SD = 0.45; F (2, 768) = 1742.653, p<0.001, η^2_p= 0.82, ε = .75). This effect was likely driven by the poorer tracking performance of the older adults, who were less accurate overall (between group effect of age; F (1, 384) = 39.07, p < 0.001, η^2_p = .092) and less capable of maintaining tracking accuracy in the fastest tracking speed condition (interaction between tracking speed condition and age; F (2,768) = 13.192, p < 0.001, η^2_p = .03).

Critically, a significant between-group effect of stance condition (i.e. Standing versus Seated visuomotor tracking), suggests that standing does negatively impact upon visuomotor attentional resources ($F(1, 384) = 15.58$, $p<0.001$, $\eta^2_p = .039$). Root Mean Square Tracking Error (RMS) scores were significantly higher when participants completed the task standing up (mean RMS for the Standing condition = 16.81mm, SD = 0.48), compared to when there was the added stability provided by the action of sitting on a chair when tracking (mean RMS for the Seated condition = 14.65mm, SD = 0.27). Furthermore, statistical analyses revealed that this difference in motor accuracy between the Standing and Seated conditions was driven mainly by the slow and medium speed tracking trials. The significant interaction between tracking speed and stance group ($F(2, 768) = 50.49$, $p < 0.001$, $\eta^2_p = .12$) suggests that RMS tracking scores performance is similar during fast speed tracking for the Standing (mean RMS for fast speed tracking = 25.04mm, SD = 0.77) and Seated (mean RMS for fast speed tracking = 25.64mm, SD = 0.44) groups. We tested this claim by running a post-hoc comparison of Standing and Seated data for the fast speed tracking condition only – this was non-significant ($t(386) = 0.74$, $p >0.05$). There are two ways in which to interpret this finding (i) the lack of difference may simply reflect the difficulty of the fast tracking condition, in that neither age group is able to use the stability provided by seating support to aid their tracking precision, or (ii) this outcome could be due to a shift in task priority towards maintaining fast tracking performance at the expense of increased sway.

- Insert Figure 4 –

Discussion

In situations where multiple task demands require an individual to use both cognitive and motor resources in order to carry out an activity, it has been observed that older adults show signs of increased postural sway, and possess a higher risk of falls when carrying out these activities (e.g. Huxford et al., 2006; Mignardot et al., 2014). This strong association between cognition and the control of balance has been noted in many previous dual-task studies, though at present, no research has examined how manual control can interact with this relationship when a task demands a significant degree of motor ability. We carried out an experiment to address this question, asking a group of healthy younger and older participants to concurrently complete a visuomotor control task at the same time as maintaining a stable standing posture.

The results of the present work firstly showed that posture was most stable when participants were asked to stand and fixate a stationary target, whereas an expected increase in postural sway occurred when eyes were closed. Sway was at its greatest while standing with eyes open and performing a concurrent visuomotor control task, and the most challenging visuomotor conditions (i.e. fast speed condition) caused the greatest sway. When comparisons were made between the younger and older age groups, there was a clear difference in both postural sway and manual control performance measures, with older adults performing worse, regardless of whether they were just asked to stand, or to stand and concurrently carry out a visuomotor task. Increased complexity of the visuomotor control task (as evident in increasing tracking speed conditions), also affected older adults' ability to maintain a stable posture, and avoid errors in tracking performance.

Increased visuomotor control task demands did not affect the younger adults to the same extent as in the older group (Figure 4B). Dual-task interference occurred for older adults with increasing levels of postural sway and tracking error as task difficulty increased. When comparing manual control between standing and seated conditions, it was also apparent that the increased stability (and hence reduced postural sway) provided by the act of sitting on a chair to complete the visuomotor tracking task, was sufficient to improve manual performance when task demands were low. In difficult manual control conditions (i.e. the fast speed condition), however, sitting down had no benefit over standing, in terms of helping participants to perform well on the tracking task.

A decline in postural control with increasing age will undoubtedly put older adults at risk of falls (e.g Mignardot et al., 2014); and this seems to be especially true under certain high demand situations such as undertaking a complex concurrent manual task. The results from the visuomotor control task showed a clear increase in postural sway for the older adult group that accompanied increased task difficulty. During the fast visuomotor tracking condition, the older adults are being pressured by temporal task constraints with the heightened speed of the moving target. The older adult group displayed poorer tracking performance compared to the young which may be linked to age-related changes in fine motor skills (Contrearas-Vidal et al., 1998; Raw et al., 2012). Older adults' deteriorating performance becomes disproportionally worse than the young as the task becomes more demanding. Previous research has observed older adults adopting either ‘Posture First’ (Lundin-Olson et al., 1997; Lion et al., 2013) or ‘Posture Second’ strategies (Huxford et al., 2006; Harley et al., 2009; Yogev-Seligman et al., 2012; Holtzer et al., 2014) during the completion of tasks which concurrently require cognitive, visuomotor and postural resources. A ‘Posture First’ strategy would have led the older adults to perform poorly on the concurrent task, whilst maintaining good posture to prioritise safety. In contrast a ‘Posture Second’ strategy would have led the older adults to perform well at the concurrent task but increase their postural sway. Our present study identified no clear systematic prioritisation strategies – the older adults performed worse in the visuomotor task when standing than when seated, but as task complexity increased so did sway. These findings support the resource competition model of dual-tasking (Huxhold et al., 2006) since neither the concurrent task nor posture was fully maintained. The fact that older adults failed to prioritise the maintenance of stability over the completion of a concurrent action, highlights that our task contains the components of a potentially hazardous scenario that could lead to an increased risk of falls.

Due to the complex nature of age-related decline, not all older adults will experience the same change in postural control systems, or deterioration in cognitive and motor function. We observed some older adults that functioned at levels comparable with the young age group, while others showed significant detriment to their stability and motor skills. Certain older adults are more at risk of poor postural control and have a higher chance of falling, especially if cognitive impairment is present (Rapp et al., 2006). It is vital for us to be able to identify such individuals, based on their personal risk. The diagnosis of cognitive impairment could prove an important early intervention point to begin prevention work to assist with balance deterioration. For older adults living independently, tasks with visuomotor attentional components, such as unlocking doors or meal preparation performed alongside daily activities, could lead to situations in which increased sway could occur.

It could be argued that even though the tracking task used required dynamic arm-movements, in terms of the postural demands on participants these tasks could be considered fairly static, because they involved no large requirements to shift the body mid-line. The tasks used here were chosen purposely to increase the visual-motor demands without drastically altering the stance of the participants. There are of course many real-world tasks that place greater dynamic demands on the postural system (e.g. reaching out to connect a plug into an electricity socket) and activities involving such body mid-line shifts can also cause loss of balance and falls. The present work highlights that independent of body-line shifts increased visual-motor demands may put older adults at greater risk of a fall.

A possible limitation of the present study is the issue of whether the findings generalize beyond a population of independent-living older adults. Older adult populations can be hugely heterogeneous depending on the selection criteria used for determining health status. Our study recruited a fairly homogeneous group of older adults who were without known neurological or other health problems. This allowed for the exploration of the relationship between postural sway and manual control with a fairly small sample of individuals. The tasks demands would have made participation difficult for older adults with limited mobility, or those with cognitive deficits. Whilst we did see impaired postural control for these older individuals, the decline may be much greater in the wider population (e.g. for older adults living in care homes). Future work should attempt to adapt our approach to accommodate a broader, more representative sample of older adults, including those with a variety of health issues.

Another weakness of the study actually helps to address the issue of generalization. We adopted a between-subjects approach to exploring the role of stance, using independent sitting and standing groups. This was primarily pragmatic, since a reviewer highlighted the possibility that standing could actually have facilitated the performance of the manual task (rather than impairing it as we proposed). In order to test (and rule out) this possibility we report tracking data from an independent group of seated participants (data collected from a separate project). Whilst there would have been some benefits to testing the same individuals when seated and standing (to remove inter-individual variability), the fact that the old and young groups perform similarly at fast tracking speeds when standing or seated does indicate that tracking performance at least does generalize beyond the particular standing group of older adults.

Conclusion

Our work highlights the multiple risk factors associated with increased postural sway, and for the first time, demonstrates the impact of visual-motor control demands on older adults’ ability to maintain postural stability in a dual-task scenario. We found that increased age and concurrent task difficulty reduced postural stability. With impaired postural control being a major cause of falls in active older adults (Tuunainen et al., 2013), further research is needed to collate and translate such findings into the development of interventions to prevent falls. This could have particular value to inform the provision of advice and support for community-dwelling older adults who may benefit from guidance on those activities which could lead to an increased risk of falling (e.g. placing a key into a locked door or opening a garden gate). It also goes without saying that, an increased understanding of how cognitive resources are allocated when carrying out activities with multiple task demands (i.e. cognitive, visuomotor, and postural load) will inform falls prevention efforts and improve our approach to rehabilitative interventions in at-risk and clinical groups.

Key Findings

Concurrent manual task difficulty reduced postural stability in older adults. Older adults exhibited increasing levels of postural sway and tracking error as motor task difficulty is increased.

What the study has added

This is the first study to examine in detail the relationship between manual task demands and postural sway in older adults. Improved understanding of this relationship should inform falls prevention.

Research Ethics: The University of Leeds Research Ethics Committee approved this experiment (reference number 11-0098, dated 20/5/2011) and all participants gave written, informed consent in accordance with the Declaration of Helsinki.

Declaration of Conflicting Interest: The Authors declare that there is no conflict of interest.

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Figures and Captions

Figure 1. Visuomotor control task (A) Screen shots taken from the KineLab task where participants had to keep the stylus on a dot as it moved around the screen at a slow, medium and fast pace; (B) Older adults completing the visuomotor control task.

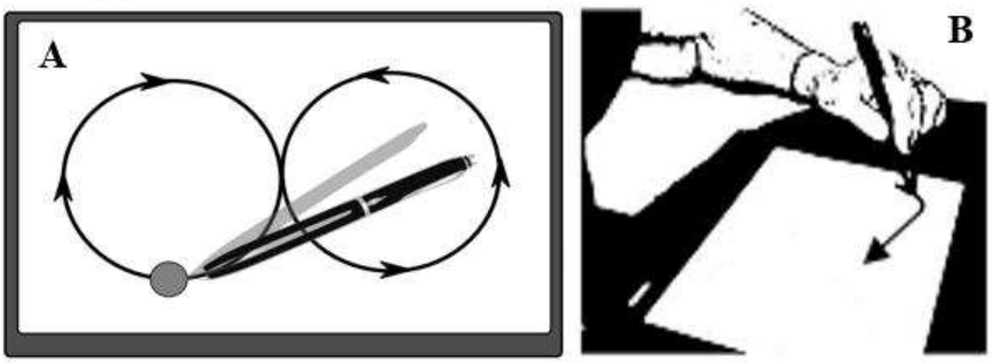


Figure 2. Testing set-up used with participants, with the tablet laptop placed on a lectern in front of the participant, who stood on a Nintendo Wii balance board for the duration of the task. This image shows a younger adult taking part in the experiment. Note that head tracking data was also collected, but not for the purpose of the present study. Head angle was not controlled – participants were free to move/hold their head in their own preferred position for the duration of the study.

Figure 3. Centre of Pressure (COP) Path Length (mm) for the young (grey bars) and older (white bars) groups, as recorded by the balance board across a 30s trial duration for each of the no-visuomotor control task conditions: (i) standing with eyes closed, (ii) standing while fixating on a static target. Two separate trials of each condition were undertaken and the average results are shown. Bars = Standard Error of the Mean.

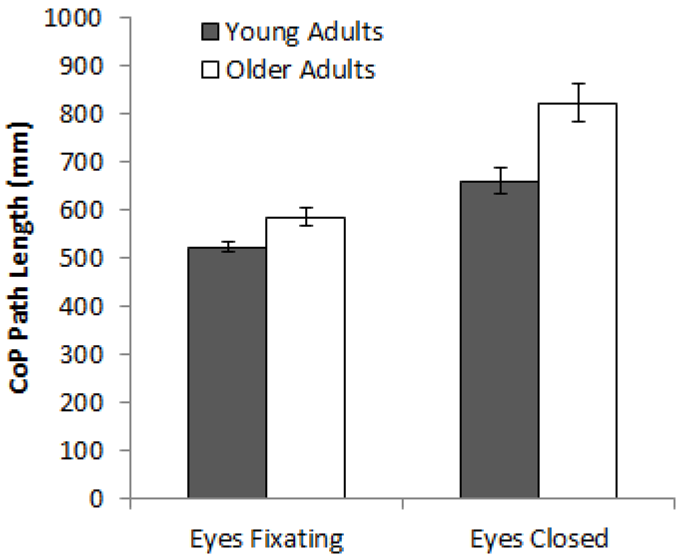
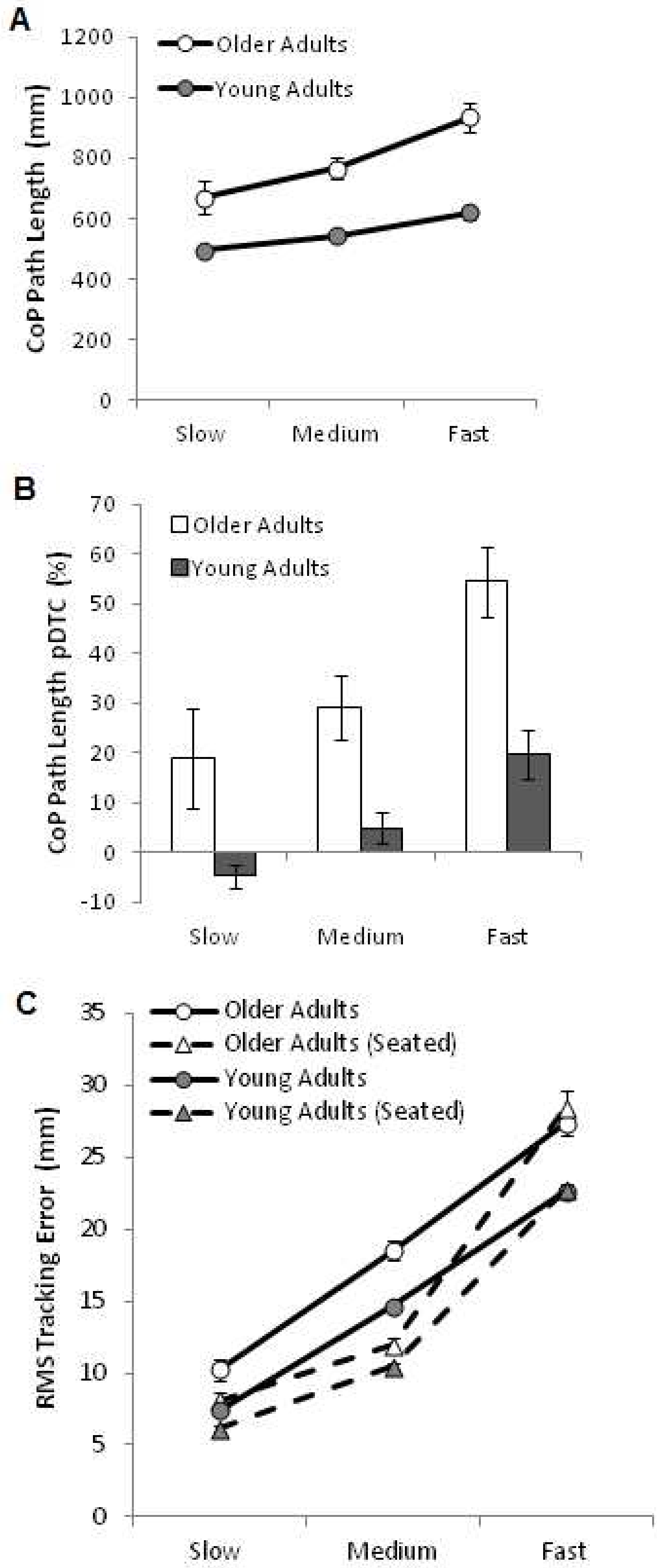


Figure 4. Outcomes measures when participants concurrently completed the visuomotor control task at the same time as standing still on the balance board. The figures show the cumulative results across the 30s trial duration of each of the three tracking speeds. Two separate trials of the visual-motor tracking task were undertaken, where the mean results are shown for: (A) CoP Path Length (mm) for the young (dark grey circular symbols) and older (white circular symbols) groups in the slow, medium and fast speed tracking conditions (B) Proportional Dual Task Costs (pDTC) for the young (dark grey bars) and older (white barsl) groups in the slow, medium and fast (symbol) tracking conditions (C) RMS Error between the position of the moving target ad the position of the participants handheld stylus, for the young (dark grey circular symbols with filled black line) and older (white circular symbols with filled black line) groups who completed the task while standing, and the young (dark grey triangular symbols with dashed line) and old group (white triangular symbols with dashed line) who completed the task while seated, in the slow, medium and fast speed tracking conditions. Bars = Standard Error of the Mean.


A
1200
1000
800
600
400
200
0
CoP Path Length (mm)
Older Adults
Young Adults
Slow
Medium
Fast
B
70
60
50
40
30
20
10
0
-10
CoP Path Length pDTC (%)
Older Adults
Young Adults
Slow
Medium
Fast
C
35
30
25
20
15
10
5
0
RMS Tracking Error (mm)
Older Adults
Older Adults (Seated)
Young Adults
Young Adults (Seated)
Slow
Medium
Fast