The relationship between memory processing and balance in older adults

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The Relationship Between Memory Processing and Blance in Older Adults

Submitted by

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The Relationship Between Memory Processing and Balance in Older Adults

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Abstract

Purpose: The purposes of this study were to determine if postural sway was affected by dividing attention between a memory test and balancing, and to compare the postural sway between a young and old group. Subjects: Fifteen subjects aged 18-30 years and 15 aged 65-85 years volunteered to participate in this study. Methods: Force platform postural sway data was collected while subjects performed three trials of static standing posture and two trials of static standing posture while completing a memory test. Results: The older group had greater postural sway than the younger group during both baseline standing balance and during the memory test in the anterior-posterior direction and in total sway. Both groups’ postural sway decreased from baseline during the memory test. In addition, the older group’s balance showed greater improvement from baseline to during the memory test than the younger group. Conclusion: The results of this study indicate that balance of both older and younger adults improved while dividing attention between static balance and a memory test. Clinically, these results may influence the assessment and treatment of balance, especially in the older adult population, which is at a greater risk for falls.

Key words: balance, aging, falls, postural sway, memory testing
INTRODUCTION

Falls were the leading cause of injury death of adults age 65 years and older in 2000.\textsuperscript{1} Approximately 35% percent of independently living persons aged 65 years and older experience a fall each year and over 50% for those persons over 80 years of age.\textsuperscript{2,3,4} Almost half of these falls result in injury, and 10-15% of these injuries are serious, including hip fractures.\textsuperscript{5}

In addition, these injuries are often complicated by co-morbidities, which can slow healing and recovery rates. Thus, falls may result in a loss of or decrease in physical functioning and independence. An injury due to a fall or even the fall itself can also have a devastating effect on the individual’s quality of life, which can lead to a further spiral of decline. The consequences of falling include a loss of confidence, fear of falling, decreased activity, social isolation, depression, institutionalism, and even death.\textsuperscript{3,6} In one study, 80% of community-dwelling persons surveyed over the age of 80 years reported they would rather die than suffer the loss of independence that a fall causing a hip fracture and subsequent institutionalism would bring.\textsuperscript{7}

Falls in the older population are the result of complex interactions between intrinsic and extrinsic factors that affect balance.\textsuperscript{2} Extrinsic factors, also considered environmental hazards, have been implicated in approximately 50% of the falls in the older adult population.\textsuperscript{2} These factors include poor lighting, slick
floors or irregular surfaces (throw rugs), furnishings with inappropriate heights, unsafe stairways, and lack of safety rails in bathrooms.\textsuperscript{2}

Intrinsically, the ability of a person to balance relies on the coordinated function of the musculoskeletal and neurological systems. Age-related changes in these systems can also contribute to instability in older adults, resulting in a fall.\textsuperscript{2} These changes include reductions in postural control, decreased proprioception, slower righting reflexes, decreased muscular tone and strength, changes in gait, reduced visual abilities, and decreased depth perception.\textsuperscript{8} Pathologic conditions (also considered intrinsic factors) such as arthritis, stroke, hip fracture, peripheral neuropathies, dementia, Parkinson’s disease, and foot disorders can also contribute to falls.

In addition to these extrinsic and intrinsic factors that influence balance, dual tasking has also been shown to affect balance. Dual tasking paradigms, which measure balance during visual, auditory, or motor tasks, have been recently studied to determine the effects of these tasks on balance in older adults. Research by Redfern, Jennings, Martin, and Furman\textsuperscript{9} found that performing a reaction time task resulted in increased postural sway (decreased balance) in older adult subjects. This study used both auditory and visual stimuli that required a motor response (pushing a button) to challenge the brain’s ability to process information during a balance activity. The results of this study suggest that attention to auditory and visual stimuli reduces balance among the older adult
population. The authors also suggest this problem may be amplified in those older adults with pathological problems that reduce balance and increase the risk of falling.\(^9\)

In another study, subjects were cognitively challenged with auditory tasks during balance testing. Two auditory tasks required the subject to listen and process information and the third required the subject to repeat back aloud words that were played from a recording. Researchers found that subjects had greater postural sway during the articulation task and concluded that this increase in sway was due to the competing motor requirements of the dual tasks.\(^10\) Another study also found that mental performance on a visuospatial task deteriorated when a challenging balance test was also required.\(^11\) Thus, competing cognitive resources in the older adult could lead to an increased risk of falling.

In addition, Brown, Shumway-Cook, and Woollcot (1999) found that older individuals had greater postural sway than younger subjects when trying to recover their balance following a perturbation.\(^12\) The authors concluded that the older adults’ ability to recover to a stable posture following a perturbation was more attentionally demanding than for younger adults. Thus, there may be an increased risk of loss of balance and falls in older adults if sufficient attention is not focused on balance and the motor task of postural recovery. Furthermore, Shumway-Cook, Woollacott, Kerns, and Baldwin (1997) found that when postural stability was impaired, balance declined even more when performing a
cognitive task. The authors suggested that the allocation of attention to cognitive tasks such as word finding during balance tasks appeared to be a large contributing factor to the decreased balance of the older subjects.

The cognitive tasks in these recent studies have focused on visual, auditory, and motor attention as the components of cognitive tests. However, the influence on balance of other cognitive tasks that do not require a sensory or motor component, such as memory tasks, has not been determined. Further research is needed to better understand the reactions and interactions of the body systems as they relate to age-associated changes in balance and postural control so that falls may be prevented through training and risk assessment testing.

Therefore, the purpose of this study was to determine the influence of the cognitive demands of memory on older individuals’ ability to maintain balance relative to young individuals. It was hypothesized that older individuals would have decreased balance with and without the cognitive task as compared to younger individuals. It was also hypothesized that the older group’s balance would decrease to a greater degree when completing the memory test relative to their balance without the test.

METHODS

Participants

Thirty male and female subjects from the greater Toledo area were asked to volunteer for this study. Of the thirty subjects, 15 were aged 21 to 28 years (X=...
23.46 ± 3.45), and 15 were aged 62-81 years (X= 71.46 ± 6.20). Males and females were evenly distributed in each group such that 7 males and 8 females were in the young group and 8 males and 7 females were in the old group. Subjects were excluded if they had any neurological or musculoskeletal disorders that affected their ability to stand independently without an assistive device, if they were legally blind or deaf, or if they were not living independently.

Instrumentation

A 3’ x 3’ force platform (Model OR6-5, AMTI Inc., Marlboro, MA) was used to measure the center of pressure movements through the feet during the standing balance protocol. The measurement of the center of pressure movements reflects postural sway, which is an indicator of balance. The force platform data were sampled at a rate of 10Hz with a gain of 4000 and were analyzed using computer software (BalanceTrak, Motion Analysis, Inc., Santa Rosa, CA) that determined postural sway in centimeters (cm). The memory test consisted of two trays of 22 different household items, one tray for each trial.

Procedure

Each subject was mailed a packet of information prior to testing, which included a cover letter, an informed consent form to review, and a medical history form to complete. Upon arriving at the Biomechanics Laboratory at the Medical College of Ohio, written informed consent was obtained and the completed
medical history form was reviewed. Each subject’s height and weight were also measured.

Subjects then completed three baseline trials of standing balance on the force platform with feet together, shoes removed, arms relaxed at their sides, and eyes looking straight ahead at a marked “X” on the wall 26 feet in front of them. Subjects were instructed to stand as still as possible. Each trial lasted 30 seconds with a 1-minute rest period between each trial. Each subject wore a safety belt, and a researcher stood next to the subject during each trial to guard against losses of balance.

Subjects then performed a 30-second trial of standing balance while completing a memory task. The tray of household items was placed on a table 21 cm in front of the force platform at a height of 69 cm. Subjects were instructed to stand just as they did for baseline trials, except instead of looking at the “X” mark, they were to look at the tray and try to memorize as many items as they could. After the 30 second trial, the tray was covered and removed, and the subject sat down and was given a paper and pen to write down as many tray items as he/she could recall in 90 seconds. A second trial was then completed in the same fashion using a tray of 22 different items.

**Data Analysis**

The amount of total sway, anterior-posterior sway, and medial-lateral sway was determined for each trial for each subject. The average of the trials of
each sway variable was then calculated for baseline and for the memory task for each subject and then the group averages were calculated.

Statistical Analysis

A repeated measures ANOVA (SPSS 10.1, SPSS Inc. Chicago, IL) was used to determine the differences in each sway variable between baseline and the memory test for both groups, the difference between groups for each condition, and the interaction between the main effects (p ≤ .05). Independent and paired t-tests were used for post-hoc analyses (p ≤ .05).

RESULTS

Subject Characteristics

Table 1 contains the average age and gender distribution in each group.

Total Sway

The average total sway of the older group during baseline testing was 36.65 ± 9.18 cm and of the young group was 20.38 ± 4.29 cm. The difference was statistically significant (p ≤ .05) such that the older group’s total sway was greater relative to the younger group. The total sway of both groups during the memory task significantly decreased from baseline. The older group’s total sway was 20.06 ± 4.65 cm (p ≤ .05) and the young group’s was 13.99 ± 3.14 cm (p ≤ .05). The difference in total sway between groups during the memory task was also significant (p ≤ .05) such that the older group swayed more than the young group. In addition, there was a significant interaction (p ≤ .05) such that the total sway of
the older group during the memory test decreased from baseline to a greater extent than the younger group. See Table 2 and Figure 1 for total sway results.

**Medial-Lateral Sway**

The average medial-lateral sway for the old group was .59 ± .20 cm at baseline and for the young group was .49 ± .16 cm. The older group’s average medial-lateral sway during the memory test was .37 ± .14 cm and the young group’s average was .29 ± .07 cm. There were no significant differences in medial-lateral sway between the old and young groups at baseline or during the memory test (p ≥ .05). However, medial-lateral sway significantly decreased for both groups from baseline to the memory test (p ≤ .05). See Table 3 and Figure 2 for medial-lateral sway results.

**Anterior-Posterior Sway**

The average anterior-posterior sway at baseline for the older group was .62 ± .19 cm and for the younger group was .47 ± .15 cm, which was significantly different between groups (p ≤ .05). The average anterior-posterior sway during the memory test for the old group was .42 ± .12 cm and for the younger group was .36 ± .12 cm, which was not significantly different. Anterior-posterior postural sway for both groups decreased significantly from baseline measurements to the memory task measurements (p ≤ .05). See Table 4 and Figure 3 for anterior-posterior sway results.
DISCUSSION

In the present study, the first hypothesis, that the older group would have greater sway as compared to the younger group due to age-associated changes in the musculoskeletal and neurological systems was supported for total sway in both conditions and for anterior-posterior sway at baseline. It has been widely supported in the literature that age-associated physiological changes can lead to balance and postural deficits as compared to younger adults. The lack of differences in medial-lateral sway between groups may be due to the small amount of overall medial-lateral sway that typically occurs during static balance. Common balance strategies for maintaining static posture are ankle strategies involving plantarflexors and dorsiflexors that produce movement in the anterior-posterior direction.

The second hypothesis, that the older adults’ postural sway during the memory test would increase from baseline due to the dual tasking required to perform the memory test while maintaining balance, was not supported. Rather, the exact opposite was found, such that all three postural sway variables decreased during the memory test for both groups from baseline. This is in contrast to previous studies that found increases in postural sway of older subjects when visual, auditory, or motor tasks were combined with a balance activity.

It is possible that differences between the cognitive tasks used for this study and those used in previous studies may account for the seemingly
contradictory findings. There are two broad types of memory, declarative and non-declarative memory, each of which requires different resources in the brain. The memory test used in this study involved declarative memory, or memory involved in recognizing, naming, and identifying things based on prior knowledge and past experiences. The hippocampus, amygdala, diencephalons, and limbic system are all involved with declarative memory.14

On the other hand, non-declarative or procedural memory is involved with the performance of a skill (such as riding a bike). Non-declarative memory also includes learned emotional responses. The primary areas of the brain involved with non-declarative memory are regions of the sensorimotor cortex, basal ganglia, and cerebellum. This may explain the differences between the results of this study, which involved declarative memory skills, and the results of previous studies that relied on other dual task/selective attention tests involving vision, motor, and auditory tasks, which require non-declarative memory skills.14 This may also explain why postural sway decreased for the young group.

In addition to differences in the type of memory tasks performed, another possible explanation for the conflicting findings between this study and previous studies is related to the three components of balance; vestibular, visual, and proprioceptive. In regards to the vestibular system, a small variance in head position between baseline and the memory test may possibly be a source of the decreases in postural sway for both groups. Two of the semi-circular canals, the
utricle and saccule, are oriented vertically and horizontally in the ear. Changes in head position cause fluid in these canals to move, which in turn causes the release of neurochemicals to signal that the head is changing position. These positional changes of the head and neurochemical signals can also influence balance. Authors of one study suggest postural sway in older adults is dependent on vestibular input for general sensory feedback regarding the body’s position in space. The head position of the subjects during this study was different for each of the two conditions (baseline and memory test). Head position for the baseline trials was determined by the instructions to the subject to “keep your eyes looking straight ahead at the black “X” on the wall in front of you”. This resulted in a level head position as opposed to a head position of approximately 20° of cervical flexion during the memory test when subjects looked down at the tray of items.

However, the release of neurochemicals to signal changes in head position is dependent upon an acceleration or deceleration-type movement. While there may have been activity when the subject first positioned his or her head in space prior to testing, there would not have been input during the test because the subject was instructed to stand as still as possible. Therefore, variations in vestibular function between baseline and the memory test are most likely not a contributing factor to the results found in this study.

In regards to the visual component of balance, it is possible that differences between near and far vision influenced postural sway. Although none
of the thirty subjects reported difficulty with their vision on the medical history forms, and each subject was instructed to wear their glasses or contacts as needed, it is possible that the visual input for balance was different between the two conditions. During baseline testing, subjects were instructed to focus on an “X” approximately 26 feet in front of them, whereas the tray of items for the memory testing was only 21 cm in front. It is possible that visual input from near distances has a beneficial effect on balance resulting in decreased postural sway.

Proprioception, a third component of balance, was adequately controlled for during this study by excluding subjects who had neurological conditions that influenced their ability to stand, and by requiring all subjects to wear only socks during testing and to stand as still as possible. There were no changes in lower extremity or foot position on the force platform between the two test conditions that could have altered proprioceptive input during testing.

Collectively, age-associated changes in these three components of balance may account for the differences in postural sway found between the old and young group regardless of test condition. However, any variability in vestibular, visual, or proprioceptive input between groups would not account for the significant reductions in postural sway found for both groups from baseline to memory testing. Further research is needed to explore and explain the factors that contributed to the improvements in postural sway found in this study when subjects performed a cognitive task during static standing. It is important to
determine the influence of different cognitive tasks, of head position, and of visual input on balance in order to further identify factors that contribute to the increasing incidence of falls with aging.

Clinically, the results of this study should be considered when assessing and treating balance, especially of older adults. For example, clinical measures of balance should take into consideration the implications of cognitive challenges during testing. It is possible that a patient could score poorly on a common balance test, such as the Tinetti, which requires a conscious effort to maintain balance during testing, but demonstrate adequate balance when performing a cognitive task that diverts attention away from balance. In contrast, if a patient is working on high-level balance skills, the patient should be required to consciously focus on balance during various activities to further challenge and improve balance.

CONCLUSION

It is well documented that older adults have decreased balance as compared to younger adults and are at greater risk for falls. This was supported in this study as well, with the old group swaying more at baseline and during memory testing than the younger group. This is congruent with the age-associated changes that have been demonstrated in the musculoskeletal and neurological systems. However, the results of this study are in contrast to the findings of other studies in which balance decreases when attention is divided between two tasks.
It is possible that balance during a dual task is influenced by the type of task being performed such that while some tasks may decrease balance, others may actually improve it. Thus, both the assessment and treatment of balance should take these results into consideration, especially with the older adult population.
REFERENCES


Table 1. Subjects

<table>
<thead>
<tr>
<th>Subject Group</th>
<th>Age</th>
<th>Gender</th>
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<tr>
<td>Young (n=15)</td>
<td>$X = 23.46 \pm 3.45$</td>
<td>7 male, 8 female</td>
</tr>
<tr>
<td>Old (n=15)</td>
<td>$X=71.46 \pm 6.20$</td>
<td>8 male, 7 female</td>
</tr>
</tbody>
</table>
Table 2. Total Sway

<table>
<thead>
<tr>
<th>Group</th>
<th>Baseline(cm)</th>
<th>Memory Test</th>
<th>t</th>
<th>df</th>
<th>p</th>
<th>power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young (n=12)</td>
<td>20.38±4.29</td>
<td>13.99±3.14</td>
<td>8.79</td>
<td>11</td>
<td>&lt;.001</td>
<td>&gt;.99</td>
</tr>
<tr>
<td>Old (n=15)</td>
<td>32.65±9.18</td>
<td>20.06±4.65</td>
<td>*#</td>
<td>8.36</td>
<td>&lt;.001</td>
<td></td>
</tr>
</tbody>
</table>

* p ≤ .05 between groups (baseline: t=-4.58, df=20.74; memory t= -4.07, df=25; power=.985)
# p ≤ .05 group x time interaction (F= 11.76, df=25, power=.909)
Table 3. Medial-Lateral Sway

<table>
<thead>
<tr>
<th>Group</th>
<th>Baseline(cm)</th>
<th>Memory Test</th>
<th>t</th>
<th>df</th>
<th>p</th>
<th>power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young (n=15)</td>
<td>.49±.16</td>
<td>.29±.07</td>
<td>4.91</td>
<td>14</td>
<td>&lt;.001</td>
<td>&gt;.99</td>
</tr>
<tr>
<td>Old (n=15)</td>
<td>.59±.20</td>
<td>.37±.14</td>
<td>5.09</td>
<td>14</td>
<td>&lt;.001</td>
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</table>
Table 4. Anterior –Posterior Sway

<table>
<thead>
<tr>
<th>Group</th>
<th>Baseline(cm)</th>
<th>Memory Test</th>
<th>t</th>
<th>df</th>
<th>p</th>
<th>power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young (n=15)</td>
<td>.47±.15</td>
<td>.36±.12</td>
<td>2.57</td>
<td>14</td>
<td>.022</td>
<td>.997</td>
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<tr>
<td>Old (n=15)</td>
<td>.62±.19 *</td>
<td>.42±.12</td>
<td>4.26</td>
<td>14</td>
<td>.001</td>
<td></td>
</tr>
</tbody>
</table>

* p≤ .05 between groups for baseline (t= -2.31, df= 28, power=.646)
Figure 1.

* $p \leq 0.05$ between groups
# $p \leq 0.05$ baseline to memory
† $p \leq 0.05$ interaction
Figure 2.

#p ≤ 0.05 baseline to memory
Figure 3.

Anterior-Posterior Sway

* $p \leq 0.05$ between groups
# $p \leq 0.05$ baseline to memory