Determination of the Effects of Cognitive Activity on Postural Sway

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Abstract

Postural control is an elaborate task, especially when simultaneous distractions and cognitive actions arise. In order to determine how postural sway is influenced by concurrent cognitive tasks, research was performed both on younger and older adults. The hypothesis was that postural sway would increase for both younger and older adults during dual-tasks with cognitive activity and balancing. The results showed that postural sway did increase for older adults when the cognitive tasks were difficult. However, this did not hold true for younger adults who showed no significant difference in sway with cognitive activity.

Introduction

An individual's posture is controlled by the vestibular, visual, and somatosensory systems (Melzer, Benjuya, & Kaplanski, 2001, p. 189). The vestibular system provides sensory information gathered from the utricle, saccule, and semicircular canals of the ears. Vertical orientation as well as linear movement of the human body are identified by the utricle and saccule bones of the ear. The semicircular canals regulate the rotational movement/acceleration of the body. There are three semicircular canals—one for each plane (sagittal, coronal, and transverse planes). The semicircular canals are full of a fluid called endolymph; therefore, when the head turns, fluid inertia occurs due to the delayed fluid movement, and this causes pressure to reach the sensory receptor on that particular canal. The canal's receptor transmits that information to the brain, and when the vestibular system is working at optimal functionality, the information sent to the brain is identical on both sides (Watson & Black, 2006). The visual system also affects posture via the photoreceptors (rods and cones) that are inside the retina. When light penetrates the photoreceptors, they transmit visual signals to the brain that orient an individual comparative to the location of other objects (Watson & Black, 2006). The somatosensory system uses pressure, touch, joint and muscle sensors to produce information about the body’s stance. Skin sensation holds a major role in the somatosensory system in everyday activities (Rogers, 2012).

The vestibular, visual, and somatosensory systems work together to immediately correct any deviations in posture/balance by sending information to the central nervous system. The central nervous system then sends information to the core and lower extremity stabilizing muscles that activate to correct the issue (Melzer, Benjuya, & Kaplanski, 2001, p. 189). These corrections are completely automatic since they happen instantaneously. There is not time to consciously think about the adjustments (Melzer, Benjuya, & Kaplanski, 2001, p. 190).

Disorders involving these systems affect individual’s balance and could consequently increase fall risk, especially in elderly individuals (Melzer, Benjuya, & Kaplanski, 2001, p. 190). Falls are a major issue for elderly individuals because falls are the number one cause of fatal as well as non-fatal injuries for older Americans (“Fall Prevention Facts”). Even when falls do not cause physical injuries, oftentimes individuals who have fallen become fearful of falling. This can cause them to become less active, which results in a weakening of the postural stabilization muscles and potentially increases the risk of falling (Rogers, 2012).

Older individuals tend to have a worsening ability to perform cognitive and motor tasks simultaneously because of a less effective visual-spatial and sensorimotor processing. Consequently, this increases the necessary cognitive demands for processing the incoming postural information (Bergamin, Gobbo, Zanotto, Sieverdes, Alberton, Zaccaria, & Ermolao, 2014). The majority of cognitive theories assert that the usable cognitive processing resources are finite. Therefore, rivalry is possible while carrying out multiple tasks and could potentially cause difficulty with simultaneous cognitive and balance tasks (Melzer, Benjuya, & Kaplanski, 2001, p. 190).

The Dual-Task Paradigm was developed in order to assess gait and cognition simultaneously. This allows the comparison of the two tasks in relation to fall risk for elderly individuals. The Dual-Task Paradigm can involve concurrent balancing with verbal responses to questions that require cognition. Balance/postural differences during a dual-task test would be the result of the task requiring thought. For example, cognitive questions requiring verbal response. As stated earlier, this is due to the fight for cognitive resources during the two tasks (Beauchet & Berrut, 2006).

The intention of this study was to determine whether or not postural sway is altered with the addition of cognitive tasks while balancing. Furthermore, the purpose of the research gathered in this paper was to pinpoint the factors contributing to the results of the study, as well as to relate the data for younger individuals to that of older individuals in relation to risk of falls.

Methods

Subjects

Thirty-four females and eighteen males with an average age of 25.9 years were participants in this study. None of these subjects had a history of balance issues/disorders. This sample of young adults was chosen in order to reflect the effect that cognitive distractions have on postural sway of young and healthy individuals.

Measures

The machine used to measure the amount of sway an individual is exhibiting is called the SMART Equi-Test machine. The method for how the machine works is best described from the Natus Medical Incorporated website that states:

> "The SMART Balance Master utilizes a dynamic force plate with rotation capabilities to quantify the vertical forces exerted through the patient's feet to measure center of gravity position and postural control; and a dynamic visual surround to measure the patient's use of visual information to maintain balance. It provides assessment and retraining capabilities with visual biofeedback on either a stable or unstable support surface and in a stable or dynamic visual environment" ("Balance and Mobility").

The research was performed through the experimental research design. Participants were tested on the balance machine while being silent and focusing to measure their sway, then the participants were tested on the same balance machine but while being asked questions such as: "Please state every name you can that begins with the letter I," "Please count backwards from 93," "Please name every animal you can that begins with the letter E," "Starting at the number 108 please count forwards by fours," and "Explain how you would make a salad." The participants did not know whether they were going to be asked to stand quietly or if they were going to be asked questions. This study was quantitative, since the SMART Balance Master machine collects data from each individual participant.

Results

The following data tables illustrate the difference in sway between the subjects when they were asked questions and when they were not asked questions.

Data Table 1.0:

Condition One		
More Sway Without Questions	*More Sway With Questions*	*Same Sway With and Without Questions*
18	5	3
13	10	3
10	13	3
10	14	2
Totals For Condition One		
51	**42**	**11**

Data Table 2.0:

Condition Two		
More Sway Without Questions	*More Sway With Questions*	*Same Sway With and Without Questions*
17	6	3
13	11	2
11	13	2
11	10	5
Totals For Condition Two		
52	**40**	**12**

Data Table 3.0:

Condition Three		
More Sway Without Questions	*More Sway With Questions*	*Same Sway With and Without Questions*

15	8	3
10	14	2
13	10	3
9	13	4
Totals For Condition Three		
47	**45**	**12**

Data Table 4.0:

Condition Four		
More Sway Without Questions	*More Sway With Questions*	*Same Sway With and Without Questions*
15	10	1
12	13	1
10	15	1
10	15	1
Totals For Condition Four		
47	**53**	**4**

Data Table 5.0:

Condition Five		
More Sway Without Questions	*More Sway With Questions*	*Same Sway With and Without Questions*
12	14	0
10	15	1

9	17	0
12	13	1
Totals For Condition Five		
43	**59**	**2**

Data Table 6.0:

Condition Six		
More Sway Without Questions	*More Sway With Questions*	*Same Sway With and Without Questions*
23	3	0
11	15	0
10	16	0
12	48	0
Totals For Condition Six		
51	**42**	**11**

Data Table 7.0:

Overall	*Without Questions*	*With Questions*	*Same Sway With and Without Questions*
	296	287	41

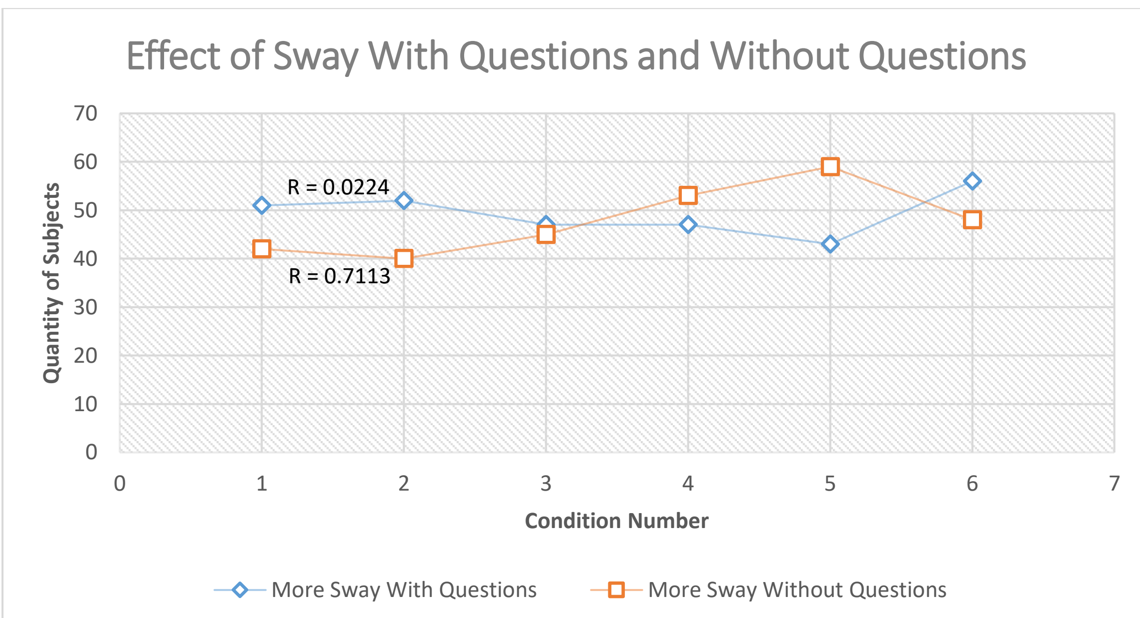
Data Table 8.0:

	Condition 1	Condition 2	Condition 3	Condition 4	Condition 5	Condition 6
More Sway With Questions	51	52	47	47	43	56

More Sway Without Questions	42	40	45	53	59	48

Based upon these above data tables, there does not appear to be a significant difference in sway between when the subjects are asked questions and when the subjects are standing silently. In order to compare the total values from each condition within the study, a graph was produced, and R-values were calculated to determine the correlation between the variables.

Figure 1.0:



As is evident in Figure 1.0, based on the data collected from the six conditions in the study performed on young adults, there is no significant correlation between cognitive questions and postural sway. For the subjects who had increased sway without being asked questions (standing silently), the R-value is 0.7113. This illustrates that there is a moderate strength, positive correlation between standing silently and increased sway. Conversely, the subjects who exhibited increased postural sway while being asked cognitive questions had an R-value of

0.0224. This extremely low R-value shows that there is a very low strength positive correlation between increased postural sway and being asked cognitive questions.

Based upon the results of this research study, since there is no strong correlation between postural sway and cognitive tasks in young adults, additional research was performed (that is included in the following section) on secondary sources to gather more information about how these variables affect the older population.

Additional Research

Two research studies performed regarding this topic compared the differences in cognitive effects on postural sway for young adults as well as for elderly adults. The first article included twenty young adult subjects with an average age of thirty-one, as well as forty older adults with an average age of seventy-four. Half of the older adult subjects had a history of falls, and the other half did not have any history of falls. There were two cognitive tasks that the subjects were asked to perform. The first was sentence completion, which is a language processing task, and the second task is judgment of line orientation, which is a perceptual matching visual task. The purpose of these two tasks in this particular study was to produce variance in attention while simultaneously standing on either a firm surface or on a compliant foam surface (Shumway-Cook, Woollacott, Kerns, & Baldwin, 1997).

One of the results gathered from this research study was that they found no significant difference in postural sway on the firm surface between the younger adults and the older adults who had no previous fall history. However, older adults who did have a history of falls had higher levels of postural sway than either the young adults group or the older adults group with no history of falls. For the compliant foam surface, there were significant differences in postural sway between all three of these subject groups. Older adults with a history of falls had the most unstable posture control on the foam surface, and younger adults were the most stable on the foam (Shumway-Cook, Woollacott, Kerns, & Baldwin, 1997).

The results regarding the condition with no cognitive task showed no significant difference between young adults and older adults without a history of falls in postural sway while standing quietly. However, older adults with fall history swayed significantly more than either of the other groups while performing no cognitive task (Shumway-Cook, Woollacott, Kerns, & Baldwin, 1997).

For the condition where cognitive tasks were added, both of the two tasks caused a significant difference in stability among the three groups. Again, older adults with a history of falls were the most unstable, and younger adults were more stable. Furthermore, the older adults with no history of falls and the younger adults had similar postural sway levels during the no-task condition as well as during the judgment of line orientation task. Although, these two groups swayed significantly more during the sentence task than any of the other two conditions. For older adults with a history of falls, they also had the highest level of postural sway during the sentence task than any other condition (Shumway-Cook, Woollacott, Kerns, & Baldwin, 1997).

“These results suggest that when postural stability is impaired (as in the elderly fallers), even relatively simple cognitive tasks can further impact balance” (Shumway-Cook, Woollacott, Kerns, & Baldwin, 1997). The results of this study did not support their hypothesis that when presented with a dual-task situation, the subjects would choose posture over the cognitive task. However, in this study it was evident that the subjects showed increased postural sway when presented with cognitive tasks, but never showed declines in the cognitive task even when on the compliant foam surface. “In dual task context, when postural demands on attentional resources are low, cognitive tasks that are similarly low in attentional demands may not affect postural stability, but more demanding cognitive tasks might" (Shumway-Cook, Woollacott, Kerns, & Baldwin, 1997). This was evident in the differences displayed between the judgment of line orientation task that did not take as much cognition, and the sentence completion task, which did take significant thought (Shumway-Cook, Woollacott, Kerns, & Baldwin, 1997).

The second article dealing with age differences regarding cognitive activity and postural sway is called, "Dual-tasking postural control: Aging and the effects of cognitive demand in conjunction with focus of attention." This article was a write-up of a research study the authors performed. The study included nineteen older adults (10 males, 9 females) with an average age of 69.80, and twenty younger adults (10 males, 10 females) with an average age of 24.52 (Huxhold, Li, Schmiedek, & Lindenberger, 2006).

During this study, the method for measuring postural control was through the use of a force platform. The platform had twelve internal sensors that gathered data for the forces due to weight-shifting/sway. A computer used that data from the sensors to calculate the center of body pressure (COP) changes. The COP values are good representations of postural control abilities in individuals. The less the COP changes signifies good postural control because there is less sway occurring and vice versa (Huxhold, Li, Schmiedek, & Lindenberger, 2006).

Subjects involved in this study were given buttons to hold in their hands in order to answer the cognitive questions/perform the cognitive tasks for each condition. For this study, there were three conditions where only cognitive tasks were given while the subject was sitting down, and there were five conditions where the subjects were on the force platform. The various standing conditions consisted of: standing with no cognitive task, focusing on one spot while standing, watching numbers while standing, as well as three dual-task conditions (Huxhold, Li, Schmiedek, & Lindenberger, 2006).

There were several results from this research study. The first was that in all of the conditions, older adults swayed more than younger adults, and the older adults performed less accurately on the cognitive tasks than did the younger adults. The second result was that as the cognitive task became increasingly difficult, postural sway in older adults increased as well. This was not the case for the younger adults, and there was not a significant difference between postural sway in either the older or the younger adults depending on spatial processing or verbal processing tasks when the difficulty is factored in (Huxhold, Li, Schmiedek, & Lindenberger, 2006). “The contrast between young and old adults confirms that individual differences in attentional capacity modulate the point at which a given level of cognitive demands change from being beneficial or detrimental for postural control” (Huxhold, Li, Schmiedek, & Lindenberger, 2006).

These two research studies seem to have similar findings. Based on this additional research performed, it appears that older adults have an increasingly difficult time controlling their sway during difficult cognitive tasks. However, it was evident that younger adults did not have much of an increase in sway with difficult cognitive tasks.

Conclusions

Finally, our hypothesis was incorrect for younger adults who did not show postural sway increases with cognitive activity. However, during difficult cognitive tasks, which could present themselves in everyday life in conjunction with balancing, older adults (especially those with a history of falls) showed increased sway. This is important because the increased sway in the older adults could potentially increase their risk of falls. Further research is needed to determine how to improve postural control in older adults during difficult cognitive tasks in order to reduce their risk of falls.

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