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Short Communication

Concurrent effects of working memory components on postural sway during quiet standing in brain stroke survivors

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Abstract
This study aimed to investigate the effects of working memory dual tasks on postural sway in chronic stroke patients. Twenty chronic stroke survivors were recruited from rehabilitation clinics in Mashhad. Centre of pressure (COP) was measured on a force plate in the baseline standing condition, the standing condition while the phonological loop component of working memory was activated, and in the standing condition while the visuospatial sketchpad component of working memory was activated. Repeated measures analysis of variance was used to analyze the data. The results indicated the effects of interference on postural sway exhibited in mean velocity in the mediolateral direction ($P=0.01$). Notably, the visuospatial task caused greater disruption to postural control compared to the phonological loop task ($P=0.019$ vs. 0.006, $P=0.03$). The mediolateral speed of changes in COP reduced significantly with the phonological loop working memory task in comparison to the without memory task. The visuospatial working memory dual task interfered more with the postural control of stroke people.
Keywords: Postural sway, Working memory components, Dual task, Stroke

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Introduction

Stroke is known as one of the most prevalent causes of physical and mental disability, the second cause of death, and the third cause of disability-adjusted life years in Iran (1). Post-stroke postural control impairment is one of the main causes of reduced mobility and increased risk of falls (2). Cognitive impairments such as reduced attention can decline the automaticity of postural control and cause difficulties in maintaining postural control during dual tasks (3). Studies have shown altered postural performance of stroke survivors during dual tasks (4).

Working memory is the active short-term storage of semantic, visual, or episodic information. Since attentional resources are limited, the simultaneous performance of a working memory task with a primarily cognitive or motor task, such as quiet standing, might interfere and lead to increases in postural sway parameters and deterioration in postural control (5). There is clear evidence that working memory as a function of attention could alter as a result of the stroke (6). Lesion to the nervous system also affects working memory in stroke patients. While quiet standing postural control requires complex cognitive processes through subcortical and cerebral cortex structures (6), some researchers have extensively suggested the attentional requirement of quiet standing postural control depending on the task or balance ability (7). Brown et al studied the effects of postural control on cognitive performance and revealed an attentional demand for postural regulation, as shown by a decrease in cognitive performance when patients moved from a sitting to a standing position (7). On the other hand, Mehdizadeh et al found differences between the healthy and stroke groups in their manner in response to different dual-task conditions (8). Studies investigating the working memory phonological loop and visuospatial sketchpad domains have shown memory impairment which is more pronounced in visual short-term memory than in other domains (9-12). However, there is a gap in the literature regarding the relationship between cognitive function and quiet standing under dual-task performance with a secondary working memory task in stroke survivors. The present study seeks to assess differences between visual and auditory working memory on postural control ability and changes in the center of pressure in the anterior-posterior and mediolateral directions.

Materials and Methods

Twenty chronic stroke survivors with hemiparetic lesions at the age of 57.55 ± 4.69 years, a height of 169.85 ± 10.12 cm, and a weight of 73.70 ± 10.95 kg were recruited via convenience sampling from rehabilitation clinics and hospitals in Mashhad between May 2021 and September

2022 for this cross-sectional study. The inclusion criteria for the stroke survivors consisted of physician confirmation of a hemiparetic cortical stroke without any aphasia (13). Individuals with other neurological conditions (e.g., Parkinson's disease, vestibular deficits, or peripheral neuropathy), musculoskeletal disorders, or cognitive deficits were excluded from the investigation. The minimum necessary sample size was 20 participants, based on findings of earlier studies (14) and the repeated measures analysis of variance (ANOVA) statistical method. This was determined to ensure an 80% power, an effect size of 0.3, and a significance level of 5%, as calculated using G*Power software.

In this study, an experimental paradigm was utilized to measure body sway parameters when standing in different working memory conditions. Three experimental conditions were performed; three trials were collected for each condition. Subjects were tested on three different tasks, including assessing postural control during quiet standing, the attentional requirements of visual working memory, and an auditory working memory task on postural control during quiet standing on an instrumented force plate (Kistler 4060-10 force platform) in a dual-task paradigm. The force plate signals were collected at 100 Hz to compute central pressure measures.

The visuospatial working memory task was presented using PowerPoint slides on a screen positioned at eye level (height 200 cm from the front of the force platform). The material was displayed in the shape of a 2 × 2 table with a moving sign between labeled cells with letters on the monitor using 88-point font, with size 2 × 2 (m), and a vertical visual angle. Participants were asked to retain and remember the letter shown at the last place of the sign in cells. A verbal working memory task was presented at a constant volume using headphones, in which the participants were instructed to count a serial mathematical function and remember the answer. A 1-2 minute rest period was provided between trials to avoid fatigue.

Centre of pressure (COP) standard deviations (SD) and velocity in the anterior–posterior (AP) and mediolateral (ML) directions were calculated using MATLAB software (MathWorks, Natick, MA, USA). The raw data were filtered using a low-pass Butterworth filter with a cut-off frequency of 10 Hz and then used to calculate postural sway parameters.

All dependent variables were analyzed in one-way repeated measures ANOVA with the factor of working memory task. Bonferroni-corrected post-hoc comparisons were utilized in the case of a significant difference between groups, and the significance level for all analyses was set at $P \leq 0.05$.

Results

Table 1 presents the results (means ± SD) under the three conditions and the effects of the working memory tasks. There was no significant difference among working memory task conditions in the AP COP SD ($P = 0.12$) and ML COP SD ($P = 0.13$).

In the analysis of total COP velocity, statistical significance was found in the ML direction ($P = 0.04$), but not in the AP direction ($P = 0.36$). Based on Bonferroni-adjusted post-hoc comparisons, there was more variability in the ML sway when participants were presented with visual stimuli compared to when they were not engaged in any specific task ($P = 0.01$). Additionally, further analysis of the ML direction showed that the overall speed of COP movement was significantly reduced during the phonological loop working memory task compared to no task conditions ($P = 0.03$).

Discussion

Our findings revealed that by changing the working memory task, the amount of postural sway in the ML direction increased in stroke patients. The greater amount of COP velocity during quiet standing concurrently with visuospatial working memory tasks could be explained by various changing postural control elements due to stroke. It was found that stroke patients showed instability and increasing visual dependency, particularly in the frontal plan, compared with healthy people (9). It is also known that the neural network involved in attention and working memory might be interlinked with those of balance control; therefore, it may be possible that greater interference is due to competition for these shared resources, which may become unbalanced due to stroke. In addition, studies reported that individuals with stroke have decreased visual attention (10), which might reduce postural stability. The primary factor in reducing postural control and balance impairment among persons with cognitive deficits, such as strokes, is central or peripheral nervous system injuries. Significant impairment in

Table 1. Means and SD of postural sway parameters in different conditions

AP		Different working memory tasks (cm)						Intergroup	
		Without working memory task		Working memory task (visual)		Working memory task (audio(		F	P
		Mean	SD	Mean	SD	Mean	SD		
AP	SD of COP	0.009	0.003	0.010	0.003	0.009	0.003	4.12	0.127
AP	Speed of changes of COP	0.018	0.008	0.020	0.014	0.020	0.006	2.00	0.368
ML	SD of COP	0.011	0.004	0.010	0.006	0.009	0.004	4.12	0.130
ML	Speed of changes of COP	0.017	0.003	0.019	0.005	0.017	0.006	0.92	0.04*

Note. AP: Anterior–posterior; ML: Mediolateral; SD: Standard deviation; COP: Center of pressure. * $P < 0.05$.

working memory and the prefrontal cortex has been demonstrated in the acute stage of stroke, which persisted for 3 months post-stroke. Consequently, the ability to control posture concurrently with a cognitive task often decreases (11,12). Similar studies that compared different dual-task functions between cognitive domains in stroke survivors indicated the greatest cognitive costs that could be attributed to the type and complexity of the cognitive task (14). Our results confirmed that in stroke survivors, postural control was more challenging with visual working memory tasks. According to the theory of limited capacity of attention, the automaticity of upright standing control is reduced after a stroke when the visual sketch is activated, which may present more possibility of risk of falling and instability. Previous studies examining the effect of dual-tasking on balance control in stroke patients reported a similar decline in motor performance (14). Although the effortless task of quiet standing is not automatic even in healthy subjects, cognitive contributions are greater in pathologic populations because of the reduction or alternation of sensory information.

Many studies examining the static balance in patients with stroke revealed that stroke patients reduced the weight load on the paretic leg while maintaining an upright standing position in dual-tasking conditions. Therefore, performing a working memory task and postural control simultaneously involves higher attentional demands than doing a single task only in the ML direction rather than the AP direction.

Conclusion

In general, our results demonstrated that stroke survivors are likely to present decrements in postural control of quiet standing while performing a dual-task visuospatial working memory. Greater postural sway could place stroke patients at more risk of falling when they face a postural challenge in the community. Furthermore, the practice of dual-task visual working memory exercises might have functional benefits in restoring balance and postural control.

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Authors' Contribution

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Conflict of Interests

The authors declare that there is no conflict of interests.

Ethical Approval

The study was approved by the Local Ethical Review Board at Ferdowsi University of Mashhad (Ethical ID: IR.UM.REC.1400.080). All participants provided their written informed consent to participate in the study.

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