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Original Article

Effects of visual cue and cognitive motor tasks on standing postural control following a chronic stroke

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Abstract. [Purpose] The objective of the study was to examine the effects of visual cue and cognitive motor tasks on quiet standing posture center of pressure (COP) and the weight loads to the paretic and non-paretic legs in chronic stroke patients. [Subjects and Methods] Twenty chronic stroke patients were included in the study. COP total distance, sway velocity, and the weight loads to the paretic and non-paretic legs of the participants were measured while they performed a visual cue task, cognitive motor task, and dual task. The parameters were compared using a repeated three-way analysis of variance. [Results] When the visual cue was provided, the COP total distance and sway velocity were significantly reduced compared with when no visual cue was given. When the cognitive motor task was performed, the COP total distance and sway velocity decreased significantly compared to when the task was not performed. [Conclusion] These findings suggest that visual cue and cognitive motor tasks could be used as parts of a rehabilitative training program to improve the control of standing in chronic stroke patients. In addition, visual cues can be used as an intervention to train the paretic leg of stroke patients.

Key words: Postural sway, Visual cue, Cognitive motor task

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INTRODUCTION

Muscle weakness on the paretic side of the body is commonly experienced after a stroke. Asymmetrical posture and an imbalance of weight load during standing occurs due to the muscle imbalance between the paretic and non-paretic sides of the body[1)]. As a result, an increase in postural sway can develop in stroke patients, which is approximately two times higher than that in a healthy group of the same age[2)]. Regaining the ability to walk independently is an important training goal of functional recovery after a stroke. To achieve this, rehabilitation training is provided to improve the balance and posture of stroke patients[3)]. Visual feedback is one of the strategies used in balance training following a stroke[4)]. Training, in which visual feedback is used, can increase the attention span when performing a task and improve the patient's motivation during the course of treatment[5)]. Geurts et al.[6)] and de Haart et al.[7)] reported an improvement in postural stability and control achieved through visual feedback training.

Postural control is caused by an unconscious or reflexive process known as the immediate and automatic response system of the human body[8)]. However, studies have shown in which dual tasks were used that the central system of the brain, governing attention, was found to influence postural control (required to maintain standing posture) [9, 10)]. Hyndman et al.[11)] and Morioka et al.[8)] reported a decrease in postural sway during a dual task in which cognitive tasks were performed, in comparison with that achieved with the use of a single task. One of the measures used to assess the postural control ability of hemiplegic patients after a stroke is to determine changes in their center of pressure (COP)[12)]. Typically, the measurement

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Table 1. General characteristics of the participants (n=20)

Variables	
Gender (male/female)	18/2
Age (years)	57.6 ± 11.2
Height (cm)	168.9 ± 6.0
Body weight (kg)	67.4 ± 10.0
Time post-stroke (months)	28.1 ± 17.9
MMSE-K (points)	27.2 ± 1.9
Type of damage (infarction/hemorrhage)	14/6
Hemiparetic side (left/right)	7/13

of postural sway is achieved through an examination of the entire COP, using both feet[13]. However, the COP in each foot was measured separately using two force plates to understand the control and strategy of the paretic and non-paretic legs in stroke patients[7]. Research has been conducted in which the entire COP was measured while a task was performed, but how the performance of each task affects the paretic and non-paretic legs has not been determined. In addition, while the use of dual tasks has been shown to affect postural control in several studies, the influence of the use of a cognitive motor task in conjunction with the use of a visual cue has not yet been examined. Therefore, the aim of this study was to investigate the impact of visual cue and cognitive motor tasks on the paretic and non-paretic legs of stroke patients, and analyze the effects of the performance of a dual task on standing postural control.

SUBJECTS AND METHODS

Twenty participants (18 males and two females) participated in this study. The mean age, height, weight, and time of stroke onset were 57.56 ± 11.17 years, 168.90 ± 5.97 cm, 67.35 ± 10.01 kg, and 28.08 ± 17.93 months, respectively (Table 1). Participants with musculoskeletal disorders and visual problems were excluded from the study. Written informed consent was obtained from participants prior to commencement of the study. This study was conducted in accordance with the principles and guidelines of the Declaration of Helsinki.

Two force plates with a sampling frequency of 200 Hz (AMTI, Newton, USA) were used to collect the data. Visual cues were provided using a full-length mirror (66 ×172 cm). Participants stood with their feet shoulder width apart, in front of the mirror for 30 seconds. COP total distance, velocity, and the weight load to both legs were measured in the right and left feet while they maintained contact with both force platforms. Thereafter, three tasks were performed in random order, namely a visual cue, cognitive motor, and dual task. The participants wore a T-shirt with a vertical line printed down the center. For the visual cue task, they were asked to stand in front of the mirror and to match the line of their shirts with the line drawn down the center of the mirror[14]. For the cognitive motor task, they held a tray with both hands containing a cup of water filled two thirds of the way to the top and were instructed not to let it spill while maintaining a postural stance. Tray-holding posture was maintained with 90° flexion of the shoulder, 0° elbow extension, and the forearm in the mid position[8]. For the dual task, the participants stood in front of the mirror holding the tray, similar to the technique described in the cognitive motor task, but were instructed to gaze at the cup in the mirror.

Analysis of the data was performed using SPSS 20.0 for Microsoft Windows. Three-way analysis of variance (a repeated-measures design) was used to test differences between the tasks (side [paretic side, non-paretic side] × visual cue × cognitive motor task). The significance level was determined to be α=0.05.

RESULTS

Analysis of the COP total distance showed the main effects of the visual cue [$F_{(1,19)}$=4.56, p<0.05] and cognitive motor tasks [$F_{(1,19)}$=9.39, p<0.05]. Significant interactions between side and visual cue [$F_{(1,19)}$=4.78, p<0.05], and visual cue and cognitive motor task [$F_{(1,19)}$=10.84, p<0.05] were also observed. A post hoc analysis of the side and visual cue interaction revealed that in the absence of a visual cue, a significant difference was found between the paretic and non-paretic sides with respect to COP total distance (Table 2). However, when the visual cue was present, a significant difference was not found. Following post hoc analysis of the interaction between the visual cue and cognitive motor tasks, it was reported that when the visual cue was present, the COP total distance did not show any significant difference, regardless of whether the cognitive motor task was performed. In the absence of a visual cue, the COP total distance of the participants decreased significantly during performance of the cognitive motor task, as compared with the result when a non-cognitive motor task was performed (p<0.05; Table 3).

COP sway velocity was primarily affected by the visual cue [$F_{(1,19)}$=4.56, p<0.05] and cognitive motor tasks [$F_{(1,19)}$=9.41, p<0.05], while significant interactions were found between the side and visual cue [$F_{(1,19)}$=4.77, p<0.05], and between the

Table 2. Center of pressure total distance during performance of the tasks (unit: cm)

	Visual cue	No visual cue
Paretic side	229.8 ± 16.4	239.3 ± 15.5*
Non-paretic side	226.6 ± 22.3	225.1 ± 16.8*

*Significant difference between the paretic and non-paretic sides; p<0.05.

Table 3. Center of pressure total distance during performance of the tasks (unit: cm)

	Cognitive motor task	Non-cognitive motor task
Visual cue	232.8 ± 16.1	236.3 ± 15.8
No visual cue	223.5 ± 18.5*	228.1 ± 20.6*

*Significant difference between the cognitive and non-cognitive motor tasks without the visual cue; p<0.05.

Table 4. Center of pressure sway during performance of the tasks (unit: cm)

	Visual cue	No visual cue
Paretic side	7.7 ± 0.6	8.0 ± 0.5*
Non-paretic side	7.6 ± 0.8	7.5 ± 0.6*

*Significant difference between the paretic and non-paretic sides; p<0.05.

Table 5. Center of pressure sway during performance of the tasks (unit: cm)

	Cognitive motor task	Non-cognitive motor task
Visual cue	7.8 ± 0.5	7.9 ± 0.5
No visual cue	7.5 ± 0.6*	7.6 ± 0.7*

*Significant difference between the cognitive and non-cognitive motor task without the visual cue; p<0.05.

visual cue and cognitive motor tasks [$F_{(1,19)}$=10.76, p<0.05]. Post hoc analysis of the side and visual cue interaction revealed that without the visual cue, a significant difference between the paretic and non-paretic sides was found with regard to COP sway velocity (Table 4). However, a significant difference was not found when the visual cue was present. Following post hoc analysis of the interaction between the visual cue and cognitive motor tasks, it was reported that when the visual cue was present, the COP sway velocity of the participants did not show any significant difference between the cognitive motor task and non-cognitive motor task (Table 5). When the visual cue was absent, the participants' COP sway velocity decreased significantly during performance of the cognitive motor task, as compared with the result when a non-cognitive motor task was performed (p<0.05). No significant difference was found between the performance of the paretic and non-paretic legs during execution of the tasks (p>0.05).

DISCUSSION

This study investigated the impact of visual cue and cognitive motor tasks on the paretic and non-paretic legs of stroke patients, and analyze the effects of the performance of a dual task on standing postural control. The COP total distance and sway velocity significantly decreased when a visual cue was provided, as compared with when no visual cue was provided. Motor control of the body using vision is considered to constitute internal feedback about a given environment and movement[15)]. The acquisition of distorted visual information such as that obtained from a moving visual field increases postural sway, whereas the acquisition of fixed visual information reduces it[16)]. Bonan et al.[17)] and Walker et al.[18)] reported that when visual information was removed, anteroposterior sway increased, whereas the visual feedback used during training decreased postural sway. In this study, postural sway was thought to decrease because information about it was modified with the use of the visual cue. In the presence thereof, no significant difference was found between the paretic and non-paretic sides of the patients with respect to COP total distance and sway velocity. This suggests that the reduced sway of the paretic leg resulted from the use of the visual cue. Singh et al.[19)] reported that visual input was associated with an ankle joint strategy used to maintain balance, which is effective in controlling anteroposterior sway. The COP total distance and sway velocity of the paretic leg were thought to decrease in our study because the visual cue provided information that improved ankle joint movement control.

When the cognitive motor task was performed, significant decreases in COP total distance and sway velocity were observed, as compared with that found when the task was not conducted. Huxhold et al.[20)] reported that an internal focus state can interfere with the automatic process of postural control when maintaining balance in a standing posture. However, postural control improved when the dual task was performed in our study. It is likely that inhibition of balance control resulted from the restriction on the self to becoming internally focused. In this study, the cognitive motor task (of lifting a tray with a cup of water and being asked not to spill it) might have facilitated the ability of the participants to shift the focus of their attention externally, thereby decreasing leg sway.

When the cognitive motor task was performed in conjunction with the visual cue, a significant difference between the use of the dual task and the visual cue was not found with regard to the COP total distance and sway velocity of the participants. Postural control is primarily dependent upon visual information after a stroke[17)], and when the visual cue and cognitive motor tasks were performed simultaneously, the dual task showed no significant difference from when only visual cue was provided in our study, probably because the concentration of the participants was distributed between trying to accomplish two tasks. Better postural control when performing a dual task, rather than a single task, has been reported in numerous studies. By contrast, the findings of our study suggested that the dual performance of tasks was not more effective than a single task in controlling posture.

The present study had some limitations. First, the sample size in this study was small. Second, the values of COP and paretic and non-paretic weights were measured. Thus the results of this study showed only some of the static postural control of stroke patients.

Overall, the use of the visual cue and cognitive motor tasks was found to be effective in reducing postural sway. In addition, the provision of a visual cue was helpful in reducing paretic leg sway. The dual performance of tasks was not as effective as either of the single tasks in alleviating postural sway. These results suggest that the effect of dual task performance on postural control varies and is dependent on the nature of the task.

Conflict of interest

None.

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