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Original Article

Effects of visual feedback with a mirror on balance ability in patients with stroke

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Abstract. [Purpose] This study aimed to examine the effects of a visual feedback obtained from a mirror on balance ability during quiet standing in patients with stroke. [Subjects] Fifteen patients with stroke (9 males, 6 females) enrolled in the study. [Methods] Experimental trials (duration, 20s) included three visual conditions (eyes closed, eyes open, and mirror feedback) and two support surface conditions (stable, and unstable). Center of pressure (COP) displacements in the mediolateral and anteroposterior directions were recorded using a force platform. [Results] No effect of condition was observed along all directions on the stable surface. An effect of condition was observed on the unstable surface, with a smaller mediolateral COP distance in the mirror feedback as compared to the other two conditions. Similar results were observed for the COP speed. [Conclusion] Visual feedback from a mirror is beneficial for improving balance ability during quiet standing on an unstable surface in patients with stroke.
Key words: Balance, Feedback, Stroke

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INTRODUCTION

Postural control refers to the sensorimotor control that maintains center of pressure (COP) within the base of support when postural sway occurs due to active or external forces[1)]. Patients with stroke show a pattern of increased postural sway during quiet standing due to motor, sensory, and cognitive impairments[2, 3)], which increases the risk of falls, as well as limits their ability to independently perform daily life activities[4–6)].

Many studies have reported that providing additional sensory information to patients with balance impairment results in improved postural control[7–9)]. One of the methods is using a computer screen to provide visual feedback on the displacement of COP. However, this method has its limitations for home-use because of its high cost[10)].

Visual feedback training using a mirror is a method that can lead to improvements in postural control by providing feedback on induced movements through a reflection of the body image in the mirror[11)]. Hlavackova et al.[12)] reported that when visual feedback was obtained by transfemoral amputees from a mirror placed in front of them, a significant decrease was observed in the subsequent measurement of sway distance. Moreover, a study of the elderly that measured the effects of visual feedback from a mirror reported significant improvement in the mediolateral postural sway[10)].

Many studies have reported that mirror therapy is effective for motor learning in patients with stroke[13–16)]. Few studies have been conducted on the effects of visual feedback from a mirror on the balance ability of patients with stroke. In addition,

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Table 1. Subject characteristics (*N*=15)

	Mean±SD
Gender (male/female)	9/6
Age (years)	54.9 ± 10.9
Height (cm)	165.7 ± 8.3
Weight (kg)	63.7 ± 8.0
Post-stroke duration (mo)	12.9 ± 4.7
Paretic side (right/left)	8/7
Lesion type (hemorrhage/ischemia)	7/8
MMSE	26.15 ± 1.83

MMSE: mini mental state examination

most of the studies only measured the effect on stable surfaces. Hence, there is a need for studies on the effects of visual feedback on unstable surfaces. This study aimed to measure the effects of visual feedback from a mirror on the balancing ability of patients with stroke on various supporting surfaces.

SUBJECTS AND METHODS

Fifteen patients with hemiparetic stroke were recruited for this study from Myongii chonnhey hospital. The inclusion criteria for subjects were as follows: patients who were diagnosed with first onset of unilateral hemisphere stroke, could stand independently for 1 minute on a stable surface, had no visual deficit, had no vestibular deficit, and were able to understand and follow simple verbal instructions. Table 1 shows a list of general characteristics of the subjects. After being informed about the study, all subjects agreed to participate and signed a consent form. The study was approved by the Institutional Review Board of Sahmyook University.

The subjects were asked to stand, barefoot and with their heels separated by a distance of 8.4 inch on a force plate. They were asked to remain in their position as quietly as possible. They were instructed to hang both the arms at the sides of the body. Experimental trials included three visual (eyes closed, eyes open, and mirror feedback) and two support surface (stable and unstable) conditions. In the eyes open condition, the subjects were asked to fix their gaze on the wall 1 m in front of them, at the eye level. In the mirror feedback condition, the subjects were able to visualize their frontal reflected image in a mirror placed on the wall 1 m in front of them[12)]. For the trials on an unstable surface, the subjects stood on a balance pad (Airex®, Aalen, Germany)[17)]. The foot positions were marked on the forceplate and maintained constant between the trials. Three trials were conducted for each condition for a duration of 30 seconds. The order of blocks was randomized for all subjects. The effect of muscle fatigue was minimized by providing a 1-minute rest between measurements. All subjects wore a harness and a therapist stood behind each of them for safety.

The subject's balance ability was measured using a force platform (Wii Balance Board [WBB], Nintendo, Kyoto, Japan). The size of the WBB with four load cells was 45 cm × 26.5 cm. This instrument is reported to have a high test-retest reliability (intraclass correlation coefficient [ICC] = 0.66–0.94) and construct validity (ICC=0.77–0.89)[18)]. Data was exchanged between the WBB and a laptop using the built-in Bluetooth and Balancia software (Balancia v2.0, Mintosystems, Seoul, Republic of Korea).

The sampling rate was set at 50 Hz, and 12 Hz low pass filtering was performed. Balancia software is reported to have a high interrater reliability (ICC=0.89–0.79) and intrarater reliability (ICC=0.92−0.70)[19)].

In order to compare balance ability in different conditions, data were analyzed using one-way repeated measures analysis of variance (ANOVA). The least significant difference post hoc test was used to examine the differences within each trials. Data were analyzed using the SPSS v12.0 statistical program. All the significance levels used were α=0.05.

RESULTS

For all directions, COP distance and speed increased when the subjects stood on the stable surface with their eyes closed. During stance on the stable surface, no significant differences were observed in COP distance and speed between the eyes open and mirror feedback conditions (Table 2).

During stance on the unstable surface, an effect of condition was observed along the mediolateral direction with a smaller mediolateral COP distance in the mirror feedback than in the eyes open and eyes closed conditions, whereas no effect of condition was observed along the anteroposterior direction. COP speed was significantly reduced by mirror feedback when the subjects stood on the unstable surface (Table 3).

Table 2. Center of pressure (COP) in patients with stroke during stance under three conditions on a stable surface

		Eyes closed	Eyes open	Mirror feedback
COP distance (cm)	Anteroposterior	58.3±24.0†#	36.8±13.0*	36.9±11.3*
	Mediolateral	43.6±12.8†#	36.2±8.9*	36.1±9.3*
	Total	80.8±27.6†#	57.7±16.7*	58.9±16.2*
COP speed (cm/s)	Anteroposterior	2.9±1.2†#	1.8±0.7*	1.8±0.6*
	Mediolateral	2.2±0.6†#	1.8±0.5*	1.9±0.5*
	Total	4.0±1.4†#	2.9±0.8†#	2.9±0.8†#

Values are expressed as mean±SD. *significant difference compared with the eyes closed condition. †significant difference compared with the eyes open condition. #significant difference compared with the mirror feedback condition

Table 3. Center of pressure (COP) in patients with stroke during stance under three conditions on an unstable surface

		Eyes closed	Eyes open	Mirror feedback
COP distance (cm)	Anteroposterior	84.9±24.6†#	47.9±14.6*	43.9±10.3*
	Mediolateral	74.1±23.3†#	48.5±13.7*#	42.1±8.3*†
	Total	125.2±37.1†#	75.8±20.8*	67.5±13.5*
COP speed (cm/s)	Anteroposterior	4.9±2.53†#	2.4±0.73*	1.8±0.6*
	Mediolateral	3.7±1.2†#	2.4±0.7*#	2.1±0.4*†
	Total	6.8±2.9	3.8±1.0	3.4±0.7

Values are expressed as mean±SD. *significant difference compared with the eyes closed condition. †significant difference compared with the eyes open condition. #significant difference compared with the mirror feedback condition

DISCUSSION

In this study we examined the effects of visual feedback from a mirror for patients with stroke in a standing position on various supporting surfaces. The sway distance and speed were the highest when the subjects were standing on a stable surface with their eyes closed, whereas no significant difference was observed in all directions when the mirror feedback was obtained with their eyes open. In a study of amputees that examined the effect of visual feedback from a mirror, a significant decrease was reported in the postural sway. This was attributed to the improved balance ability through the visual information reflected in the mirror that acted as a sensory substitution for diminished proprioception from the injured limb[12]. Furthermore, visual feedback from a mirror helps in learning accurate motions through adjustment of errors observed during task performance[20]. A study that used visual feedback in conducting balance training in patients with stroke also reported that such training improved weight distribution and balance ability[21].

However, in this study, no significant improvement effect was observed from visual feedback for subjects who could maintain a standing position on their own for at least 1 minute on the stable surface with relatively small postural sway. Horak et al.[22] indicated that dependency on the vestibular organs and vision increased for postural control as the surface became more unstable. A study on the effects of providing additional somatic sensory information for balance in the elderly also reported that greater improvements were observed on a more unstable surface with increased postural sway[23].

Accordingly, the effect of visual feedback from a mirror on the postural sway on unstable surfaces was observed in this study. Significant improvement was observed in the mediolateral sway distance and speed. It has been reported that mediolateral sway is significantly correlated with falls and can be a predictive factor for falls[24, 25]. Therefore, improving postural control in this direction is important for reducing the incidence of falls[26].

Mediolateral sway can be recognized as the error associated with the movement that deviates from the body's centerline, while anteroposterior sway can be visually recognized through changes in the sizes of images reflected in the mirror. Valiant et al. [10] reported that when visual feedback from a mirror was obtained by the elderly, significant improvement was observed only in the mediolateral direction, and the authors attributed this to the threshold difference in the visual recognition of mediolateral and anteroposterior sway. Decreased mediolateral sway distance and speed was observed when visual feedback was obtained from a mirror, compared to the condition in which the eyes were either closed or open, but the findings were not statistically significant. Moreover, since the anteroposterior sway was not large enough to show changes in the size of the image, a significant difference based on the visual feedback was not exhibited.

The visual feedback from a mirror for patients with stroke led to a significant decrease in the postural sway on surfaces that are more unstable, where the sway distance and speed had increased. However, generalization of the result is difficult due to the small number of subjects. In addition, because the subjects were recruited regardless of fall experience, a correlation of visual feedback with falls could not be determined. Therefore, future studies should examine the effects of visual feedback from a mirror in dynamic states such as sit to stand, and visual feedback training using a mirror on balance and falls in patients with fall experience.

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