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Concurrent effects of attentional focus on postural sway during quiet standing in chronic stroke patients.

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Abstract

The purpose of this study was to investigate the effects of attentional focus on static postural control in chronic stroke patients. Twenty four subjects diagnosed with chronic stroke participated in the experiment. All subjects maintained quiet standing on a force plate for 30 s with three attentional focus conditions: baseline (BL), internal focus (IF), and external focus (EF). No instructions regarding attentional focus were given to the subjects for the BL condition. The subjects were instructed to stand with their attention focused on their feet for the IF condition. Under the EF condition, the subjects were first instructed to check red markers indicated on the force plate. Then the subjects were asked to look front but to concentrate on the markers. The results demonstrated that the EF condition reduced the amount and instability of postural sway more than the other attentional focus conditions. The effects of attentional focus on postural sway were only exhibited in the mediolateral direction. This study suggests that directing attention focused on the movement effect that occurs in the external environment around the body may help stroke patients enhance the postural control of quiet standing. This might result from reduced asymmetric weight distribution with external focus. The present results provide a possible use of external focus to stabilize static posture in physical therapy for patients with stroke.

Keywords: attentional focus, stroke, quiet standing, postural sway, stability

1. Introduction

A stroke is the damages of brain tissue due to ruptured blood vessels or blood clots in the brain. Stroke causes various problems involving motor skills, senses, cognition, language, and perception depending on the region, size, and cause of damage, and its major physical symptom is hemiparesis (Kelley and Borazanci, 2009). Stroke patients with hemiparesis are known to have reduced balance control because of asymmetric weight distribution between the affected and non-affected sides and the weakening of muscles on the affected side (Tyson et al., 2006; Yang et al., 2007). Stroke patients are also known to exhibit increases in static postural sway by about two times compared to normal individuals at the same age (Geiger et al, 2001). These problems with balance are subsequently accompanied by reduced functional recovery and the risk of falling (Lamb et al., 2003). Therefore, it is important to improve the balance ability of stroke patients (for review, Geurts et al., 2005; van Duijnhoven et al., 2016).

The quality of motor performance can be influenced by instructions about attentional focus (for review, Wulf, 2013). Attentional focus can be divided into internal focus and external focus. Internal focus (IF) refers to the state of an individual focusing attention on the body movement that occurs inside the body during physical activity, while external focus (EF) is the state of an individual focusing attention on the movement effect that occurs in the external environment around the body (McNevin and Wulf, 2002). A number of studies have shown that motor performance and learning with EF are more effective than those with IF (for review, Wulf, 2013). In particular, the advantages of EF are also being revealed in control and learning of balance (for review, Kim et al., 2017; Park et al., 2015). Not only studies on normal individuals (Shea and Wulf, 1999; Wulf et al., 2003), but also studies on special populations such as elderly people (Chiviacowsky et al., 2010), patients with Parkinson's disease (Landers et al., 2005; Wulf et al., 2016), and patients with ankle sprain (Laufer et al, 2007) showed that EF is more effective in balance control and learning than IF.

Studies in patients with stroke have also shown that EF improves the quality of motor performance more than IF (Durham et al, 2014; Fasoli et al., 2002; Mückel and Mehrholz, 2014). Fasoli et al. (2002) performed functional reaching tasks for patients with stroke. While the instructions for EF focus on the task of reaching (e.g., "think about where is it on the shelf"), those for IF use a movement-focused task (e.g., "think about how much you straighten your elbow"). Results showed that the EF instructions improved reaching kinematics compared to the IF instructions. Durham et al. (2014) using a reach-to-grasp task also showed that EF feedback is superior to IF feedback. These results suggest that EF produces more stable postural balance to achieve stable arm movement in patient with stroke compared to IF (Geurts et al., 2005). Recently Kim et al. (2019) examined the effect of attentional focus on the gait of stroke patients. The results of this study showed that the quality of walking improved when stroke patients used EF. Specifically, the gait speed increased with longer step and stride lengths in the subjects with EF compared to with IF. Moreover, more weight was applied to the affected leg under EF condition compared to IF.

Although effects of attentional focus in patients with stroke have been examined in several studies, the effects on the postural control are generally unknown. As far as we know, no studies have yet examined effects of attentional focus on static balance for patients with stroke. Static balancing ability for patients with stroke is important not only for prevention of fall but also for foundation of dynamic movements. The purpose of this study was to investigate the effects of attentional focus on static postural control in patients with stroke. A comprehensive review of the results of previous studies suggests that external focus of attention would have positive effects on the balance control of stroke patients (Kim et al., 2017; Park et al., 2015). This study applied internal and external focus while chronic stroke patients were performing quiet standing, and examined the effects of attentional focus by measuring the patients' postural sway. The study set the hypothesis that external focus would be more effective in balance control during the quiet standing of chronic stroke patients than internal focus.

2. Methods

- **Subjects**

The protocol and consent form for this study were approved by the Institutional Review Board of Daegu Catholic University. All subjects signed a written consent from prior to their participation. A total of twenty four subjects voluntarily participated for the study.

The subjects were those who met the following research conditions among patients diagnosed with stroke based on the results of computerized tomography (CT) or magnetic resonance imaging (MRI): those who had symptoms of stroke for over six months; those who had neither visual field defects nor abnormalities in vestibular organs; those who had no orthopedic diseases in their trunk and lower extremities. In addition, the subjects had to be capable of walking independently without an aid or assistive device, and score 24 points or above in the Korean mini-mental state examination (MMSE-K), thereby being able to communicate with others properly. Those who met the above criteria and completed this study were 24 patients (19 men, 5 women) in total. In terms of the paretic side, 14 patients were paralyzed on the right side and 10 patients were paralyzed on the left side. For injury types, 13 subjects showed ischemic injuries and 11 subjects exhibited hemorrhagic injuries. The general characteristics of the subjects are shown in Table 1.

Table 1. General characteristics of subjects

Variable	Mean	Std Dev	Range
Age (yrs)	52.21	10.01	37-73
Height (cm)	166.79	7.02	153-180
Weight (kg)	67.54	8.24	51-88
Time since stroke (months)	29.75	15.20	8-66

3. Experimental procedures

Each subject stood on a force plate (AccuGait®, Advanced Mechanical Technology Inc., MA, USA). The subject then put his/her feet shoulder length apart and attached both arms to the trunk in a comfortable manner. The locations of the feet of each subject were marked so that the respective subject would be able to place his/her feet on the same locations throughout the experiment. During the experiment, the subjects were instructed to look to their front. A white screen was installed 2 m away from the front of the subject to minimize visual confusion.

During quiet standing, the subjects performed all three conditions regarding attentional focus: baseline, internal focus, and external focus. Under the baseline (BL) condition, no instructions regarding attentional focus were given to the subjects. Under the internal focus (IF) condition, the subjects were instructed to stand with their attention focused on their feet while performing quiet standing. Under the external focus (EF) condition, the subjects were first instructed to check red markers indicated on the force plate. And then the subjects were asked to look at the screen but to concentrate on the markers. The two red markers were circles with a diameter of 3 cm and were placed at 10 cm in front of the subjects' feet. All subjects first performed the BL condition. To offset the order effects of attentional focus, 12 subjects first performed the IF, followed by EF, and the remaining 12 subjects performed the two conditions in the reverse order. The orders regarding the conditions of attentional focus were selected randomly. The subjects performed quiet standing three times for each condition of attentional focus. They performed one trial for 30 seconds and were given a one-minute break between the trials to prevent their fatigue. After they completed standing in a condition, they were given a five-minute break to remove any influences of the earlier condition.

4. Data analysis

Postural sway data generated during quiet standing were collected using the AccuGait® (AMTI, Watertown, MA, USA) force plate. Force sensors under the force plate convert the physical force excreted by an individual into ground reaction forces and moments in X (medial-lateral), Y (anterior-posterior), and Z (vertical) axes. The signals from the force plate were recorded by a computer with sampling frequency of 200 Hz, and prepared for offline analysis using MATLAB® (Mathworks, Natick, MA, USA). The raw data of the signals consisted of the ground reaction forces and moments in each axis (F_x, F_y, F_z, M_x, M_y, and M_z). The raw data were filtered using a low-pass Butterworth filter with a cut-off frequency of 15 Hz, and then used to calculate time-varying center of pressure (COP) in anterior-posterior (AP) and medial-lateral (ML) displacements. COP displacements represent postural sway. The followings are COP equations:

$$\mathrm{COP_{AP}} = \frac{M_x - (F_y \cdot dz)}{F_z} \quad \text{and} \quad \mathrm{COP_{ML}} = \frac{M_y - (F_x \cdot dz)}{F_z}$$

where d_z is the distance from the surface to the plate.

The COP displacements were used to calculate the postural sway parameters; COP displacement range, total distance of COP displacement, displacement variability, and mean COP velocity using following equations. All parameters were calculated separately in AP and ML direction. Followings are equations for all parameters.

$$\text{Range} = |\max(\mathrm{COP}) - \min(\mathrm{COP})|$$

$$\text{Total distance} = \sum_{n=1}^{N} |\mathrm{COP}[n]|$$

Displacement variability = stdev(COP)

$$\text{Mean velocity} = \frac{\sum_{n=1}^{N-1} \sqrt{(\mathrm{COP}[n+1] - \mathrm{COP}[n])^2}}{T}$$

where N is the total number of data points (60,000) for the given trial length and T is the time of the trial (30 s). Range represents the linear distance between the most positive and negative COP trajectory positions and indicates the limit of postural sway. Total distance of COP displacement represents the length traveled by the COP for 30 seconds and indicates the total amount of postural sway. Displacement variability is the standard deviation of all COP lengths traveled for 0.005 seconds and indicates that how variable is postural sway length. Mean velocity refers to postural sway length per unit time (1 s). A larger value in this variable indicates a corresponding longer postural sway length per unit time. Displacement variability and mean velocity may represent the instability of postural sway.

5. Results

Figure 1 is an example of COP displacements on ML(x)–AP(y) axes while a participant performed quiet standing with BL, IF, and EF condition. First, we examined the effect of the order of the attentional focus trials. All dependent variables were analyzed in a 2 Order (Internal focus first, External focus first) × 3 Attentional Focus (BL, IF, EF) ANOVA with last factor repeated. For all data sets, neither the main effects of order, nor the interaction between order and attentional focus conditions were significant ($ps > 0.05$), meaning that the order of experimental conditions participants performed did not affect subsequent performance.

COP: center of pressure; AP: anterior-posterior; ML: medial-lateral.

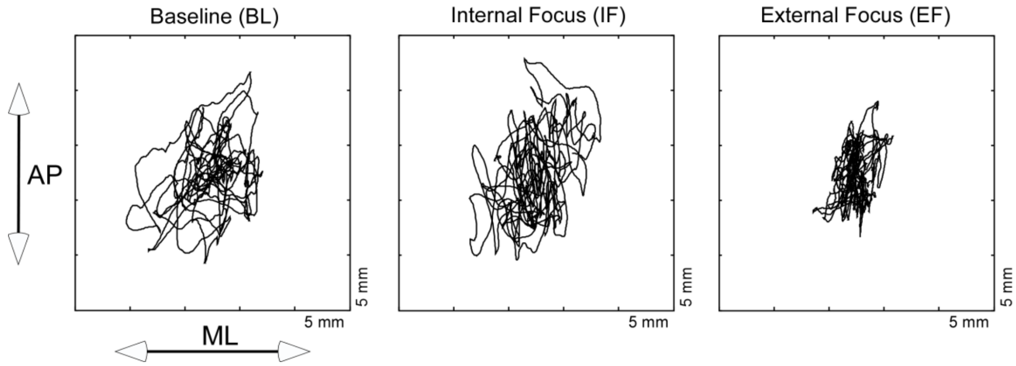

Figure 1. Exampled COP displacements from one participant are shown on ML (medial-lateral) and AP (anterior-posterior) directions during quiet standing with baseline (BL), internal focus (IF), and external focus (EF) conditions.

To examine the effect of the attentional focus on postural sway, all dependent variables were analyzed in one-way repeated measures ANOVAs with the factor of Attentional Focus. There was no significant difference among attentional focus conditions in AP COP range, and ML COP range (ps > 0.05) (Table 2). These findings suggest that attentional focus did not affect range of postural sway. In the analyses of total distance of COP displacement, statistical significance was found in the ML direction ($F_{(2, 46)} = 3.62$, $p < 0.05$), but not in the AP direction ($p > 0.05$). Post-hoc test for the ML direction revealed that total distance of COP displacement was significantly shorter in the external focus condition compared to the other two conditions (Table 2). The analyses of COP displacement variability showed no significance in the AP direction ($p > 0.05$). However, statistical significance was found in the ML direction of displacement variability data ($F_{(2, 46)} = 3.61$, $p < 0.05$). Post-hoc test for the ML direction revealed that the COP displacement was less variable in the external focus condition compared to the other two conditions (Table 2). The analyses of mean COP velocity showed statistical significance in the ML direction ($F_{(2, 46)} = 3.78$, $p < 0.05$), but not in the AP direction ($p > 0.05$). Post-hoc test for the ML direction revealed that the mean COP velocity was less in the external focus condition compared to the other two conditions (Table 2).

Table 2. Means and standard deviations of all dependent variables in all experimental conditions

COP parameters	COP direction	Experimental condition		
		Baseline (BL)	Internal focus (IF)	External focus (EF)
Range (mm)	AP	21.42 ± 5.98	21.78 ± 6.15	20.34 ± 5.82
	ML	14.53 ± 5.59	13.98 ± 5.55	13.11 ± 4.96
Total distance (mm)	AP	354.94 ± 165.20	363.31 ± 167.77	351.52 ± 158.54
	ML	223.80 ± 82.19	216.16 ± 74.95	202.80 ± 75.25

Displacement var. (mm)	AP	0.050 ± 0.025	0.052 ± 0.027	0.049 ± 0.023
	ML	0.032 ± 0.013	0.031 ± 0.011	0.028 ± 0.011
Mean velocity (mm/s)	AP	23.59 ± 11.02	25.15 ± 11.22	23.35 ± 10.55
	ML	14.83 ± 5.50	14.32 ± 5.03	13.42 ± 5.04

6. Discussion

The purpose of this study was to identify the effects of attentional focus on the maintenance of quiet standing in chronic stroke patients. The results of the present study showed that the EF condition was overall effective for chronic stroke patients with difficulties in balance control due to hemiparesis. This result was found to be influenced by the direction of postural sway. That is, the effects of attentional focus were only exhibited in the ML direction, but not in the AP direction.

The present study also demonstrated that while chronic stroke patients were maintaining quiet standing, the EF condition reduced the amount and instability of postural sway more than the other attentional focus conditions. In specific, under the EF condition the values of displacement variability and mean velocity in the ML direction were lower than those under the other attentional focus conditions. That is, the EF condition produced a more consistent and shorter postural sway compared to the other two conditions. This suggests that under the EF condition the motor system better controlled quiet standing to be maintained "quietly", thereby reducing the instability of postural sway. Furthermore, this reduction in the instability of postural sway is thought to be the result of the reduced total amount of postural sway. These present findings accord with a number of previous studies on attentional focus, which are related to balance control and learning (Chiviacowsky et al., 2010; Landers et al., 2005; Laufer et at., 2007; Shea and Wulf, 2009; Wulf et al., 2016; Wulf et al., 2003).

Why was the EF condition effective in reducing the amount and instability of postural sway, unlike the other conditions of attentional focus? Based on the constrained action hypothesis, while internal focus prevents the process of automatic information processing, external focus makes the motor system facilitate this process and therefore helps improve motor control (Kal et al., 2013; McNevin et al., 2003; Wulf et al., 2001; Wulf and Prinz, 2001). The facilitation of automatic motor control can produce faster reactions to perturbations, which eventually increasing the stability of motor behavior (Wulf et al., 2001). A recent study with patients with stroke showed that movements with an external focus of attention were smoother and more stable compared to an internal focus, suggesting the external focus facilitated automatic motor control in the stroke patients (Kal et al., 2013). In the present study, decreases in the amount and instability of postural sway may have resulted from faster reactions to perturbations called "postural sway" through the facilitation of the automatic control of the motor system.

An interesting part of this study was that differences in postural sway were observed only in the ML direction while the AP direction produced no changes in attentional focus. A plausible reason might be that asymmetric weight distribution between affected and non-affected sides in stroke patients influenced their postural sway in the ML direction rather than in the AP direction. Many studies examining static balance in patients with stroke have shown that imbalance in weight distribution increases postural fluctuations (for review, Kamphuis et al., 2013). Marigold and Eng (2006) observed that during quiet standing, larger degrees of asymmetric weight distribution in patients with stroke resulted in larger amounts of postural sway in the ML direction, but showed no correlation with the AP direction. In particular, a recent study by Mansfield et al. (2011) found that patients with stroke had a deficit to synchronize COP control between the limbs, which leads to increased postural sway in ML direction. These results indicate that postural sway of stroke patients is proportional to the degree of weight bearing asymmetry between both feet, which affects selectively the ML direction. Trying these previous findings combined and applied into the finding of the present study, it suggested that the chronic stroke patients in the present study may have been be able to relieve their asymmetric weight distribution more effectively by using the EF condition rather than the other conditions of attentional focus. It should be further examined through in-depth studies about relationship between attentional focus and weight distribution in patients with stroke.

The present results demonstrated that external focus of attention may help stroke patients enhance the postural control of quiet standing and provide physical therapists with clinical implications on their treatment of stroke patients. When stroke patients perform tasks requiring static postural balance, the therapists would be able to improve the patients' postural control effectively by instructing them to practice external focus of attention. Some recent studies have observed the instructions physical therapists use to rehabilitate patients with stroke (Durham et al., 2009; Johnson et al., 2013; Kal et al, 2017). Kal et al. (2017) showed that physical therapists used external focus of attention more often in rehabilitation of stroke patients. On the other hand, according to Johnson et al. (2013) and Durham et al. (2009), both instruction and feedback preferred internal focus of attention in the treatment of patients with stroke. As such, in clinical settings, physical therapists still use a variety of instructions in stroke rehabilitation. However, there is still a lack of evidence as to whether a particular instruction would be effective in motor performance and learning in patients with stroke. The results of this study showed that the external focus of attention during quiet standing seems to help to maintain a static posture, which would be therapeutically feasible to improve postural stability and balance in patients with stroke. Thus, this study will provide a basis for the instruction on the external focus used in clinical practice of stroke patients. Further studies are strongly needed to investigate effects of attentional focus on postural control for patients with stroke.

The limitation of this study is that only one force plate is used for the whole body COP characteristics. Since stroke patients are hemiplegia, characteristics of the feet during static balance should be observed. Future studies need to include the kinetic characteristics of the feet during attentional focus (Mansfield et al., 2011). Second, the present study only examined concurrent changes in postural sway during quiet standing, without an answer to the question of what to expect in balance learning. Further researches are strongly recommended to examine effects of attentional focus on balance learning for patients with stroke.

7. Conflict of Interest

The authors have declared that no competing interests exist. No financial assistances were provided for the present study.

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