

# EEG-biofeedback Intervention Improves balance in Stroke Survivor

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## Abstract

Postural instability while performing daily activity is main problem to individuals with stroke. Increased postural sway is related to postural instability resulting in falls. Internal and external foci of attention were used to decline postural sway of individuals with neurological deficits. Electroencephalogram (EEG) biofeedback may be efficiency device for clinical training which external focus of attention. The purpose of this study is to explore whether external (EEG biofeedback) and internal foci of attention with unstable surface would affect postural sway in chronic stroke. Twenty-one hospitalized people with stroke were participated. Postural sway was measured at three conditions randomly while participants stood on the force platform with unstable surface. The conditions were control (quiet stand), internal focus of attention (focus on the own body), and external focus of attention (focus on the outside of body by EEG biofeedback). The external focus of attention resulted in less postural sway relative to both the internal focus of attention and control conditions. There was no significant difference between the external and internal foci of attention on anteroposterior sway velocity. In conclusions, the results are suggested that external focus of attention better to postural control than internal focus of attention or control condition during standing for individuals with stroke. The outcomes have possibly important for intervention by clinicians and the reduction of postural instability in stroke patients.

**Keywords:** Attention, Balance, Electroencephalogram, Feedback, Stroke

## 1. Introduction

Balance is an essential factor for proper functioning of the locomotor system and many activities of daily living<sup>1</sup>. Postural instability is common in individuals with stroke, resulting in increased risk of falls. Secondary impairments and participation limitations are come from these falls have become socio-economic problems<sup>2</sup>. Thus, optimal rehabilitation goals for functional recovery of patients with stroke should include improving balance and preventing falls<sup>3</sup>.

The ability to maintain balance and an upright posture is a function of intricate interaction among motor, sensory, and cognitive systems<sup>4</sup>. Cognitive impairment is common after stroke and has a negative impact on rehabilitation outcome. The process of maintaining postural

stability requires attention<sup>5</sup>. Attention deficits, parts of cognitive impairment, after stroke affect mobility and a variety of task performances. The task of maintaining a posture requires more attention because of decreased sensory information after stroke<sup>6-8</sup>. Hence, stroke patients should also be trained using attention tasks.

Attention processes employed during rehabilitation utilize either an internal or external focus of attention. When using the internal focus, the performer concentrates on his or her own body and movements; in external, the focus of attention is on the results of their movements and surrounding environment<sup>9</sup>. Although attention resources play a vital role in postural balance, internal focus of attention, focusing on one's own body or movements, may constrain the motor system and interfere with the autonomic postural control process<sup>10</sup>. Several

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studies have reported that external focus is a more effective attention resource than internal focus for improving postural sway in elderly people with reduced balance<sup>11,12</sup>. Fasoliet al.<sup>13</sup> found that both participants with and without cerebrovascular accidents performed functional reach tasks, such as moving an apple from a shelf into a basket and moving an empty coffee mug, more efficiently when presented with external focus rather than with internal focus instructions. These foci of attention improve postural stability and performance.

Balance training using force platform with visual feedback system has been applied to improve balance and function in chronic stroke patients<sup>14,15</sup>. The participant detects the movement and position of his or her center of gravity using delivered information through visual feedback. This information employs a form of attention, such as external focus, to improve postural stability<sup>16</sup>. Electroencephalogram (EEG) biofeedback has been found to improve attention in those with attention deficits<sup>17,18</sup>. However, its main use is to ameliorating certain states related to brain electrical dysfunction<sup>19</sup>. In the present study, EEG biofeedback was used as an external focus of attention in the form of visual feedback. Participants were instructed to concentrate on the fireworks displayed on a monitor and to blink their eyes to burst the firework.

In a study on individuals with Parkinson's disease<sup>20</sup>, no variations in postural sway on task performance on a stable surface was noted between those using external and internal focus. However, when an unstable surface was used, external focus group had less sway than both internal focus and control groups.

We assessed the effect of EEG biofeedback, as an external focus of attention, on balance on an unstable surface in stroke survivors.

## 2. Methodology

### 2.1 Study Subjects

Twenty-one hospitalized individuals (16 males and 5 females, aged 41–75 years) diagnosed with stroke by a neurologist at H rehabilitation hospital participated in this study. Inclusion criteria were chronic (more than 6 months) first instance hemi-paretic stroke with ability to maintain upright posture on an unstable surface independently for more than 30 seconds, a score of 24 or more in the mini-mental status examination, and the ability to look continuously at a screen. Those with

dizziness or light headedness were excluded. Participants were also excluded if they had cerebellar dysfunction affecting balance ability and other musculoskeletal disorder. Demo-graphic characteristics of the participants are described in Table 1. The study was approved by the Institutional Review Board of the Sahmyook University and informed consent was obtained from all participants.

### 2.2 Apparatus and Procedure

Balance assessment was conducted using the Good Balance System (GBS; Metitur Ltd., Jyväskylä, Finland) that consisted of a triangular force platform and safety bar. The GBS transmits wireless data through Bluetooth to the laptop PC with data sampling rate of 50 Hz. Mediolateral and anteroposterior postural sway velocities, represented by x and y velocities, respectively, were measured. Velocity moment, mean area of trajectory of center of pressure, was also calculated.

Participants stood barefoot on the GBS with unstable surface over a 6 cm-thick balance pad (Airex, Sins, Switzerland) and measurements were taken under three conditions: control, internal and external foci of attention, while standing as immobile as possible. When postural sway was measured, participants were instructed to look straight ahead and hang their arms naturally<sup>9,11,16,21</sup>. They were asked to look at a dot 2 m ahead and stand quietly (control condition), to focus on their foot to minimize postural sway while looking the dot (internal focus of attention condition), and to focus on the screen ahead by EEG biofeedback (external focus of attention condition) showed in Figure 1. EEG-biofeedback was designed as follows; 1. EEG signal was detected by EEG single dry



**Figure 1.** Participant is performing the task under external focus of attention.

**Table 1.** Demographics of the subjects

Patient	Sex	Age (year)	Weight (kg)	Height (cm)	Time since onset of stroke (months)	MMSE (score)	Falls
1	Female	45	48	150	80	27	Yes
2	Female	56	56	150	40	25	No
3	Male	68	57	165	17	29	Yes
4	Male	62	63	168	32	26	No
5	Male	60	77	170	27	29	No
6	Male	75	70	168	13	29	No
7	Male	42	73	172	7	28	No
8	Male	41	70	170	35	25	No
9	Female	69	59	158	9	27	Yes
10	Male	50	67	164	53	26	No
11	Female	63	57	162	8	29	No
12	Male	71	54	160	7	27	No
13	Male	47	75	162	19	29	No
14	Male	42	51	170	21	29	No
15	Male	64	78	141	19	27	No
16	Male	74	70	178	7	26	No
17	Male	43	63	176	11	26	No
18	Male	62	62	168	22	29	No
19	Male	55	58	164	18	28	No
20	Female	51	58	157	60	29	Yes
21	Male	69	58	153	16	29	Yes
<i>Total</i>	16/5	57.57(11.38)	63.86(8.93)	164.10(7.72)	24.81(19.44)	27.57(1.47)	5/16

MMSE: Mini-Mental State Examination.

Total values are represented as means(standard deviation), Sex(male/female), and Falls(yes/no).

sensor mobile headset (Mindwave, Neurosky, San Jose, CA, USA). 2. The detected signal was embodied to fireworks displayed on screen using the software(blinkzone, Neurosky, San Jose, CA, USA). 3. Participants were asked to focus on the fireworks. The software was designed so that the fireworks rose higher when a participant focused more and the firework would burst when they blinked. The higher the point of burst the greater was score. To minimize the impact of unfamiliar EEG-biofeedback, time for practice was given in advance. The sequence of conditions in each participant was determined randomly to prevent a carryover effect. Base of support within measurements was maintained equally under all conditions. Each attention condition was implemented for 35 seconds per trial for three trials, and results were measured only

for 30 seconds. The first 5 seconds were not measured to provide allowances for adaptation. To minimize fatigue due to focusing and worsening of postural sway due to long durations of standing, 10 minute breaks were given between conditional changes. Three measurements were averaged for the final result.

Since all measurements were taken on an unstable surface, to prevent falls, a therapist always accompanied each participant.

### 2.3 Method of Data Analysis

All data were analyzed using SPSS 19.0 software (SPSS Inc., Chicago, IL, USA). Descriptive statistics are expressed as means and standard deviations. Postural sway in each 30 second trial was analyzed across three conditions

(Foci of attention: external, internal and control) using repeated measures analysis of variance. Multiple comparisons between foci of attention were conducted using Bonferroni’s adjustment. The significance level was set at 0.05.

### 3. Results

The postural sway of attention conditions is shown Table 2. The external focus of attention condition showed a significant decrease in mediolateral and anteroposterior sway velocities and velocity moment compared to control condition ( $p < .05$ ). The internal focus of attention condition showed a significant reduce in anteroposterior sway velocity compared with control condition ( $p < .05$ ). For external compared to internal focus of attention conditions, external focus decreased significantly in mediolateral way velocity ( $p < .05$ ). In anteroposterior sway velocity, the external and internal focus of attention did not differ significantly. However, the percentage change compared to control condition of external focus was higher percentage than internal focus (10.19% versus 4.19%, respectively) showed in Figure 2.

### 4. Discussion

This research was conducted to study the effect of external focus of attention through EEG-biofeedback, on the improvement of chronic stroke patients’ stability. Postural sway was demonstrated to be less under

**Table 2.** Comparison of postural sway for participants with stroke based on the type of attentional focus (control, internal, or external)

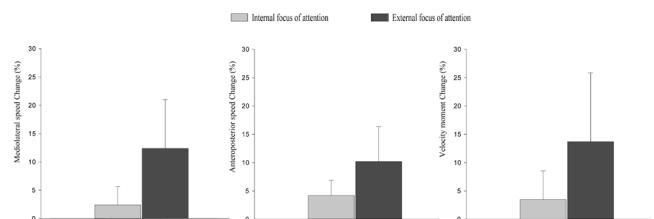
	Control	Attention		P
		Internal focus	External focus	
ML (mm/s)	15.08(5.77)	14.49(4.96)	12.76(4.21)*,§	.003
AP (mm/s)	18.02(6.30)	17.07(5.46)*	16.04(6.18)*	.010
VM (mm <sup>2</sup> /s)	86.25(56.99)	79.81(46.89)	67.98(35.51)*,§	.009

Values are represented as means (standard deviation). ML; Mediolateral sway velocity, AP; Anteroposterior sway velocity, VM; Velocity Moment.

Multiple comparisons are adjusted by Bonferroni. \*Represents significant difference compared to control group. §Represents significant difference compared to internal focus of attention group. Statistical significance was set at p value of 0.05.

the external focus of attention condition wherein the patient focused on fireworks through EEG-biofeedback as compared to the internal focus of attention condition wherein the focus was on his/her own foot and control condition wherein they still. This is in conformance with previous studies that have shown that external focus is more effective than either internal focus or control condition in balance and performance of actions. Studies<sup>11,22</sup> have been performed in patients with Parkinson’s disease and elderly adults by instructing them to focus on the unstable surface or a specific point on it, respectively. The finding that an external focus of attention improves balance has important applications in balance training for stroke patients with lack of balance and increased risk of falls. A study of Pedalo riding was demonstrated that the external focus of attention was valuable motor learning method in performance and skill<sup>23</sup>. According to these results, attention training using EEG-biofeedback in stroke patients may be useful intervention for acquiring novel functional skills. Enhancement of task performing was done by not focusing his or her own movement but focusing an external environment<sup>24</sup>. Thus, intervention for stroke can be consisted of external focus of attention to facilitate motor learning.

Our results show that an internal focus of attention also reduced posture sway significantly in comparison to control conditions. This is contrary to previous research finding from healthy volunteers and studies that show that internal focus decrease the efficiency in maintaining static balance by interrupting the auto regulatory mechanism for postural control<sup>9</sup>. It is also different from a few other studies that have concluded that internal focus does not provide any additional advantage over a control condition without any attention component<sup>22</sup>. It is possible that the internal focus made patients became aware of



**Figure 2.** Percentage changes in mediolateral and anteroposterior speeds and velocity moment in internal and external focus compared to control condition.

their body movement and did not disturb their control of movement, since the subjects of this study were stroke patients with reduced automatic posture control capability.

A significant difference in sway velocity between internal and external focus was noted only in mediolateral sway and not in anteroposterior sway in this study. Previous retrospective study of balance during narrow base standing, eyes closed condition in elderly<sup>21</sup>, elderly fallers demonstrated greater mediolateral postural sway than non-faller. The result of this study implies the external focus of attention can be solutions to reduce the risk for falls. Nafati and Vuilleme<sup>10</sup> revealed that executing concurrent attention demanding task could improve static balance by decreasing internal focus of attention. Our results demonstrate that EEG-biofeedback training is possible to embody in balance training for stroke patients.

Single dry sensor mobile headset was used as EEG equipment for this study. Measuring EEG using wet EEG electrodes with multiple channels poses many difficulties. Multiple electrodes being attached to their heads is stressful experience for the subjects. It is also difficult for examiners to install the electrodes in accurate locations<sup>25</sup>. However, the EEG headset used in this study is simple and portable, and hence easily accessible at homes and hospitals, thus better suited to training using EEG-biofeedback. It can be easily applied on stroke patients who have attention and cognitive deficits and therefore useful for home exercise programs for balance improvement.

The limitations of this study are as follows: 1. Since only the immediate postural sway was measured, the effect of attention training was not accounted for, 2. Effect of change of focus could not be studied since EEG-biofeedback was used only for external focus of attention and 3. The results have limited generalizability as the sample size was small and only chronic stroke patients were included. The improvement of balance through long term focus training in stroke patients in various stages of recovery, and improvement of focus through EEG-biofeedback for stroke patients with persistent attention deficits needs to be further studied.

## 5. Conclusion

In conclusion, EEG-biofeedback can be used as an external focus of attention in the rehabilitation of chronic stroke patients to improve balance and prevent falls.

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