



Original Article

## Whole body vibration may have immediate adverse effects on the postural sway of stroke patients

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**Abstract.** [Purpose] This study applied whole body vibration (WBV) at different vibration frequencies to chronic stroke patients and examined its immediate effect on their postural sway. [Subjects and Methods] A total of 14 (5 males, 9 females) stroke patients participated. The subjects were randomly assigned to one of the two vibration frequency groups (10 Hz and 40 Hz). Right before and after the application of WBV, the subjects performed quiet standing for 30 seconds, and COP parameters (range, total distance, and mean velocity) were analyzed. [Results] The 10 Hz WBV did not affect the postural sway of stroke patients. The 40 Hz WBV increased postural sway in the ML direction. [Conclusion] The results suggest that WBV application to stroke patients in the clinical field may have adverse effects and therefore caution is necessary.

**Key words:** Whole body vibration, Stroke, Postural sway

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### INTRODUCTION

Stroke has been recognized as having significant deleterious outcomes, which limit patients' quality of life<sup>1-3</sup>). A major physical symptom of stroke is hemiplegia<sup>4</sup>). Hemiplegia triggers asymmetric weight distribution between the affected side and the non-affected side, which causes problems with balance control<sup>5, 6</sup>). Another problem of hemiplegia is loss of somatosensation and this is a factor which makes balance adjustment of stroke patients difficult<sup>7-9</sup>). Recently, whole body vibration (WBV) has been used to improve the balance ability of stroke patients. Whole body vibration (WBV) exercise improves elderly individuals' balance and gait and is an effective intervention for fall prevention. WBV exercise is also effective at improving bone strength, muscle strength of the lower extremities, and functional mobility<sup>10</sup>).

One of the reasons why WBV improves balance ability is somatosensory stimulation<sup>11</sup>). It has been reported that WBV is effective at decreasing the risk of a fall<sup>12</sup>), increasing the stability of elderly people<sup>13</sup>), and improving the postural stability of patients with Parkinson's disease<sup>14, 15</sup>). In addition, in the case of stroke patients, the application of WBV is known to immediately decrease postural sway<sup>16</sup>).

The effect of WBV according to vibration frequency is known to some extent. In the case of healthy people, in the frequency range of 3 to 30 Hz, motor ability adjustment is elicited through sensory nerve facilitation, and in the frequency range of 25 to 200 Hz, WBV activates sensory and motor nerves, which elicit motor ability adjustment through the corticospinal pathway<sup>17, 18</sup>). However, it is not clear yet how WBV of different vibration frequencies affects the postural control of stroke patients. This study applied WBV at different vibration frequencies to chronic stroke patients and examined its immediate effects on their postural sway.

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## SUBJECTS AND METHODS

The protocol and consent form for this study were approved by the Institutional Review Board of the Catholic University of Daegu. All subjects signed a written consent form prior to their participation. All the subjects understood the purpose of this study and consented to voluntarily participation in this study. The selection criteria for the patients with hemiplegia resulting from a stroke were as follows: onset of stroke six months or longer before, absence of orthopedic disease in both limbs, the ability to independently walk without the help of assistive devices, a score in the mini-mental status examination-Korea of 24 or higher points, and the ability to communicate with and understand others. Fourteen subjects satisfied the above criteria and completed this study (5 males, 9 females). Eight subjects' paretic side was the right side and six subjects had a paretic left side. Seven subjects were ischemic stroke patients, and 7 were hemorrhagic stroke patients. The general characteristics of the subjects are shown in Table 1.

### Procedure

For vibration stimulation of the whole body, Vibro Wedge<sup>®</sup> (NEXT, Seoul, Korea) was used. Vibro wedge<sup>®</sup> generates motor vibration in the up and down (vertical) direction. Its range of vibration frequency is 10 Hz at the minimum and 40 Hz at the maximum. This study utilized vibration frequencies of 10 Hz (N=7) and 40 Hz (N=7). The subjects were randomly assigned to one of the two vibration frequency groups.

The subjects stepped on the board of the Vibro Wedge<sup>®</sup> in shoes, independently maintained a posture, with both feet spread at shoulder width. The subjects independently maintained this standing posture while the board was vibrating. In order to protect the subjects from falling, two assistants stood on the left and right sides of the subjects. Vibration was applied once for 10 minutes. After the application of 10-minute WBV, a one-minute break was given to prevent fatigue of the subject.

Right before and after the application of WBV, the subjects performed quiet standing for 30 seconds. Each subject stood on a force plate (AccuGait<sup>®</sup>, Advanced Mechanical Technology Inc., MA, USA). The subject then put his/her feet shoulder width apart and held both arms by the sides of the trunk in a comfortable manner. The locations of the feet of each subject were marked so that the subject would be able to place his/her feet on the same locations throughout the experiment (before and after WBV). During the experiment, the subjects were instructed to look to the front.

### Data Analysis

Postural sway data generated during quiet standing were collected using the AccuGait<sup>®</sup> force plate. Force sensors under the force plate convert the physical force exerted by an individual into ground reaction forces and moments in the medial-lateral, anterior-posterior, and vertical directions, the x, y, and z axes, respectively. The signals from the force plate were recorded by a computer at a sampling frequency of 200 Hz, and prepared for offline analysis using MATLAB<sup>®</sup> (Mathworks, 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 the time-varying center of pressure (COP) of the anterior-posterior (AP) and medial-lateral (ML) displacements. COP displacements represent postural sway, and were calculated as follows:

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

where  $d_z$  is the distance on the surface of the plate.

The COP displacements were used to calculate the postural sway parameters: COP displacement range, total distance of COP displacement, and mean COP velocity. All parameters were calculated separately in the AP and ML directions as follows:

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

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

**Table 1.** General characteristics of the subjects

Variable	Mean	Stdev	Range
Age (years)	68.2	1.3	66–70
Height (cm)	156.3	7.4	150–170
Weight (kg)	66.5	7.1	54–74
Time since stroke (months)	18.4	4.5	12–29

$$\text{Mean velocity} = \frac{\sum_{n=1}^{N-1} |\text{COP}[n+1] - \text{COP}[n]|}{T}$$

where  $N$  is the total number of data points (60,000) and  $T$  is the total duration (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 in 30 seconds and indicates the total amount of postural sway. Mean velocity refers to postural sway length per unit time (1 s). A larger value of this variable indicates a corresponding longer postural sway length per unit time. Mean velocity may represent the instability of postural sway.

### Statistical Analysis

Statistical analyses were performed separately for each of the vibration frequencies of 10 and 40 Hz. Dependent variables in the current study were the COP displacement range, total distance of COP displacement, and mean COP velocity. All dependent variables were analyzed in the AP and the ML directions. The paired t-test was used to examine the significance of differences between pre- and post-trial within each frequency group. The statistical significance level was chosen as  $\alpha=0.05$ .

## RESULTS

Table 2 shows the results of COP parameters of the different vibration frequencies. Between before and after the application of WBV of 10 Hz, there were no significant differences ( $p > 0.05$ ) in the COP parameters. This result signifies that the application of 10 Hz WBV did not affect the stroke patients' static balance ability. After WBV of 40 Hz, there were significant differences in the total distance of COP displacement and mean COP velocity in the mediolateral (ML) direction. This means that application of 40 Hz WBV increased the amount of static postural maintenance (total distance) and instability (velocity) in the ML direction, suggesting an adverse effect on static balance maintenance.

## DISCUSSION

This study applied 10 Hz and 40 Hz WBV to chronic stroke patients and examined how the vibration frequency of WBV affected postural sway. The 10 Hz WBV did not affect the postural sway of the stroke patients, while the 40 Hz WBV increased the postural sway in the ML direction. The results of this study are discussed below.

First, the results of this study show that WBV of low vibration frequency (10 Hz) did not improve the immediate balance ability of the chronic stroke patients. This result is different from the result of a study by van Nes et al.<sup>16)</sup>, in which WBV of 30 Hz decreased immediate postural sway of chronic stroke patients. This might suggest that 10 Hz WBV is not fast enough to activate the integration of somatic sense in comparison to WBV of 30 Hz as reported by Priplata et al.<sup>11)</sup>. In addition, 10 Hz WBV did not activate excitation of the spinal reflex to elicit improvement in the adjustment ability of the lower limb and trunk muscles<sup>19)</sup>.

Second, WBV of 40 Hz, a relatively high vibration frequency, increased postural sway. That is, WBV at a frequency higher than the 30 Hz employed by van Nes et al.<sup>16)</sup>, triggered a decrease in the immediate static balance ability of the chronic stroke patients. There are two possible explanations for this result. First, there is a possibility that WBV of 40 Hz disturbed the integration of the stroke patients' somatic senses<sup>11)</sup>. In the case of stroke patients, there is a loss of somatic sense of about 50%<sup>20)</sup>, and integration of somatic sense information is difficult<sup>7-9)</sup>, therefore, their postural sway is larger than that

**Table 2.** Statistical analysis of the dependent variables of the experimental conditions

Frequency	COP parameters	Direction	Pre-test		Post-test	
			Mn (stdev)	Range (min-max)	Mn (stdev)	Range (min-max)
10 Hz	Range (cm)	AP	3.05 (0.71)	2.03-4.18	2.89 (0.50)	2.27-3.57
		ML	3.08 (2.24)	1.16-7.09	3.17 (1.28)	1.72-4.56
	Total distance (cm)	AP	47.42 (16.43)	29.89-72	47.75 (16.57)	26.14-72.54
		ML	34.38 (16.34)	15.38-58.22	30.74 (9.62)	20.19-44.36
	Velocity (cm/s)	AP	3.15 (1.09)	1.99-4.77	3.33 (1.40)	1.73-5.74
		ML	2.28 (1.10)	1.01-3.87	2.06 (0.67)	1.34-3.04
40 Hz	Range (cm)	AP	3.79 (1.52)	2.45-5.83	5.36 (2.09)	3.25-8.8
		ML	2.79 (1.14)	1.46-4.78	5.62 (3.73)	3.05-12.52
	Total distance (cm)	AP	71.54 (37.90)	29.25-114.4	89.25 (50.58)	38.35-178.03
		ML	36.3 (17.03)	21.44-59.77	57.18 (29.51)	25.2-180.42*
	Velocity (cm/s)	AP	4.76 (2.52)	1.94-7.61	6.08 (3.42)	2.55-11.85
		ML	2.41 (1.13)	1.42-3.87	3.86 (1.93)	1.67-7.21*

\*:  $p < 0.05$

of healthy subjects<sup>21</sup>). Also, strong WBV stimulates muscle spindle receptors, generating hallucinatory perception<sup>22</sup>) in the articular locations, and this would elicit large errors in joint position sense<sup>23</sup>). Second, WBV of 40 Hz may trigger excessive tension in the lower extremity muscles, fatiguing them. It has been reported that WBV of greater than 30 Hz may trigger muscle fatigue even in healthy adults<sup>24</sup>). In stroke patients whose balance ability has been reduced due to muscle weakening and asymmetric weight load, strong WBV caused relatively greater activity in the lower limb muscles of the non-paretic side as evidenced by the accumulation of fatigue markers, such as lactic acid, within the muscles<sup>25–29</sup>). Muscle fatigue results from exhaustion of glucoside and adenosine triphosphate, triggering decrease in postural adjustment ability and balance ability<sup>30–33</sup>).

In conclusion, this study showed that application of WBV to chronic stroke patients was not helpful for improving their immediate balance ability. The adverse effects of WBV have been reported in previous studies<sup>24, 34–38</sup>). However, some studies have reported positive effects<sup>16, 39–43</sup>). These conflicting results mean that further research is needed. Finally, this study proposes that application of WBV to stroke patients in the clinical field may have adverse effects, and therefore caution is necessary.

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