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# Does whole-body vibration training in the horizontal direction have effects on motor function and balance of chronic stroke survivors? A preliminary study

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**Abstract.** [Purpose] The objective of this study was to investigate the effects of whole-body vibration (WBV) in the horizontal direction on the motor function and balance of chronic stroke survivors. [Subjects and Methods] This study was a randomized controlled trial. Twenty-one individuals with chronic stroke from an inpatient rehabilitation center participated in the study. The participants were allocated to either the WBV training group or the control group. The WBV training group (n = 12) received whole-body vibration delivered in the horizontal direction (15 min/day, 3 times/week, 6 wks) followed by conventional rehabilitation (30 min/day, 5 times/week, 6 wks); the control group (n = 9) received conventional rehabilitation only (30 min/day, 5 times/week, 6 wks). Motor function was measured by using the Fugl-Meyer assessment, and balance was measured by using the Berg Balance Scale (BBS) and the Timed Up and Go (TUG) test before and after the interventions. [Results] After the interventions, all variables improved significantly compared with the baseline values in the WBV training group. In the control group, no significant improvements in any variables were noted. In addition, the BBS score in the WBV training group increased significantly compared with that in the control group. [Conclusion] WBV training with whole-body vibration delivered in the horizontal direction may be a potential intervention for improvement of motor function and balance in patients who previously experienced a stroke.
**Key words:** Stroke, Whole-body vibration, Motor function

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## INTRODUCTION

Common impairments after stroke include muscle weakness, abnormal muscle tone, and sensory loss. These impairments are related to limitations in daily activities as well as balance ability and gait performance[1)]. In particular, impaired balance likely leads to decreased activities of daily living and quality of life[2)]. Therefore, the ultimate goal of stroke rehabilitation is reducing the degree of dependence in daily activities, and for this goal, the recovery of balance ability is important.

Many interventions for improving balance ability have been studied and developed. Among them, whole-body vibration (WBV) is promoted as an alternative to other interventions. WBV training is performed by standing on a vibrating platform in a static position or while performing dynamic movements. In previous studies, it was suggested that WBV training could improve physical functions. A few studies claimed that WBV training has beneficial effects on balance and gait ability in nursing home residents[3, 4)]. Additionally, several studies asserted that WBV training is effective in patients with neurological abnormalities such as cerebral palsy[5–7)] and multiple sclerosis[8, 9)]. A few studies in particular identified WBV training as a feasible intervention for poststroke patients[10–14)]. Van Nes et al. observed a short-term effect of WBV on postural control in patients who experienced a hemiplegic chronic stroke[10)], and a second study by van Nes et al. demonstrated the long-term effect of WBV on balance recovery and activities of daily living in the post-acute phase of stroke[11)]. Additionally, a recent study by Silva et al. suggested the effect of WBV on the Six-Minute Walk Test and Timed Get-Up-and-Go Test in stroke patients[14)].

Commonly, the vibrations in WBV training are believed to initiate muscle contractions by stimulating the muscle spindles and alpha motor neurons, thereby having a similar effect as other forms of conventional training such as resistance training[15)]. The vibrations are typically delivered in a vertical or alternately vertical direction. In other words, WBV training is repeated using two forms of vibration such as vertical forces delivered to both feet simultaneously or upward forces delivered to only one foot at a time[16)]. However, it has been suggested that WBV has a number

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of adverse effects known to disturb normal function in the visual, vestibular, digestive, and reproductive systems[17–19].

Recently, a system for delivering WBV in the horizontal direction was developed. A WBV device including a footplate that could move perpendicularly was developed as a training device. However, no study has investigated the effect of WBV provided in the horizontal direction. Thus, in this study, we investigated the effect and potential of WBV delivered in the horizontal direction on the motor function and balance ability of poststroke patients.

## SUBJECTS AND METHODS

This randomized controlled trial was conducted over a 6-week period with measurements of motor function and balance performed before and after the interventions. Poststroke inpatients at H Rehabilitation Hospital were recruited. To recruit participants, we advertised the purpose of the study and its criteria throughout the hospital. Thirty patients were recruited, and a research assistant screened volunteers by using the following inclusion criteria: > 6 months after stroke onset, no problems with auditory or visual functions, ability to stand for > 10 min independently, not taking any medication that can influence balance and gait ability, no orthopaedic injuries that could influence balance and gait ability, and a Mini-Mental State Examination score > 24. Moreover, participants who had uncontrolled blood pressure or angina, a history of seizure, or had received any intervention other than conventional therapy were excluded. Four participants who did not meet the selection criteria were excluded from the study. These patients included 2 patients who had a stroke < 6 months previously, 1 patient who could not stand for > 10 min independently, and 1 patient who was using a medication that could influence balance ability. The 26 participants who fulfilled the inclusion criteria participated in this study. Patients provided informed consent. Table 1 presents the characteristics of the participants.

A research assistant randomly allocated the participants into the WBV training group or control group by using a random number table. The WBV training group received whole-body vibration training with conventional rehabilitation (n = 13), and the control group received conventional rehabilitation only (n = 13). The researcher and assessors were unaware of the group assignments. Before applying each intervention and 1 day after the interventions over a 6-week period, the motor function and balance of all participants were measured by using clinical tools, such as the Fugl-Meyer (FM) assessment, Berg Balance Scale (BBS), and Timed Up and Go (TUG) test. During the study, one patient was discharged from the WBV training group; in the control group, one patient dropped out due to hip fracture as a result of falling, and three patients were discharged.

WBV training was performed by using a WBV device (Extream 1000; AMH International Inc., Incheon, Republic of Korea) at a frequency of 1–3 Hz with an amplitude of 30 mm. Training was performed thrice a week for 6 weeks, with each session lasting for 20 min. The Extream 1000 applies WBV in the horizontal direction. The device consists of a slide-alternating vibrator working as a platform, control panel for operation, and safety bar. Before the intervention, a research assistant explained the procedures for using the device and its safety issues. During WBV training, participants stood with their knees and hips slightly bent on a platform. The platform only moves alternately back and forth in the anterior and posterior directions. The participants stood on the platform moving back and forth in the anterior posterior directions for 10 minutes, and then they changed their posture that could move side to side directions for same time. During the WBV training, the participants performed standing static only and were allowed to hold a safety bar located on each side. If the participants complained of any discomfort such as pain, dizziness, and nausea, the training was discontinued. However, no reports of discomfort during WBV training were documented. Conventional physical therapy included muscle facilitation exercises emphasizing the neurodevelopmental treatment approach, muscle strengthening, balance training, and gait training.

The motor function of the lower extremities was measured by using the FM assessment[20]. It is a tool used to examine the degree of motor recovery in stroke patients quantitatively. The highest possible score for lower motor function in the FM assessment is 34. The BBS and TUG test were used for dynamic balance assessment. The BBS and TUG test are valid and reliable instruments for measuring both the static and dynamic aspects of balance in stroke patients[21].

PASW Statistics for Windows ver. 18.0 was used for statistical analysis. For all data, the mean and standard deviation of each factor were calculated by using descriptive statistics. A paired t-test was conducted to compare the changes between baseline and after training within each group. An independent t-test was conducted to compare the changes between the 2 groups during follow-up. The level of statistical significance was set as $p < 0.05$.

**Table 1.** General characteristic of the participants

| | WBV training group | Control group |
|---|---|---|
| Gender (male/female) | 8/4 | 6/3 |
| Age (years) | 59.3 (13.2) | 56.0 (9.1) |
| Height (cm) | 166.2 (9.1) | 166.1 (10.7) |
| Weight (kg) | 71.1 (14.4) | 67.6 (9.6) |
| Time since onset (months) | 19.0 (9.1) | 18.0 (10.9) |
| Etiology (infarction/haemorrhage) | 7/5 | 7/2 |
| Affected side (right/left) | 5/7 | 6/3 |

Values are expressed as the mean (SD) or frequency.

## RESULTS

After training, there were significant improvements in the results of the FM assessment, BBS, and TUG test compared with baseline in the WBV training group ($p < 0.05$). Patients in the control group exhibited no significant improvements in any variables. However, there were significant differences between the two groups at follow-up with respect to the BBS only ($p < 0.05$) (WBV training group vs. control group = FM assessment, −1.58±1.39 vs. −0.44±1.33; BBS, −6.00±5.17

**Table 2.** Changes in outcome measures

| | WBV training group | | | Control group | | |
|---|---|---|---|---|---|---|
| | Baseline | Follow-up | Changes | Baseline | Follow-up | Changes |
| FM-LE (score) | 16.8 (5.4) | 18.3 (5.6)* | −1.6 (1.4) | 14.4 (7.6) | 14.9 (6.8) | −0.4 (1.3) |
| BBS (score) | 43.9 (7.5) | 49.6 (5.1)* | −6.0 (5.2)# | 37.2 (15.4) | 37.8 (15.3) | −0.6 (0.9) |
| TUG (sec) | 37.1 (21.3) | 32.5 (20.5)* | 4.6 (4.1) | 52.5 (29.0) | 52.1 (28.6) | 0.4 (1.5) |

Values are expressed as the mean (SD).
FM-LE: Fugl-Meyer assessment-lower extremity; BBS: Berg Balance Scale; TUG: Timed Up and Go Test
*Significant difference compared with the baseline value within a group.
#Significant difference compared with the control group at follow-up.

vs. −0.56±0.88; TUG test, 4.58±4.09 vs. 0.44±1.51) (Table 2).

## DISCUSSION

In this study, we investigated the effect of WBV delivered in the horizontal direction on the motor function and balance of patients with chronic stroke. The findings suggested that WBV delivered in the horizontal direction may be effective for improving the balance of patients with chronic stroke.

Previous studies have discussed the effect of WBV. A study reported a significant improvement in the anteroposterior COP velocity under the eyes closed condition and the speed of weight shifting in the frontal plane in stroke patients[10]. The present study measured balance by using the BBS and TUG, identified a significant improvement in only the BBS score in the WBV group after training compared with the findings before training, and noted a significant improvement in the WBV group relative to the control group at follow-up. However, in their study, WBV was applied for only a short time, and 30-Hz oscillations were given at an amplitude of 3 mm in the frontal plane. Van Nes et al. applied WBV to stroke patients for 6 weeks and reported significant improvements in BBS and functional ambulation categories after 6 and 12 weeks compared with the baseline[11]. However, they utilized music therapy for the control group and reported no significant difference between the 2 groups after the intervention. This result differed from the findings of our study, which identified a significant difference in balance between the WBV training and control groups after training, as measured by using the BBS. This difference may be attributable to the lack of an additional intervention in the control group in this study. In the study by BrogÅrdh et al., it was demonstrated that there were no significant improvements between a WBV with exercise group and a sham WBV with exercise group in terms of the results of the BBS, TUG test, and 6-min walk test at follow-up[22]. There was a significant improvement in physical function and gait performance after training compared with the baseline in both groups. Consequently, they proposed that WBV had no significant effect. However, no intervention was provided to the control group, and it was not determined whether the effect observed in the WBV group at follow-up was a placebo effect. It is difficult to conclude whether such a difference in study design allows for comparison with our study or the study by BrogÅrdh et al. Therefore, it appears necessary to investigate the placebo effect of WBV administered in the horizontal direction in future studies. A few studies reported negative results concerning the effect of WBV. Marín et al. applied exercise and WBV in an experimental group consisting of patients with stroke versus only exercise in a placebo group for 3 months to investigate the effects of the interventions on the muscle architecture, muscle strength, and balance[23]. They also did not report any significant difference in BBS score and other variables. Pang et al. applied WBV thrice per week for 8 weeks and reported no significant improvement in the functional status of the paretic leg[24]. Although a few studies had findings similar to our study, the effect of WBV remains controversial.

It has been proposed that vibration can provide more intensive and deep stimulation of muscle afferents in patients who have experienced a stroke and induce improvement in postural control compared with sensory input provided by electrical stimulation[25, 26]. In particular, WBV can increase proprioceptive sensory input by targeting the Ia and II afferents of muscle groups and thus induces sensory system-mediated postural control[15, 27]. In addition, WBV provides bilateral stimulation, which may induce plastic changes in both hemispheres after a stroke[28]. On the basis of the functional magnetic resonance imaging and positron emission tomography studies that identify plastic changes in both the cerebral and cerebellar hemispheres after a unilateral stroke, the application of somatosensory stimulation to both sides of the body may be more effective than application only on the paretic side[29, 30].

With this as the background, WBV has been proposed as an effective intervention for patients with a history of stroke. WBV, as utilized in this study, appears to have a beneficial effect. However, WBV was applied in the horizontal direction in this study as opposed to vertically or in a rotating manner. In a sense, a perturbation was applied as a low-frequency, high-amplitude vibration in the horizontal direction. This is why the body moves in the anteroposterior or mediolateral direction, which enables weight bearing in either the anteroposterior or mediolateral direction. In previous studies, weight-shifting training was considered essential in stroke rehabilitation because it facilitates the contraction of antigravity muscles in the lower extremities and can help patients with a history of stroke regain balance and gait ability[31–33]. WBV, as used in this study, is likely to have an effect as a type of weight-shifting training and to provide sensory stimulation to both sides because vibration is provided in the horizontal direction. This is why WBV had a positive effect on the balance of the patients who participated in this study.

Many studies have attempted to study the effect of WBV, but no study has investigated WBV delivered in the horizontal direction. Therefore, this was the first study to investigate the effect of WBV delivered in the horizontal direction. As a result, WBV delivered in the horizontal direction is likely to improve balance in patients who have previously experienced a stroke. However, this study has a few limitations. First, it is difficult to generalize the findings of this study because of its small sample size. Second, a long-term follow-up study on the effect of WBV training was not conducted. So, the lasting training effect was not investigated. Furthermore, bias related to the placebo effect was not controlled because there was no group in which a sham therapy was applied. Finally, the adverse effects caused by vibration delivered in the horizontal direction were not investigated clearly. Therefore, a long-term follow-up study on the effect of WBV delivered in the horizontal direction with larger, more diverse patient groups, as well as an evaluation of the adverse effects of vibration delivered in the horizontal direction, is needed.

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