■ ORIGINAL ARTICLES

Effect of whole-body vibration training on body balance in chronic stroke patients

Koji Nagino[1)], Yoshiteru Akezaki[1)], Kenta Shigemori[1)], Youhei Okada[2)], Kentaro Tokuhisa[3)], Koji Shomoto[2)]

1) Division of Physical Therapy, Department of Rehabilitation Sciences, Faculty of Allied Health Sciences, Kansai University of Welfare Sciences: 11-1 Asahigaoka 3-chome, Kashiwara, Osaka, 582-0026, JAPAN TEL: +81-72-978-0088 FAX: +81-72-978-0377
2) Department of Physical Therapy, Faculty of Health Science, Kio University
3) Department of Rehabilitation Medicine, Nishiyamato Rehabilitation Hospital

JAHS 4 (2): 42-49, 2013. Submitted August. 27, 2010. Accepted April. 18, 2013.

ABSTRACT: Falls are serious problems that disrupt rehabilitation in post-stroke hemiplegic patients. Approximately 5% of falls result in severe injuries, such as hip fractures. Therefore preventing falls is one of the most important goals of post-stroke rehabilitation. Exercise is generally thought to be effective for the prevention of falls. Whole body vibration (WBV) training has been developed as a new modality that can improve lower extremity muscle strength and body balance in elderly people. However, little is known about the effects of WBV training in hemiplegic patients. The aim of this study was to clarify the effect of WBV training for 4 weeks on chronic stroke patients. Thirty chronic stroke patients were enrolled and allocated to either WBV group (WBV, n=15) or control group (CON, n=15). Difference between these two groups was assessed with the Berg Balance Scale, Fugl-Meyer lower extremity score, knee extension strength and 10m gait time before the training or 4 weeks after of it. Although there were no significant effect on Fugl-Meyer lower extremity score, knee extension strength and 10m gait time, the Berg Balance Scale was significantly improved by the WBV training. These results show that WBV training may have the potential to improve body balance in patients with chronic hemiplegia.

Key words: Chronic stroke, whole body vibration, body balance

INTRODUCTION

Falls and fall relate injuries are serious events in stroke patients, because they disrupt rehabilitation and lower the activities of daily living. Approximately 5% of all falls result in severe injuries, such as femur neck fracture. The risk factors for falling in post-stroke patients are old age, sensory loss, dysfunction of lower extremity and a cognitive disability. Preventing falls is therefore one of the most important goals of post-stroke rehabilitation. Improving body balance and activities of daily living following strengthening lower extremities are thought to be important in order to achieve that goal.

It has been generally believed that somatosensory stimulation promotes change in brain plasticity, but the underlying mechanisms are still unclear[1]. Some studies of the functional recovery in stroke patients demonstrated the beneficial effects of somatosensory stimulation for motor functions, body balance, and the activities of daily living : A randomized, controlled trial in 1993 first indicated that electro-acupuncture applied at the paretic body side facilitated recovery of body balance, mobility, and activities of daily living in post-acute stroke patients[2], and some of these effects persisted for up to 2 years after the stroke.[3]

Another method of somatosensory stimulation that shows considerable promises for rehabilitation is vibration therapy. Recently, whole body vibration (WBV) training has been focused by the effect of preventing falls in elderly people. Controlled WBV is a type of physical therapy thought to activate muscles via reflexes.[4] Moreover, clinical studies on the controlled mechanical WBV reported that it may improve muscular performance[5-7] and body balance in young, healthy adults. In 1999, a prospective randomized controlled trial study has been performed to determine effectiveness of controlled WBV and physical therapy.[8] They indicate that controlled WBV and physical therapy are more effective than physical therapy alone in elderly nursing home residents and that WBV and physical therapy improved gait speed, body balance, and timed up and go test time. Regular rehabilitation with WBV in post-stroke patients is considered to have beneficial effects on body balance control and activities of daily living.[9] The post-stroke interval of patients in this study was less than 6 weeks ; therefore in order to clarify the effect of the WBV training for chronic stroke patients, we performed and assessed the WBV training for 4 weeks.

SUBJECTS AND METHOD

Subjects

A total of 30 stroke patients were recruited. All patients had their first supratentorial stroke, confirmed by computed tomography or magnetic resonance imaging scan, and were admitted to the rehabilitation hospital. Inclusion criteria were patients who have (1) more than 6 months interval after the stroke event and (2) an ability to independently walk more than 10 m with or without any gait assistance. Exclusion criteria were who have (1) no stroke-related sensory or motor impairments, (2) cognitive problems that impaired the ability to follow simple verbal instructions, (3) contraindications for WBV such as pregnancy, recent fractures, gallbladder or kidney stones, malignancies, and cardiac pacemakers. All subjects gave their written informed consent to participate in this study. This study was approved by the president of the rehabilitation hospital where this study was carried out.

Intervention

All patients were treated with a conventional rehabilitation program 5 days/week for 4 weeks.

The conventional rehabilitation program was 1 hour/day of physical therapy and occupational therapy. Speech therapy was added to the program if needed.

The WBV training was provided through a commercially available device (Galileo 900, Novotec Medial, Germany). This apparatus consists of a moveable rectangular platform built within a circular ground surface with a support bar, which is mounted on the front. The platform makes fast oscillating movements around a sagittal axis in the middle. Subjects were required to stand on the platform with their feet at an equal and standardized distance from the axis of rotation so that the vibration amplitude was about 3 mm. The frequency was set at 20 Hz. The subjects were instructed to adopt a “squat” position with slight flexion at the hips, knees, and ankle joints to damp the vibrations nearly at the pelvic level. They were allowed to hold the support bar, and wear a harness that was hung from the ceiling (Fig. 1). An experienced physical therapist supervised all the WBV administration. The WBV was administered in 5 x 60 sec sessions, 3 days per week for 4 weeks.

Outcome measures

The state of functional balance was assessed with the Berg Balance Scale (BBS) and Functional Reach Test (FRT). The state of all patients was assessed with the Fugl-Meyer Assessment of lower extremities, strength of knee extension on the paretic side and non-paretic side, and gait speed (m/min).

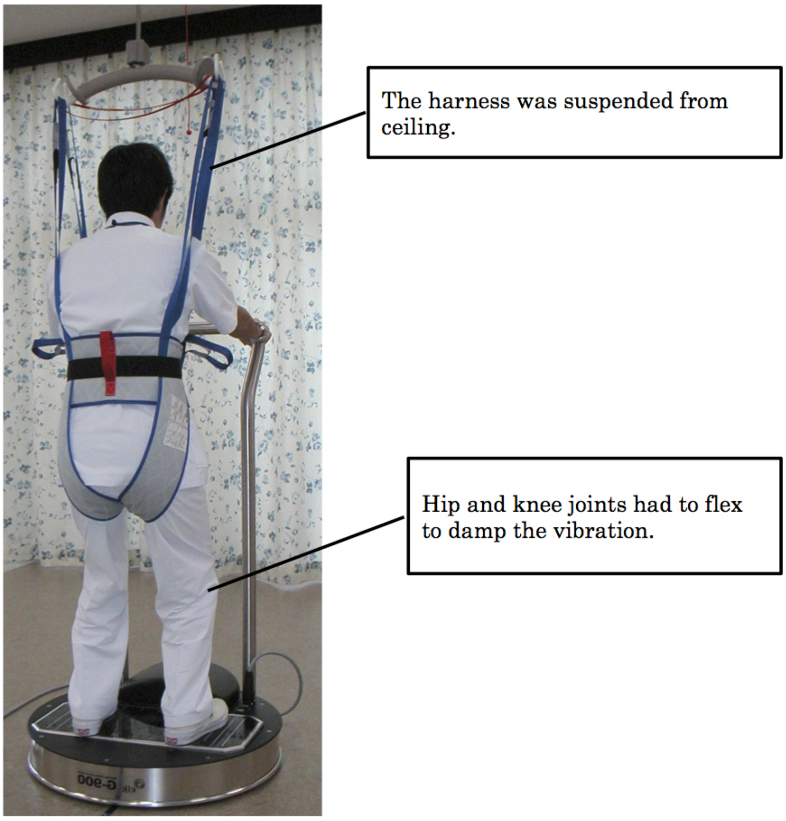

Figure 1　Whole-body vibration training
Subject stand on the device with knee and hip flexed, and they must wear a harness suspended from ceiling to prevent falls.

Procedure

Thirty patients that conform to the criteria were randomly allocated to the WBV or control (CON) group by using a random number table. Patient characteristics were gathered from the medical history and a baseline assessment was carried out before the start of the program. The outcome measures were repeated after 4 weeks of the program.

Statistical Analysis

Independent samples *t* -test and the χ^2test were used to compare both groups at baseline. A 2-way analysis of variance (group × time) was used to assess the effects of treatment depending on the group allocation. Statistical significance was set at $p<0.05$. All statistical analyses were carried out with the GraphPad Prism software package, ver. 4.0 (GraphPad software, Inc. CA, USA).

RESULTS

Thirty patients were allocated to either the WBV group (n=15) or the CON group (n=15). All patients participated in both the baseline and after intervention assessment. All patients in the WBV group completed all of the entire program.

Patients' characteristics of the WBV and the CON groups were compared at baseline (Table 1). Table 2 indicates the values of all outcome measures with their standard deviations. Significant differences were observed in the BBS (F=9.569, p=.005), the Fugl-Meyer assessment (F=11.50, p=.002), knee extension strength on the paretic side (F=4.888, p=.035), and the FRT (F=4.409, p=.05) between these two groups. However, there were no significant differences in the knee extension strength on the non-paretic side and gait speed. We performed further analysis about time or group effect on the BBS, the Fugl-Meyer assessment, and knee extension strength on the paretic side by the WBV training (Fig. 2). Significant difference of the time effect was observed in the BBS, the Fugl-Meyer assessment, and knee extension strength on the paretic side, but the group effect was observed only in the BBS. These results indicate that the WBV training might have a weak effect on the Fugl-meyer assessment, and knee extension strength on the paretic side. Finally, the WBV training has no significant effect on the FRT in ether time or group effect.

No adverse reactions occurred during or directly after WBV.

DISCUSSION

In the present study, we examined the effects of repeated WBV on standing balance in chronic stroke patients. A time difference in the functional improvement between the WBV and the CON group was observed only on the BBS, although a group difference was observed on the BBS, the Fugl-Meyer assessment, knee extension strength on the paretic side, and the FRT. Our current study, therefore, indicates that the WBV training was, at least in part, effective on chronic stroke patients.

Vibration is one of the strongest methods for stimulating proprioception, capable of long-lasting postural effects in healthy subjects.[10, 11] The current study was subjected only to the chronic-state patients that who had a stroke at least 6 months before these tests, because they were assumed to keep relatively stable physical conditions in their body balance performance and the motor function in comparison with the acute-state patients. Although all patients could walk independently to some extent, most subjects showed a suboptimal, moderate, or poor score on the BBS, indicating that these subjects had substantial balance problems. Maeda et al. showed that the BBS score could predict falling among stroke

Table 1.　Patient Characteristics

	WBV(n=15)	CON(n=15)	
Sex			
Female	7 (47%)	5 (34%)	NS*
Male	8 (53%)	10 (66%)	NS*
Age	68.9±11.6	70.2±7.7	NS†
Type of stroke			
Ischemic	9 (60%)	7 (46%)	NS*
Hemorrhagic	6 (40%)	8 (54%)	NS*
Side of palesis			
Right	10 (66%)	7 (46%)	NS*
Left	5 (34%)	8 (54%)	NS*
Time post stroke (month)	11.3±1.2	8.7±1.1	NS†
BBS	36.3±9.2	30.1±10.9	NS†
Fugl-Meyer	20.5±7.5	19.5±7.5	NS†
Knee extension strength			
paretic side (kg)	12.2±11.9	10.0±5.4	NS†
non-paretic side (kg)	19.3±8.8	18.8±6.2	NS†
FRT (cm)	18.3±8.6	20.3±6.1	NS†
Gait speed (m/min)	25.1±15.2	26.3±28.3	NS†

* = χ^2test　　† = independent t -test　　NS = not significant

Table 2.　Outcomes for the Baseline and 4weeks

	Baseline		4Weeks		Interaction	group	time
	WBV (n=15)	CON (n=15)	WBV (n=15)	CON (n=15)	p value	p value	p value
BBS	36.3±9.2	30.1±10.9	40.3±8.0	30.1±11.2	.005*	.029*	.005*
Fugl-Meyer	20.5±7.5	19.5±7.5	22.7±8.2	19.1±7.1	.002*	.410	.019*
Knee extension strength							
paretic side (kg)	12.2±11.9	10.0±5.4	14.1±14.0	10.0±5.4	.035*	.396	.033*
non-paretic side (kg)	19.3±8.8	18.8±6.2	21.3±8.7	19.4±6.2	.094	.559	.103
FRT (cm)	18.3±8.6	20.3±6.1	21.5±7.6	19.1±5.8	.045*	.866	.058
Gait speed (m/min)	25.1±15.2	26.3±28.3	29.1±16.3	27.9±33.4	.275	.996	.017*

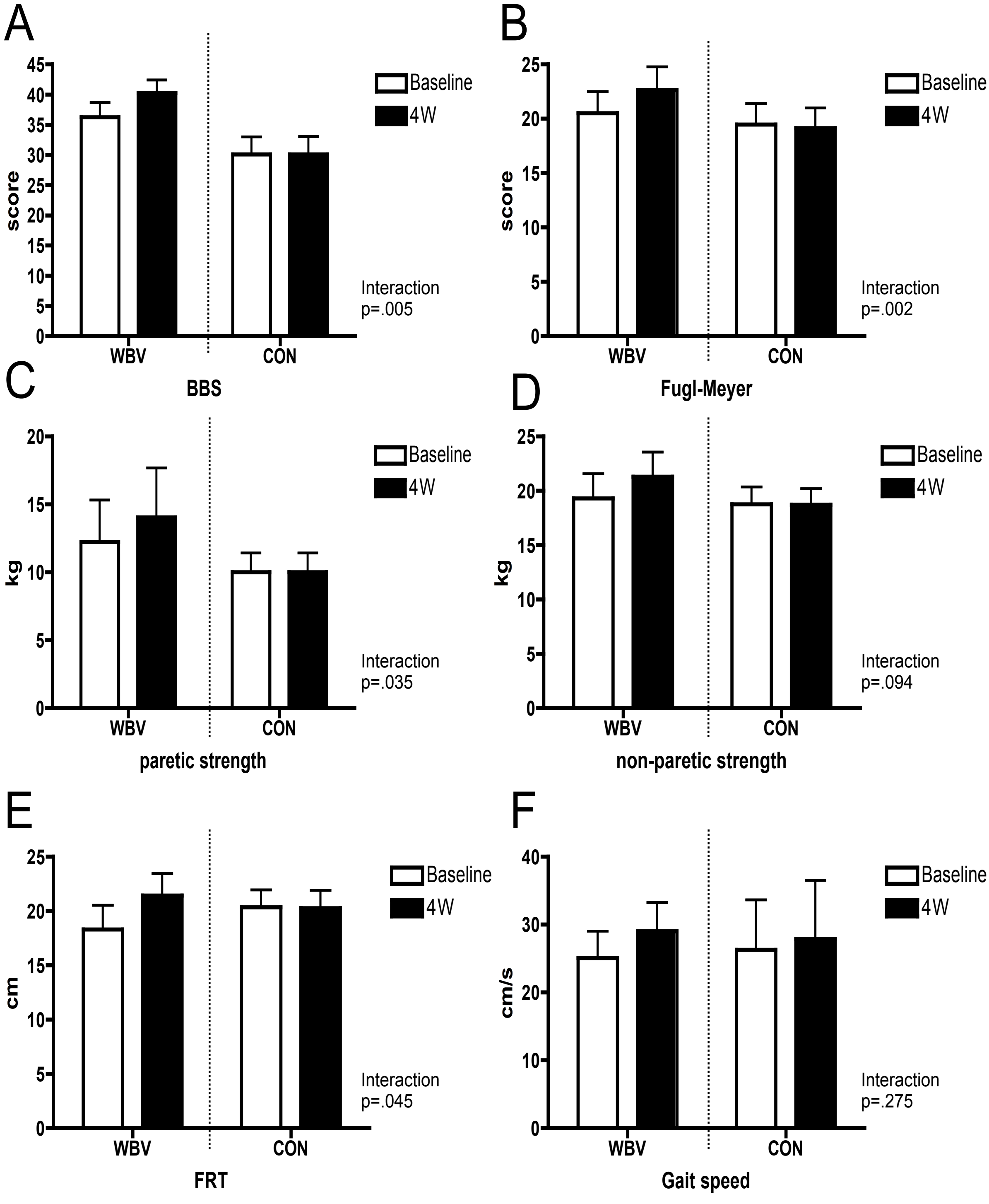

Figure 2 Effects of WBV
(A)Berg Balance Scale, (B)Fugl-Meyer Assessment lower extremity, (C)strengtth of knee extension in paretic side, (D)strength of knee extension in non-paretic strength, (E)Functional Reach Test, (F)Gait speed

patients and that the cutoff point of the score was <29.[12] However, Muir et al. claimed that the risk of falling among community-dwelling elderly people could be predicted with the BBS score and the cutoff point was <49.[13] The BBS score of the patients in the current study therefore might indicate a high risk of falling.

The mechanism by which WBV training can

improve the BBS is considered to alter brain plasticity by the somatosensory stimulation. Vibratory stimulation stimulates Ia sensory neurons and initiates sensation required for postural control. Priplata et al.[14] showed that sub-threshold vibratory stimulation could improve postural control in subjects with diabetic neuropathy, subjects with stroke, and senescence. They suggested that sub-threshold vibratory stimulation applied to the feet of quietly standing individuals leads to enhanced the detection of pressure changes in the soles of the feet, and reduced postural sway. Wierzbicka et al.[15] showed that vibration produced strong, long-lasting dynamical modification of posture mainly in the anterior-posterior direction. They concluded that sustained Ia sensory inflow, evoked by vibration, has a powerful after-effect on the motor system at the postural level. They concluded that sustained Ia sensory inflow, evoked by vibration, has a powerful after-effect on the motor system at the postural level. The current patients also underwent conventional rehabilitation programs that included range of motion exercise, balance exercise and training in the activities daily living. Although these rehabilitation programs could also evoke Ia sensory inflow, WBV training could selectively evoke Ia sensory inflow. Therefore, it might be suspected that Ia activation by the WBV training contributes to the greater improvement of the BBS score in the WBV group.

In general, strength of knee extension on the paretic side shows a tendency to increase. The mechanism underlying muscle strengthening with WBV is thought to be “tonic vibration reflex (TVR)”. The TVR has been studied extensively, both in normal man and in the cat. Hagbarth and Eklund[16] reported that muscle vibration often produces a rapidly developing tonic contraction in spastic limbs. As a result vibration, therefore the WBV training may have evoked tonic contraction of the knee extensor muscles. Ahlborg et al.[17] compared the effect on spasticity, muscle strength, and motor performance in adults with cerebral palsy after 8 weeks of these training. They concluded that muscle strength increased in both groups, however spasticity decreased only in the WBV group. The current results showed that paretic side muscle strength increased and motor function was improved by the WBV training, when assessed by the Fugl-Meyer assessment of the lower extremities. The Fugl-Meyer assessment evaluates tendon reflexes and the quality of extremity movement, so that in the current results suggested that WBV training reduced spasticity then improved function and then induced muscle contraction leading to muscle strengthening.

In the current study gait speed did not significantly improve by the WBV training. However, ten of 15 patients in the WBV group showed obvious gait speed improvement at 4 weeks after the training. In three of five patients who did not improve gait speed with the WBV training showed very low score (<15), and the remaining two patients showed low score (<30) in the Fugl-Meyer assessment. These results indicate that patients who had poor function of their lower extremities, showed no improvement in their muscle strength, but who had higher function, showed a faster gait speed in the baseline assessment. Thus, WBV training might have no effect on severe paralysis. Finally, there were no serious adverse events during the WBV training.

All of these results show that the WBV training may have the potential improve body balance in patients with chronic hemiplegia. However, further studies need to clarify the precise mechanisms for improvement of body balance by the WBV training.

REFERENCES

1) Johansson B. Brain plasticity and stroke rehabilitation. The Willis lecture. Stroke. 31: 223-30, 2000
2) Johansson K, Lindgren I, Widner H, et al. Can sensory stimulation improve the functional outcome in stroke patients? Neurology. 43: 2189-2192, 1993
3) Magusson M, Johansson K, Johansson B. Sensory stimulation promotes normalization of postural control after stroke. Stroke. 25: 1176-1180, 1994
4) Rittweger J, Beller G, Felsenberg D. Acute physiological effects of exhaustive whole-body vibration exercise in man. Clin Physiol. 20: 134-142, 2000
5) Torvinen S, Kannus P, Sievanen H, et al. Effect of a vibration exposure on muscular performance and body balance. Randomized cross-over study. Clin Physiol Funct Imaging. 22: 145-152, 2002
6) Bosco C, Cardinale M, Tsarpela O. Influence of vibration on mechanical power and electromyogram activity in human arm flexor muscles. Eur J Appl Physiol. 79: 306-311, 1999
7) Issurin V, Tenebaum G. Acute and residual effects of vibratory stimulation on explosive strength in elite and amateur athletes. J Sport Sci. 17: 177-82, 1999
8) Bruyere O, Wuidart MA, Palma ED, et al. Controlled whole body vibration to decrease fall risk and improve health-related quality of life of nursing home residents. Arch Phys Med Rehabil. 86: 303-307, 2005
9) Van Nes W, Latour H, Schils F. Long-term effects of 6-week whole-body vibration on balance recovery and activities of daily living in the postacute phase of stroke. Stroke. 37: 2331-2335, 2006
10) Priplata AA, Niemi JB, HarryJD, et al. Vibrating insoles and balance control in elderly people. Lancet. 362: 1123-1124, 2003
11) Wierzbicka MM, Gilhodes JC, Roll JP. Vibration-induced postural posteffects. J Neurophysilo. 79: 143-150, 1998
12) Maeda N, Kato J, Shimada T. Predicting the probability for fall incidence in stroke patients using the Berg Balance Scale. J Int Med Res. 37: 697-704, 2009
13) Muir SW, Berg K, Chesworth B, et al. Use of the Berg Balance Scale for predicting multiple falls in communitiy-dwelling elderly people: a prospective study. Phys Ther. 88: 449-459, 2008
14) Priplata A, Patritti L, Nieme B, et al. Noise-Enhanced balance contorol in patients with diabetes and patients with stroke. Ann Neurol. 59: 4-12, 2006
15) Wierzbicka M, Gilhodes C, Roll P. Vibration-induced postural posteffects. J Neurophysiol. 79: 143-150, 1998
16) Hagbarth E, Eklund G. Tonic vibration reflexes (TVR) in spasticity. Brain Research. 2: 201-203, 1966
17) Ahlborg L, Andersson C, Julin P. Whole-body vibration training copared with resistance training: effect on spasticity, muscle strength and motor performance in adults with cerebral palsy. J Rehabil Med. 38: 302-308, 2006