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Brief Report

Short-Term Effects of Whole-Body Vibration on Postural Control in Unilateral Chronic Stroke Patients

Preliminary Evidence

ABSTRACT

van Nes IJW, Geurts ACH, Hendricks HT, Duysens J: Short-term effects of whole-body vibration on postural control in unilateral chronic stroke patients: Preliminary evidence. *Am J Phys Med Rehabil* 2004;83:867–873.

The short-term effects of whole-body vibration as a novel method of somatosensory stimulation on postural control were investigated in 23 chronic stroke patients. While standing on a commercial platform, patients received 30-Hz oscillations at 3 mm of amplitude in the frontal plane. Balance was assessed four times at 45-min intervals with a dual-plate force platform, while quietly standing with the eyes opened and closed and while performing a voluntary weight-shifting task with visual feedback of center-of-pressure movements. Between the second and third assessments, four repetitions of 45-sec whole-body vibrations were given. The results indicated a stable baseline performance from the first to the second assessment for all tasks. After the whole-body vibration, the third assessment demonstrated a reduction in the root mean square (RMS) center-of-pressure velocity in the anteroposterior direction when standing with the eyes closed ($P < 0.01$), which persisted during the fourth assessment. Furthermore, patients showed an increase in their weight-shifting speed at the third balance assessment ($P < 0.05$) while their precision remained constant. No adverse effects of whole-body vibration were observed. It is concluded that whole-body vibration may be a promising candidate to improve proprioceptive control of posture in stroke patients.

Key Words: Cerebrovascular Accident, Balance, Vibration, Proprioception

There is a general and strong belief that somatosensory stimulation (SSS) promotes brain plasticity, although the underlying mechanisms are not well known.[1] Studies regarding the functional recovery in stroke patients have suggested beneficial effects of SSS in terms of motor functions, balance, and activities of daily living. In 1993, a randomized, controlled trial first indicated that electro-acupuncture applied at the paretic body side facilitated recovery of balance, mobility, and activities of daily living in postacute stroke patients,[2] and some of these effects were shown to persist for up to 2 yrs after stroke as assessed by posturography.[3] However, recently, a new randomized, controlled trial from the same research group no longer demonstrated differential effects on motor function, mobility, or activities of daily living of either high-intensity–low-frequency transcutaneous electrical nerve stimulation or electro-acupuncture applied at the paretic body side when compared with sham–transcutaneous electrical nerve stimulation of low intensity and high frequency.[4] These differences in outcome could not be unambiguously explained. Although others have demonstrated potentially strong immediate effects of transcutaneous electrical nerve stimulation applied at the contralesional side of the neck on postural orientation and stability while sitting in postacute stroke patients with spatial neglect,[5,6] the long-term effects of transcutaneous electrical nerve stimulation or (electro-)acupuncture on functional recovery from stroke are, as yet, equivocal.[2–4,7,8] The effects of other forms of SSS are still unknown.

One form of SSS that shows considerable promises for rehabilitation is vibration therapy. Priplata et al.[9] reported that randomly vibrating insoles could ameliorate age-related impairments in balance control. Apparently, vibration is able to enhance postural stability in persons without specific neurologic diseases. It is, therefore, possible that in stroke patients intensive and deep stimulation of muscle afferents using vibration may induce stronger sensorimotor recovery than more superficial stimulation of (sub)cutaneous afferents by electrical stimulation. In addition, based on functional magnetic resonance imaging and positron emission tomography studies showing plastic changes in *both* cerebral and cerebellar hemispheres after unilateral stroke, it may be that application of SSS at both sides of the body is more effective than only at the paretic side.[10,11] Against this background, the purpose of this study was to demonstrate beneficial short-term effects of whole-body vibration (WBV) on postural control in chronic stroke patients and to register any possible adverse effects.

METHODS

Subjects. A total of 23 ischemic stroke patients (13 men, 10 women; mean age 58.1 ± 11.4 yrs) with a poststroke interval of at least 6 mos (mean interval 23.3 ± 11.4 mos) were recruited from an outpatient population of a rehabilitation center to participate in this research study. Eight patients had a right-hemisphere lesion, and 15 had a left-hemisphere lesion. To be included, patients must have only one stroke in their lifetime, be able to stand without support for 30 secs, understand the goal and methods of the study, and give their informed consent. Patients with non–stroke related sensory or motor impairments and those with medication that could interfere with postural control were not included. Also patients with contraindications for WBV (pregnancy, recent fractures, gall or kidney stones, malignancies, cardiac pacemaker, recent thromboembolic or infectious disease) and patients already treated with WBV were excluded. To obtain reference values for postural control, 23 healthy, elderly controls (mean age 63.9 ± 9.3 yrs) were recruited, mostly relatives of employees of the rehabilitation center. The Committee on Research Involving Human Subjects, Region Arnhem-Nijmegen, approved the study methods, and all patients gave their written informed consent according to specified guidelines.

Figure 1: Picture of the Galileo 900.

Intervention. All patients were subjected to one series of four consecutive repetitions of 45-sec WBV with a 1-min pause between administrations. WBV was provided with a commercially available device (Galileo 900, Galileo2000, Enschede, The Netherlands) (Fig. 1). This apparatus consists of a moveable rectangular platform built within a circular ground surface on which a support bar is mounted at the front. The platform makes fast oscillating movements around a sagittal axis in the RMS 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 approximately 3 mm. The frequency was set at its maximum of 30 Hz. While standing on the vibration platform, subjects were instructed to maintain a "squat" position with slight flexion at the hips, knees and ankle joints, to damp the vibrations approximately at the pelvic level.[12] They were allowed to hold the support bar in front of them. An experienced therapist guided all WBV administrations.

Assessments. Postural control and symmetry were assessed in terms of center-of-pressure (COP) movement and position registered with a dual-plate force platform (LM-100KA, Kyowa Electronic Instruments) connected to a personal computer, sampling vertical ground reaction forces at a rate of 60 Hz. During all balance registrations, patients stood barefoot on the force platform with their arms (if possible) alongside their trunk and their feet against a fixed foot frame with an interheel distance of 8.4 cm and a toeing-out angle of 9 degrees. Every balance assessment consisted of two consecutive test series. Each series incorporated two 30-sec quiet-standing tasks (one with eyes open and one with eyes closed) and one 30-sec voluntary weight-shifting task in a fixed sequence (eyes open, eyes closed, weight-shifting task), which was repeated in the reversed order (weight-shifting task, eyes closed, eyes open). During quiet standing with the eyes closed, patients were wearing a pair of closed, dark goggles. From each quiet-standing registration, the overall COP was calculated for every set of force samples from the two plates. Then, the lateral deviation of the mean position of this COP from the sagittal midline, relative to the base of support width, was determined as a measure of weight-bearing asymmetry.[13] The RMS COP velocity in both the anteroposterior and lateral directions was calculated as a measure of postural instability, because it integrates changes in COP amplitude and frequency. Indeed, of various posturographic measures, the COP velocity has been shown to be most reliable,[14] sensitive to task manipulations,[14] and related to measures of functional balance.[15,16] During the weight-shifting task, real-time visual COP feedback was provided by a color monitor placed in front of the subject at eye level. Two stationary square goals were presented on the monitor at either side of the virtual vertical through the middle of the screen (corresponding to the sagittal midline of the body), such that approximately 15% extra weight had to be borne on each leg to reach the middle of the corresponding goal. During each registration, always one of the two goals was lit by the computer indicating the target. Subjects had to shift their weight toward this target as fast and fluently as possible and hold their COP within it for 1 sec to make a hit. As soon as a hit was made, the contralateral goal was lit and became the target. In this way, subjects made standardized frontal-plane weight shifts at a self-selected speed. Patients were allowed to practice this weight-shifting task until an optimal performance was reached. From each weight-shifting registration, the number of hits was calculated as a measure of weight-shifting speed, whereas the lateral COP displacement per weight shift was determined as a measure of imprecision, after adjusting for individual differences in the intergoal distance, according to Geurts et al.[17]

To assess their clinical status, all patients were subjected to a standardized functional evaluation consisting of the Motricity Index of the affected lower limb[18] as a measure of muscular strength, the Berg Balance Scale[19] as a measure of functional balance, and the Functional Ambulation Categories[20] as a measure of gait independence.

Procedure. Each patient underwent four balance assessments at 45-min intervals at the same part of the day. The first two assessments served to establish a baseline performance. After the first assessment (A), the functional evaluation was completed in approximately 30 mins. After the second assessment (B), patients were allowed to rest for about half an hour, which was followed by the four WBV administrations. Then, the third (C) and fourth (D) balance assessments were made. Between the latter two assessments, patients were allowed to rest. Figure 2 shows a time schedule for the assessments.

For each of the four balance assessments, identical posturographic measures from the two test series per assessment were averaged into one result to reduce intrasubject variability. Because the balance measures yielded rather skewed distributions across patients, possible differences between balance assessments were identified by means of the (nonparametric) Wilcoxon's matched-pairs signed-ranks test. First, assessment A (mean of test series 1 and 2) was compared with assessment B (mean of test series 3 and 4) to determine a stable baseline. Then, assessment C (mean of test series 5 and 6) and assessment D (mean of test series 7 and 8) were both compared with the average result of assessments A and B (mean of test series 1–4) to determine any immediate or prolonged effect of WBV. The healthy elderly control subjects were only tested once using the same methods (one assessment consisting of two test series).

RESULTS

The functional measures are presented in Table 1 and indicate that all patients could walk independently with or without aids or supervision but had impaired balance skills and

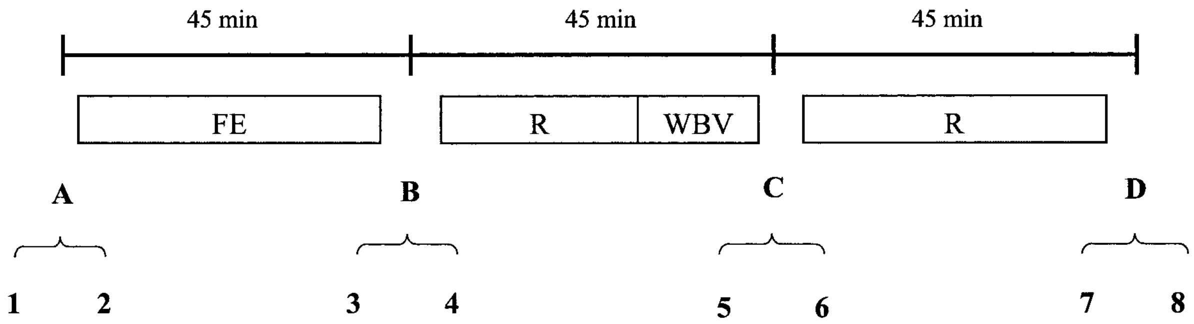

Figure 2: Time schedule of the procedure. Each balance assessment (*A*, *B*, *C*, and *D*) consisted of two test series (*1–8*). *FE*, functional evaluation; *R*, rest; *WBV*, whole-body vibration.

motor functions of the affected leg. All patients were able to tolerate the selected 30-Hz frequency already during the first administration of WBV. No administration of WBV had to be aborted due to immediate adverse effects nor did patients mention any subjective complaints after the vibration.

None of the selected balance measures showed a significant change between balance assessments A and B, indicating a stable baseline performance ($P > 0.22$). When quiet standing at assessment C was compared with the average results of RMS assessments A and B, the RMS COP velocity in the AP direction during the eyes-closed condition showed a small but significant decrease in 22 patients (one patient was not able to perform the eyes-closed condition) ($P = 0.009$). This beneficial effect was still noticeable at assessment D ($P = 0.01$) (Fig. 3). As for the weight-shifting task, the number of hits showed a small but significant increase at assessment C ($P = 0.027$), but no longer at assessment D, in 21 patients (two patients were not able to perform the weight-shifting task) (Fig. 4). All other balance measures remained stable across the four balance assessments.

To test for possible aspecific learning effects due to repeated testing, we also analyzed the four test series 1–4 within the first two assessments (A and B) individually. No systematic improvement was found between any pair of consecutive test series nor between the first and fourth test for any selected balance measure ($P > 0.09$). The influence of functional level (Motricity Index, Berg Balance Scale, Functional Ambulation Categories) on the effects of WBV was not tested because of the relatively small number of severely affected patients.

DISCUSSION

This within-subject study investigated the occurrence of any short-term effects of WBV on postural control in stroke patients as a novel method of SSS. Indeed, it has been reported that vibration is one of the strongest methods for stimulating proprioception, capable of long-lasting postural effects in healthy subjects.[9,21] Only chronic patients were included who had their stroke at least 6 mos previously because they were assumed to be relatively stable in their balance performance compared with postacute stroke patients. Although all patients could walk independently to some extent, most subjects had a suboptimal, moderate, or poor score on the Berg Balance Scale, indicating substantial balance problems. This result is corroborated by the posturographic balance measures indicating substantially greater COP velocities compared with healthy elderly.

TABLE 1
Functional measures of patients

Functional Measures (maximum range)	Median	Range
Functional Ambulation Categories (0–5)	5	3–5
Berg Balance Scale (0–56)	52	20–56
Motricity Index (0–100)	75	37–100

Preliminary evidence was found of short-term beneficial effects of WBV on postural control in stroke patients. As for quiet standing, the COP velocity in the sagittal plane decreased slightly but systematically in most of the subjects, indicating a tendency toward improved postural stability after WBV. The finding that this effect was only significant while standing with the eyes closed may be explained by a relatively great reliance on proprioceptive information during visual deprivation in stroke patients.[22] If WBV specifically promotes proprioceptive control of standing balance in stroke patients, one would indeed expect greater functional effects while standing with the eyes closed than with the eyes opened. This reasoning, however, does not explain why no such effect

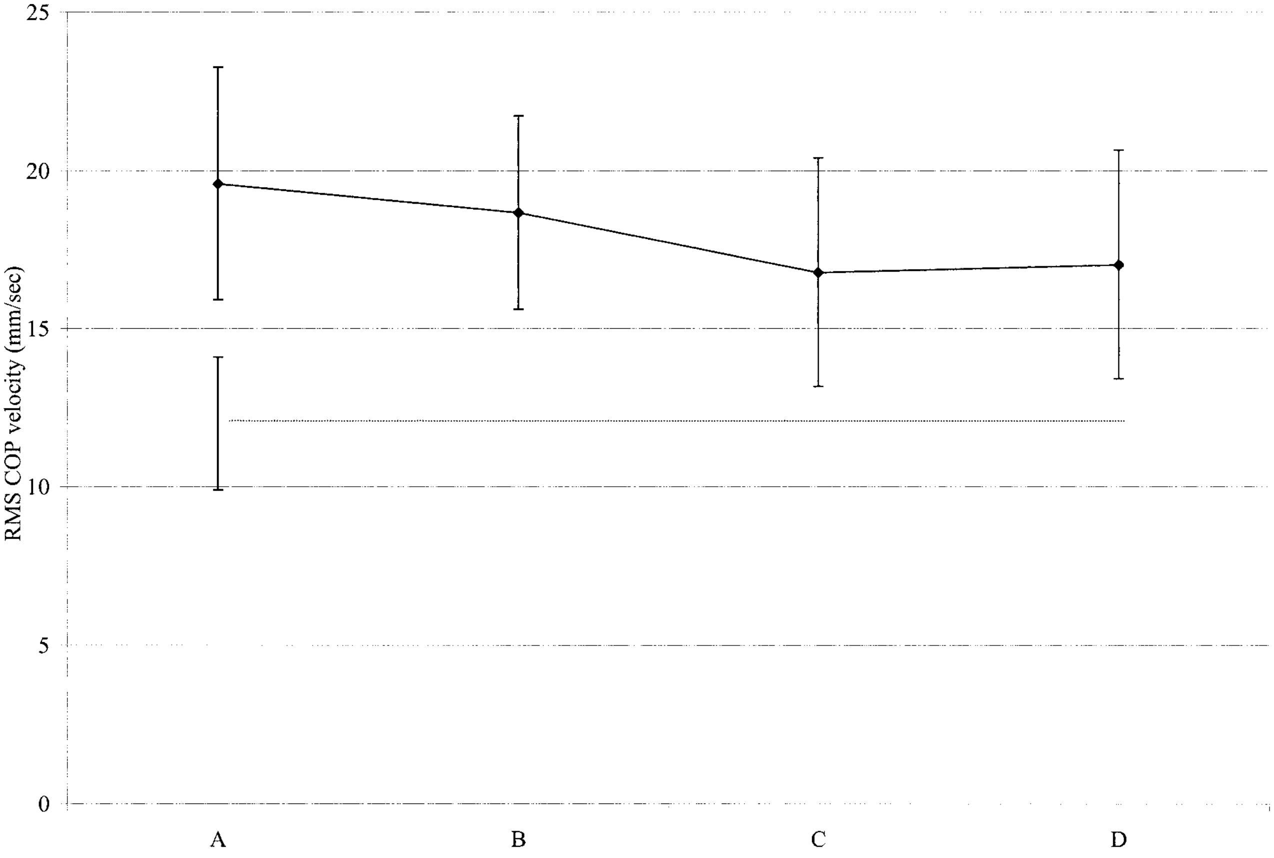

Figure 3: Sagittal plane postural instability in the eyes-closed condition, expressed as the root mean square (RMS) center-of-pressure (*COP*) velocity, for four assessments in 22 stroke patients (group mean values with 95% confidence intervals). The *dotted line* indicates the average performance of the 23 healthy elderly subjects with 95% confidence intervals.

was found for quiet-standing control in the frontal plane. As for the weight-shifting task, the number of hits slightly but systematically increased in most subjects, yielding a tendency toward improved weight-shifting capacity after WBV. The fact that the level of weight-shifting precision did not change precludes a possible "speed–accuracy tradeoff." This positive effect of WBV also on self-paced frontal plane weight shifts may again be related to proprioceptive stimulation because loading and unloading the legs is highly dependent on proprioceptive feedback.[23] Indeed, it is assumed that WBV primarily increases proprioceptive input (mainly through Ia-afferents),[24,25] thus stimulating a sensory system that is of vital importance to postural control. Based on recent insights in brain plasticity, it is possible that bilateral proprioceptive stimulation may induce spinal and cortical reorganization both through the affected and nonaffected body sides.[26]

This study used a within-subject design and not a parallel group design because it was anticipated that the presumably small short-term effects of WBV would be hard to demonstrate in a group comparison due to relatively large within-group variability of balance performance. As a consequence, aspecific learning effects related to repeated testing may have influenced the balance improvements that were found. There are, however, several arguments against this possibility. Most importantly, comparing the first four balance test series did not provide any evidence of aspecific learning effects. Because such effects are usually strongest between the first two or three repetitions, it seems unlikely that they would have played a significant role in this study after the fourth test. Second, with regard to the weight-shifting results, the observed data pattern, in which significance was lost at the last assessment (D), does not match with a learning process in which one would expect further improvement or at least stabilization. We therefore conclude that this study provides preliminary evidence of specific short-term beneficial effects of WBV on postural control in chronic stroke patients.

The finding that no adverse effects occurred and that nearly all patients reported pleasant subjective sensations both during and after the vibration therapy suggests that WBV may also be a safe application of SSS in (chronic) stroke patients. This latter conclusion is further supported

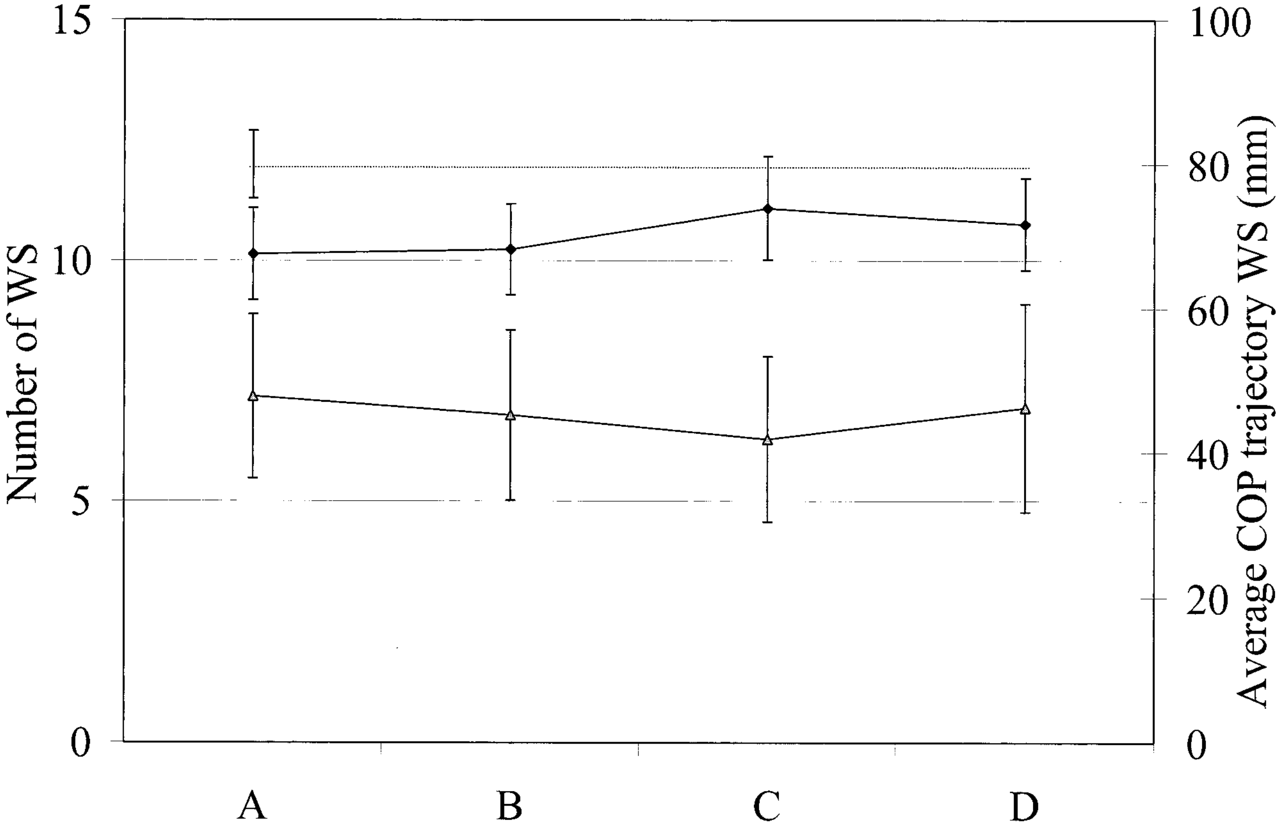

Figure 4: Frontal plane weight-shifting speed, expressed as the number of weight shifts (*WS*, *black line*), and weight-shifting imprecision, expressed as the average lateral center of pressure (*COP*)–trajectory per weight shift (*gray line*), for four assessments in 21 chronic stroke patients (group mean values with 95% confidence intervals). The *dotted line* indicates the average weight-shifting speed of the 23 healthy elderly subjects with 95% confidence intervals.

by our experiences with postacute stroke patients included in an ongoing randomized, controlled trial investigating the effects of prolonged vibration therapy (daily during 6 wks) on postural control. Nevertheless, further research is needed to determine both the safety, the short-term effectiveness, and the long-term effectiveness of WBV in different groups of stroke patients.

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