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Feasibility of using whole body vibration as a means for controlling spasticity in post-stroke patients: A pilot study

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A B S T R A C T

To examine the feasibility of adapting whole body vibration (WBV) in the hemiplegic legs of post-stroke patients and to investigate the anti-spastic effects, and the improvement of motor function and walking ability. Twenty-five post-stroke patients with lower-limb spasticity were enrolled in the study. Each subject sat with hip joint angles to approximately 90° of flexion, and with knee joint angles to 0° of extension. WBV was applied at 30 Hz (4–8 mm amplitude) for 5 min on hamstrings, gastrocnemius and soleus muscles. The modified Ashworth scale was significantly decreased, active and passive range of motion (A-ROM, P-ROM) for ankle dorsiflexion and straight leg raising increased, and walking speed and cadence both improved during the 5-min intervention. Our proposed therapeutic approach could therefore be a novel neuro-rehabilitation strategy among patients with various severities.

1. Introduction

Spasticity, commonly defined as a velocity-dependent hyperexcitability of the muscle stretch reflex, is characterized by exaggerated tendon reflexes, increased resistance to passive movement and hypertonia resulting from loss of upper motor neuron inhibitory control [1]. It is a well known syndrome, most commonly arising after stroke, cerebral palsy (CP), multiple sclerosis (MS), spinal cord injury (SCI) and other central nervous system (CNS) lesions. Indeed, many patients with a spinal or cerebral lesion have a spastic movement disorder. In prolonged spasticity, the constant flexed joint position, transformation of the spastic muscles and changes in periarticular connective tissue lead to a shortening of muscles and connective tissue, resulting in reduced active and passive joint mobility, voluntary lower limb movements, impaired gait stability and restricted activities of daily living. It is therefore important to control muscle tonus, especially in physiotherapy, in order to improve these symptoms.

There is a wide range of treatment options available for spasticity including the injection of botulinum toxin [2], which requires practitioners to have specialized technical skills. Conventional therapies, muscle stretching [3], and physical agents treatment such as ultrasound therapy [4], thermotherapy [5] and electrical stimulation [6] have also been shown to be useful. Recently, vibratory stimulation was proposed as a new therapeutic modality for the treatment of focal spasticity in post-stroke patients [7,8]. It applies a low-amplitude vibratory stimulus to a specific muscle using a mechanical device and generates Ia inputs by activating muscle spindle primary endings [9]. These Ia inputs can alter the excitability of the cortico-spinal pathway [10] by modulating intracortical inhibitory and facilitatory inputs to the primary motor cortex [11].

Whole-body vibration (WBV) involves the performance of static or dynamic movements on a vibrating platform. The vibrations are believed to initiate muscle contractions by stimulating muscle spindles and alpha motor neurons, resulting in an effect similar to that of conventional resistance training [12]. Several previous studies reported that WBV has anti-spastic effects in patients with CP, SCI and MS [13–15]. To date only 2 studies have been published in which authors examined the anti-spastic effects in patients with stroke. More recently, Brogardh et al. (2012) reported that WBV training (twice weekly for six weeks) tended to decrease muscle tonus, but had no or only small changes on body function and gait performance in chronic stroke [16]. Chan et al. (2012) reported that a single session of WBV training can reduce ankle plantarflexion spasticity in chronic stroke, thereby potentially increasing ambulatory capacity [17]. In previous studies, WBV training was

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performed by standing on a vibrating platform in a static position or performing dynamic movements simultaneously [12–17]. However, in the preliminary study, the standing position was not suitable because some patients could not tolerate the vibration in standing position without support. The primary aims of this study were to examine the feasibility of WBV in sitting position in the hemiplegic legs of post-stroke patients and to investigate the anti-spastic effects, and the improvement of motor function and walking ability.

2. Methods

2.1. Subjects

Twenty-five post-stroke patients with lower-limb spasticity were enrolled in this study (20 males and five females; mean age, 52.2 ± 15.6 years; range, 20–75 years). Patients with hemiplegia were recruited from inpatients admitted to the Kirishima Rehabilitation Center of Kagoshima University, Japan, between 1 June 2011 and 30 September 2012. Stroke diagnosis was based on computed tomography (CT) or magnetic resonance imaging (MRI), as well as neurological functions. Of the 25 post-stroke patients, 15 were diagnosed with cerebral hemorrhage and 10 with cerebral infarction. Thirteen patients had right hemiplegia and 12 had left hemiplegia. The mean time since onset was 26.6 ± 26.3 months (range, 4–101 months). The Brunnstrom Recovery Stage [18] of the hemiplegic lower limb was stage 3 in six patients, stage 4 in 14, stage 5 in four, and stage 6 in one. The modified Ashworth scale (MAS) score for the gastrocnemius muscles was 1 in six cases, 1+ in 11 cases and 2 in eight cases. All patients had increased muscle tonus of the affected lower limb (MAS score ≥1), and were able to walk without assistance using a T-cane or ankle-foot orthosis. Exclusion criteria were any medical condition preventing vibratory stimulation (such as higher cortical dysfunction, uncontrolled cardiopulmonary disease, severe joint disability and severe sensory disturbance), severe aphasia that made it impossible to follow verbal instructions, and dementia that interfered with outcome assessments. Subject characteristics are shown in Table 1.

Experimental procedures complied with the 1975 Declaration of Helsinki, as revised in 1983. Informed consent was obtained from each subject for study participation according to the ethical guidelines of the hospital, after they fully understood the study purpose and methodology. The study was carried out with permission from the Ethical Committee of Kagoshima University.

2.2. Procedure

The WBV was delivered via a vibrating platform (Powerplate®, Performance Health Systems UK Ltd., UK), which delivers vibrations at a frequency of 30, 40 or 50 Hz. The amplitude of the vibrations could be altered between low (1–3 mm) and high (4–8 mm). Each subject sat with hip joint angles to approximately 90° of flexion, and with knee joint angles to 0° of extension (Fig. 1(A)). One physiotherapist used manual correction to maintain the ankle joint angles of dorsiflexion at maximum (Fig. 1(B)). The WBV was applied at 30 Hz, 4–8 mm amplitude, for 5 min on hamstring, gastrocnemius and soleus muscles.

Table 1
Demographic and clinical data on study participants, mean (SD).

Age, years	52.2 ± 15.6
Gender (*n*)	Male = 20, Female = 5
Diagnosis (hemorrhage/infarction)	15/10
Side of hemiplegia (*n*)	Right = 13, Left = 12
Time since onset of hemiplegia (months)	26.6 ± 26.3
Brunnstrom recovery stage of legs (*n*)	
3	6
4	14
5	4
6	1
Modified Ashworth scale (MAS) (*n*)	
1	6
1+	11
2	8

2.3. Outcome measures

After 5 min relaxation in the supine posture, subjects received the interventions for 5 min. We investigated the MAS score, motor function (active and passive range of motion; A-ROM, P-ROM) and the 10-m walk test before and immediately after intervention.

The extent of spasticity was measured using the MAS score [19] for hip adductor muscles, hamstrings and gastrocnemius muscles. The MAS is an established and reliable instrument, which uses a six-point scale to score the average resistance to passive movement for each joint. To facilitate data analysis, the MAS scores (0, 1, 1+, 2, 3 and 4) were assigned numerical values designated 'computed MAS scores' (0, 1, 2, 3, 4 and 5, respectively) [20].

The active range of motion (A-ROM) of ankle dorsiflexion was measured with a hand-held goniometer in 14 patients who could voluntarily perform ankle dorsiflexion. Measurements were taken with the knee flexed at 90° in a sitting posture. The passive range of motion (P-ROM) of ankle dorsiflexion and straight leg raising (SLR) were also measured. The P-ROM of ankle dorsiflexion was measured with the knee minimally flexed in a supine position. For the P-ROM of SLR measurement, patients rested in a supine position and the knee was fixed to the extension position by manual correction. The sensitivity of all measurements was quantified to 5° [21].

The 10-m walk test assessed walking ability. Patients were instructed to walk at a comfortable speed over a standardized 10-m distance. A stopwatch was used for timing and a counter was used to obtain the number of steps. To eliminate acceleration and deceleration periods, patients started and ended their laps 3 m before and beyond the walkway, respectively. Each patient performed a practice trial followed by three trials. The data were used to determine the comfortable walking speed (m/min) and cadence (steps/min). The times of the three trials were averaged and used for statistical analysis [22].

2.4. Statistical analysis

Results are presented as means ± standard deviations. Wilcoxon signed rank tests were used to compare the pre- and post-intervention MAS scores, A-ROM, P-ROM, walking speed and cadence. Data were analyzed using PASW Statistics ver. 18. A *P*-value of 0.05 was chosen as the level of significance.

3. Results

None of the subjects experienced discomfort before, during or after the intervention and all assessments were completed safely in all subjects. Table 2 shows the pre- and post-intervention changes of MAS, A-ROM, P-ROM and walking ability.

A significant decrease was observed in the MAS score of the muscles examined as a result of the 5-min intervention: hip adductor muscles, pre: 1.3 ± 0.7, post: 0.9 ± 0.7, $P = 0.002$; hamstring muscles, pre: 1.2 ± 0.9, post: 0.5 ± 0.5, $P = 0.001$; gastrocnemius muscles, pre: 2.1 ± 0.8, post: 1.6 ± 0.7, $P = 0.002$.

The A-ROM of ankle dorsiflexion increased significantly after WBV (pre: 5.0 ± 3.9, post: 9.6 ± 4.1, $P = 0.001$), while the P-ROM