

# Effect of whole-body vibration on motor neuron excitability in healthy young men

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## Background

Whole-body vibration (WBV) has been increasingly used for performance enhancement as well as for treatment of some conditions. There is much focus on the study of muscular performance accompanied by WBVs; however, little is known about its effect on motor units – whether it has excitatory or inhibitory effects. The purpose of this study was to investigate the effect of a single bout of WBV on motor neuron excitability in healthy individuals immediately and 30 min after application.

## Participants and methods

Sixty healthy men participated in this study; their ages ranged between 18 and 25 years. They were randomly divided into two equal groups – the study group and the control group – each containing 30 men who were selected by drawing ballots from sealed envelopes. The experimental group received WBV with a frequency of 50–60 Hz and amplitude of 0–10 mm for 1 min, with a 1 min rest period between each vibration set, which was repeated five times. The control group stood on the WBV device for the same duration while it was off. Hoffman reflex amplitude and *H/M* ratio were measured from the soleus muscle (posterior tibial nerve) before and 0 and 30 min after application in both groups using surface electromyography.

## Results

There was significant decrease in Hoffman reflex amplitude at 0 and 30 min in the study group compared with the control group ( $P=0.002$  and  $0.01$ , respectively). Moreover, there was significant decrease in *H/M* ratio at 0 and 30 min in the study group compared with the control group ( $P=0.0001$  and  $0.03$ , respectively).

## Conclusion

WBV decreases motor neuron excitability and thus may have therapeutic implications for people with central nervous system disorders, in whom spasticity is a major manifestation.

## Keywords:

H-reflex, motor neurons, whole-body vibration

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## Introduction

Whole-body vibration (WBV) is a relatively new method that is increasingly used in physical therapy. However, the effectiveness and its underlying mechanisms are still under debate. Previous studies reported that WBV could offer a therapeutic alternative for people with limited physical ability [1,2].

Several studies have supported the effects of WBV in neuromuscular rehabilitation: the displacement of the platform is stated to mimic gait; vibration of the feet could evoke postural responses; and it might as a somatosensory stimulant have musculoskeletal benefits. Motor neuron excitability is a relatively new topic in the era of WBV. A few studies had been conducted to determine whether WBV has an excitatory or inhibitory effect on motor units [3,4].

Improvement in neuromuscular performance following WBV might be attributed to different mechanisms.

WBV is believed to induce the tonic vibration reflex (TVR), the stretch reflex response, due to rapid changes in the length of the tendon. However, both excitation and inhibition of the stretch reflex during vibration have been reported [5,6].

One way to identify motor neuron excitability of WBV is by measuring the Hoffman reflex (H-reflex). The H-reflex is an electrical equivalent of the mechanically induced stretch reflex in which Ia fibers are activated. As the H-reflex bypasses the muscle spindle, it is a valuable tool to assess modulation of monosynaptic reflex activity. Modulation of the H-reflex is altered after neurological injury. Therefore, modulation of the H-reflex by WBV would have clinical implications in

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the rehabilitation setting in improving functional performance [7]. WBV has attracted much attention in both research and clinical practice. Upper motor neuron lesions are associated with muscle tone abnormalities. There are different physical therapy modalities to normalize muscle tone. One of these interventions is the application of WBV, which can have facilitatory or inhibitory effects [8].

Studies investigating the effects of WBV on the H-reflex have noted conflicting response patterns, most likely due to methodological differences in H-reflex application and WBV parameters [5,9–11].

Thus, this study was conducted to answer the following question: can a single bout of WBV have both immediate and remote effects on motor neuron excitability?

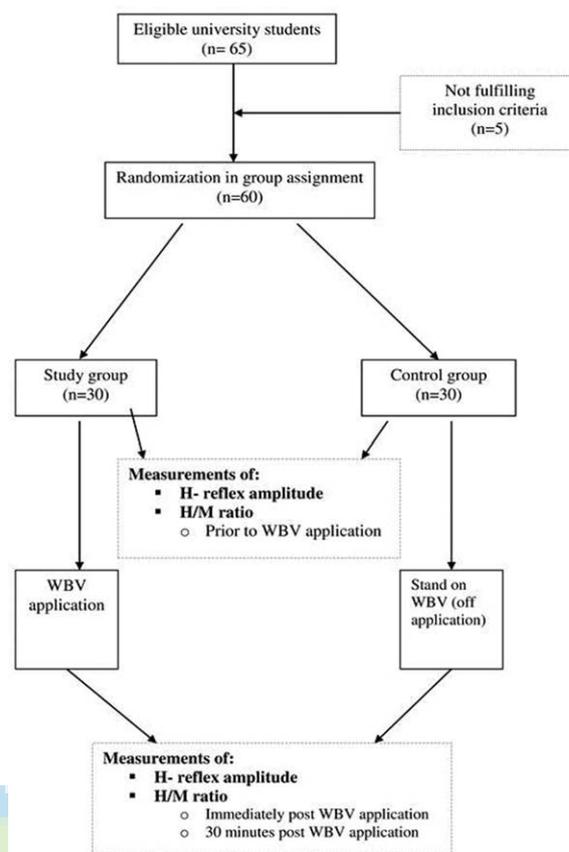
## Participants and methods

A randomized controlled trial designed as a pretest–post-test single-bout study was carried out at the Neurophysiologic Unit in Zagazig University Hospital, Egypt, from May to August 2015 to investigate the effect of a single bout of WBV on H-reflex amplitude and *H/M* ratio in healthy individuals.

### Participants

The present study recruited 65 healthy male students between the ages of 18 and 25 years from Zagazig University; five of them were excluded from the experiment as they did not meet the inclusion criteria. Thus, 60 participants were included in the study after obtaining approval from the ethical committee of the Faculty of Physical Therapy, Cairo University, and all participants were given verbal instructions concerning the purpose and procedures of the study and asked to signed a consent form. The participants were randomly assigned to two groups – the control group ( $n = 30$ ) and the study group ( $n = 30$ ) – by an independent person who selected them from sealed envelopes containing numbers chosen by a random number generator. The randomization was restricted to permuted blocks of different sizes to ensure that an equal number was allocated to each group. Each random permuted block was transferred to a sequence of consecutively numbered, sealed, opaque envelopes that were stored in a locked drawer until required. As each participant formally entered the trial, the researcher opened the next envelope in the sequence in the presence of the participant (as shown in Fig. 1).

Figure 1



Flow chart of participants through the study. H-reflex, Hoffman reflex; WBV, whole-body vibration.

### Control group

The control group included 30 healthy individuals. They stood on the WBV device for 9 min (switched off). Their weight ( $75.75 \pm 5.77$  kg), height ( $173.3 \pm 5.11$  cm), H-reflex amplitude, and *H/M* ratio were measured initially, immediately, and 30 min after the experiment.

### Experimental group

The experimental group also included 30 healthy individuals, who received WBV for 1 min, with a 1 min rest period between each vibration set, which was repeated five times. Their weight ( $77.25 \pm 3.76$  kg), height ( $174.9 \pm 3.74$  cm), H-reflex amplitude, and *H/M* ratio were measured initially, immediately, and 30 min after the experiment.

Participants were included if they were nonsmokers and aged between 18 and 25 years. They should not have exercised regularly for at least 3 months before the study. All participants were new to WBV.

The exclusion criteria for participants were the following: recent episode of or at risk for thrombosis, presence of diabetes, severe headache,

vestibular disorders, arthritis, lower-limb implant, synthetic implant, lumbar disc disorder, acute systemic infection or inflammation, recent fracture, gall bladder or kidney stone, or malignancy, or history of neurological, orthopedic, or cardiovascular problems.

Participants were instructed to avoid heavy physical activities 12h before the study [12], to refrain from eating or drinking any substances containing caffeine 2 h before the study [13], and to refrain from taking any tranquilizers or analgesics that may affect motor neuron excitability [14].

Electromyography (EMG) device: a computerized EMG Toennies Neuroscreen plus 1.59 was used to record the H-reflex and  $H/M$  ratio in both groups before, immediately after, and 30 min after WBV application. The apparatus included an amplifier with four electrically isolated amplifier channels with impedance 100 M $\Omega$  and sensitivity 40 000 mV/0.5. The amplifier gains up to 10 traces on screen with a resolution of 1000 points per trace.

Room temperature was constant at 23°C.

#### Whole-body vibration device

The FitVibe Medical pro (GymnaUniphy, Bilzen, Belgium) was used in this study. It consists of platform and control units for the variables (frequency, speed, and time).

#### Electromyography application

- (1) The subject was positioned prone with eyes closed. The head and arms were supported to reduce variability of the H-reflex and maintain subject comfort throughout the test with the examined leg positioned in zero position in extension, midway between abduction and adduction in the hip joint. The knee joint was flexed about 20° by placing a small cushion under the leg to relax the gastrocnemius muscle, and the ankle joint was placed in plantar flexion.
- (2) All participants were asked to refrain from taking analgesic medication for 24h before testing, from consuming caffeine, alcohol or nicotine, and from undertaking strenuous exercise 2h before testing, and empty their bladder before the study [15].

#### Skin preparation

The skin was rubbed lightly with a piece of cotton soaked with alcohol to reduce the skin impedance.

Figure 2



H-reflex electrode placement. H-reflex, Hoffman reflex.

#### Electrode position

The stimulating electrode was placed on the popliteal fossa at the posterior tibial nerve. The active recording electrode was placed over the soleus muscle 2 cm below the junction of the two heads of the gastrocnemius muscle in line with the Achilles tendon. The ground electrode was placed between the stimulating and recording electrodes. The reference electrode was placed on the Achilles tendon [16] (as shown in Fig. 2).

The H-reflex was elicited by stimulating the posterior tibial nerve at the popliteal fossa using 1000 ms pulse duration with a stimulus frequency 0.5 Hz. A wide range of stimulus intensities were applied, starting from that needed to obtain the threshold value for  $H$  or  $M$  to the highest value required for maximum  $M$  ( $M_{max}$ ). This range of stimulus intensity also provided the maximum value of the H-reflex ( $H_{max}$ ). The normalized value of  $H_{max}/M_{max}$  was computed for each participant.

The  $H/M$  ratio was measured for each participant according to the following sequences: the current intensity was slowly increased until the stimulus activates only the large Ia afferent fibers without concomitant activation of the motor fibers or just threshold for only motor fibers. The stimulus was delivered at a rate of 1 stimulus every 2–3 s to avoid suppressing the H-reflex. The intensity of the stimulus was gradually increased to record the  $H_{max}$  as well as the  $M_{max}$ .

#### Whole-body vibration application

To eliminate probable circadian effects, all experiments were performed between 9 and 11 a.m. Participants were instructed to stand comfortably on the vibration

platform with their knees extended. They were familiarized with the device before the experimental procedure. They were instructed to grasp the handle of the device, keeping their feet and shoulders apart. Vibration was delivered for 1 min, with a 1 min rest period between each vibration set, which was repeated five times [17] at a frequency of 50–60 Hz, 0–10 mm amplitude, and 50 m/s speed [18,19]. Participants were instructed not to shift their weight or step off the WBV platform during the rest period. The vibration (the side altering) platform delivered an asynchronous stimulus (vertical sinusoidal stimulus) while balancing around a central point. All participants stood on the WBV device barefoot to eliminate any effect of footwear on the vibration (as shown in Fig. 3).

### Sample size determination

In this study, the primary outcome measure was H-reflex amplitude. Before the main study, we performed a pilot study to obtain H-reflex score mean and SDs for estimating the sample size using G\*Power 3.1 software (Universitat Dusseldorf, Dusseldorf, Germany). For a significance level of 5% (two-tailed) and statistical power of 80%, 25 participants were required in each group. Considering the dropout and withdrawal rate, the adequate sample size was determined as 30 participants in each group in this study.

### Outcome measures

The primary outcome measure in this trial was H-reflex amplitude assessed by using surface EMG (mV)

Figure 3



Participants' position during WBV application. WBV, whole-body vibration.

before (baseline), immediately (0 min), and 30 min after application of WBV. The secondary outcome measure was *H/M* ratio calculated using surface EMG before (baseline), immediately (0 min), and 30 min after application of WBV.

### Statistical analysis

Descriptive statistics were analyzed and *t*-tests were conducted for comparison of the mean age, weight, height, and BMI between the two groups. A two-way mixed-model analysis of variance with repeated measures was performed to compare the effect of WBV application between groups, as well as the interaction between time and group on mean values of H-reflex amplitude and *H/M* ratio. Also, the Bonferroni post-hoc test was used to identify the most significant differences between the study and control groups and time. The level of significance for all statistical tests was set at *P* less than 0.05. All statistical measures were determined using the statistical package for social studies, version 19, for Windows (SPSS Inc., Chicago, Illinois, USA). The Kolmogorov–Smirnov test was applied to check the normality of data.

The data obtained from both groups before, immediately, and at 30 min after WBV application (30 min measurement) regarding H-reflex amplitude and *H/M* ratio were statistically analyzed and compared.

## Results

### Participants' characteristics

The demographic data of the participants of both groups revealed no significant difference between the two groups in terms of mean age, weight, height, and BMI ( $P > 0.05$ ) (Table 1).

### Effect of whole-body vibration on H-reflex amplitude

Comparisons between the two groups showed that there was no significant difference in the mean values of H-reflex amplitude before WBV application ( $P = 0.97$ ). However, there was a significant decrease in H-reflex amplitude at 0 min in the study group compared with the control group ( $P = 0.002$ ). Also, there was a significant decrease in H-reflex amplitude at 30 min in the study group compared with the control group ( $P = 0.01$ ), and there was a significant interaction between time and application effect ( $P = 0.0001$ ) (Table 2 and Figs. 4, 6, 7).

### Effect of whole-body vibration on *H/M* ratio

Comparisons between the two groups showed no significant difference in the mean values of *H/M* ratio before application ( $P = 0.13$ ). However, there

**Table 1 Demographic characteristics of participants**

Variable	Study group (n=30)	Control group (n=30)	P value	Significance
Age (years)	21.45±2.32	21.55±2.41	0.89	NS
Weight (kg)	77.25±3.76	75.75±5.77	0.33	NS
Height (cm)	174.9±3.74	173.3±5.11	0.26	NS
BMI (kg/m <sup>2</sup> )	25.25±1.09	25.19±1.06	0.85	NS

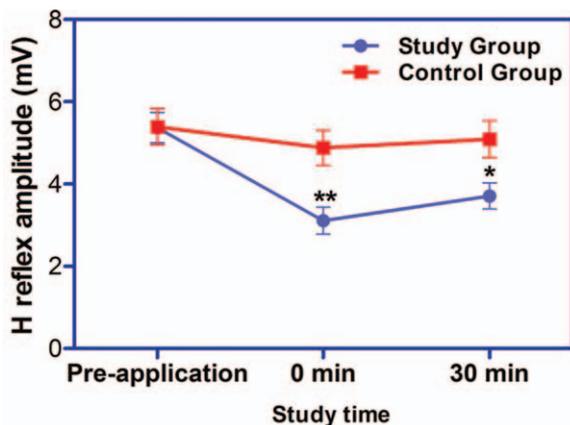
NS, nonsignificant.

**Table 2 Results of two-way mixed model ANOVA within groups for H-reflex amplitude at pre, 0, and 30 min measurements post-WBV application of both groups**

H-reflex amplitude (mV)				
Two-way mixed model ANOVA with repeated measures				
Within group comparison (time effect)				
F=149.84				P=0.0001
Multiple pairwise comparison (Bonfornni correction)				
	MD	% of change	P value	Significance
Study group				
Preapplication vs. 0 min	2.26	42.08	0.0001	S
Preapplication vs. 30 min	1.66	30.91	0.0001	S
0 vs. 30 min	-0.6	19.29	0.0001	S
Control group				
Preapplication vs. 0 min	0.51	9.46	0.001	S
Preapplication vs. 30 min	0.3	5.56	0.03	S
0 vs. 30 min	-0.21	4.3	0.16	NS

ANOVA, analysis of variance; H-reflex, Hoffman reflex; MD, mean difference; NS, nonsignificant; S, significant; WBV, whole-body vibration.

**Figure 4**



Mean values of H-reflex amplitude before and 0 and 30 min after application in both groups. H-reflex, Hoffman reflex. \*P<0.05; \*\*P<0.01.

was a significant decrease in *H/M* ratio at 0 min in the study group compared with the control group (*P*=0.0001). Also, there was a significant decrease in *H/M* ratio at 30 min in the study group compared with the

control group (*P*=0.03), and there was a significant interaction between time and application effect (*P*=0.0001) (Table 3 and Figs. 5–7).

### Discussion

The purpose of this study was to investigate the effect of a single bout of WBV on motor neuron excitability in healthy individuals. The results of this study showed that both groups had a decrease in H-reflex amplitude and *H/M* ratio, but statistically significant difference was recorded between the two groups, with results in favor of the study group.

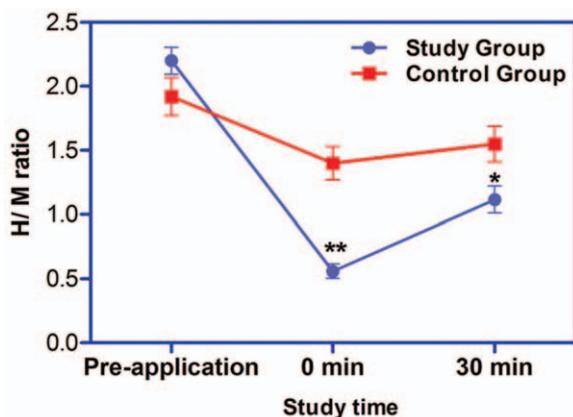
The major findings of this study were that a single bout of WBV produced a significant decrease in H-reflex amplitude and *H/M* ratio at 0 min and 30 min after application in healthy men.

The results of the control group might be attributed to the transition between prone, standing, and ambulation to and from the vibration platform. Prolonged static position during the off-time intervention might have

**Table 3 Results of two-way mixed model ANOVA within groups for H/M ratio at pre, 0, and 30min measurements post-WBV application of both groups**

H/M ratio				
Two-way mixed model ANOVA with repeated measures				
Within group comparison (time effect)				
$F=221.61$ <span style="float: right;"><math>P=0.0001</math></span>				
Multiple pairwise comparison (Bonferroni correction)				
	MD	% of change	P value	Significance
Study group				
Before application vs. 0 min	1.64	74.54	0.0001	S
Before application vs. 30 min	1.04	47.27	0.0001	S
0 vs. 30 min	-0.6	107.14	0.0001	S
Control group				
Before application vs. 0 min	0.52	27.08	0.0001	S
Before application vs. 30 min	0.37	19.27	0.0001	S
0 vs. 30 min	-0.15	10.71	0.08	NS

ANOVA, analysis of variance; H-reflex, Hoffman reflex; MD, mean difference; NS, nonsignificant; S, significant; WBV, whole-body vibration.

**Figure 5**

Mean values of H/M ratio before and 0 and 30 min after application in both groups. \* $P < 0.05$ ; \*\* $P < 0.01$ .

made participants less stressful. However, there was no significant difference in H-reflex amplitude and H/M ratio between 0 and 30 min.

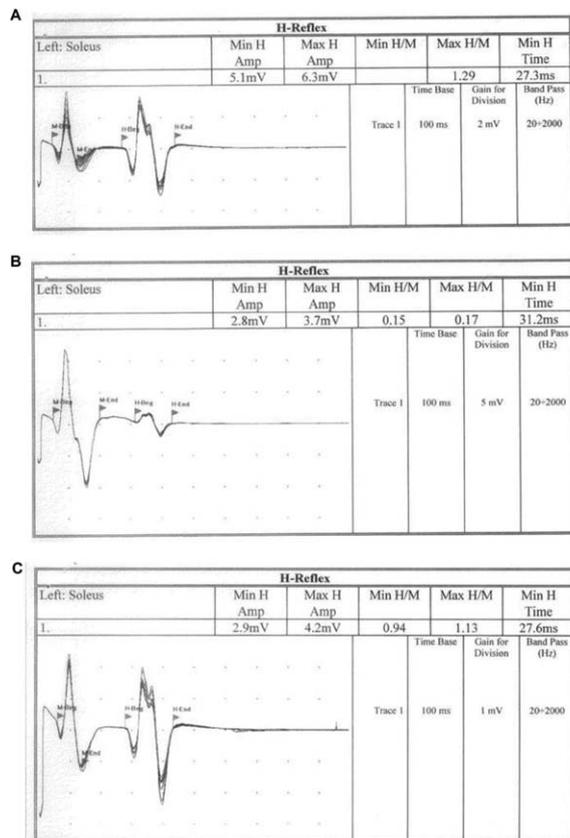
Our results are in agreement with those of other previous research [5,11,18,20–22]. H-reflex is used to study the effects of vibration on motoneuron (MN) pool excitability. It is a monosynaptic reflex that can show the changes of MN recruitment [8]. The most common parameter of the H-reflex that is studied is the H-reflex amplitude. The H-reflex recruitment curve is a better parameter that provides a more precise evaluation of MN excitability [23]. H-reflex is extensively used both as a research and as a clinical tool [24]. It is known that modulation of the

H-reflex is altered after neurological injury. Thus, modulation of the H-reflex by WBV would have clinical implications for use in the rehabilitation setting to improve functional performance [7].

WBV has been shown to modulate Ia afferent motor neuron synaptic transmission by causing presynaptic inhibition. Previous studies have shown that H-reflex was depressed during and after WBV in young adult healthy individuals. Using transcranial magnetic stimulation, it was found that WBV increases the excitability of the corticomotor pathway and intracortical inhibition while decreasing intracortical facilitation. Also, there is some evidence that WBV could increase temperature and blood flow in both skin and lower-limb muscles, which may lead to alterations in the viscoelastic properties of soft tissue [25]. In addition, the ratio of the  $H_{max}$  to the  $M_{max}$  is a proper index for revealing the level of excitability of the motor neuron pool [26].

The results could help to explain the beneficial effects of WBV in people suffering from exaggerated reflex activity. In hemiparetic patients, for instance, the WBV-induced reduction of Ia afferent transmission might help to reduce the abnormal muscle tone and reduce the cocontraction of their muscles. Furthermore, the partial and largely long duration of reflex suppression after WBV is probably helpful to facilitate voluntary motor actions in patients with a high muscle tone caused by exaggerated Ia afferent input. This assumption is well in line with previous observations showing that WBV training enhances the walking ability and balance control in persons with

Figure 6



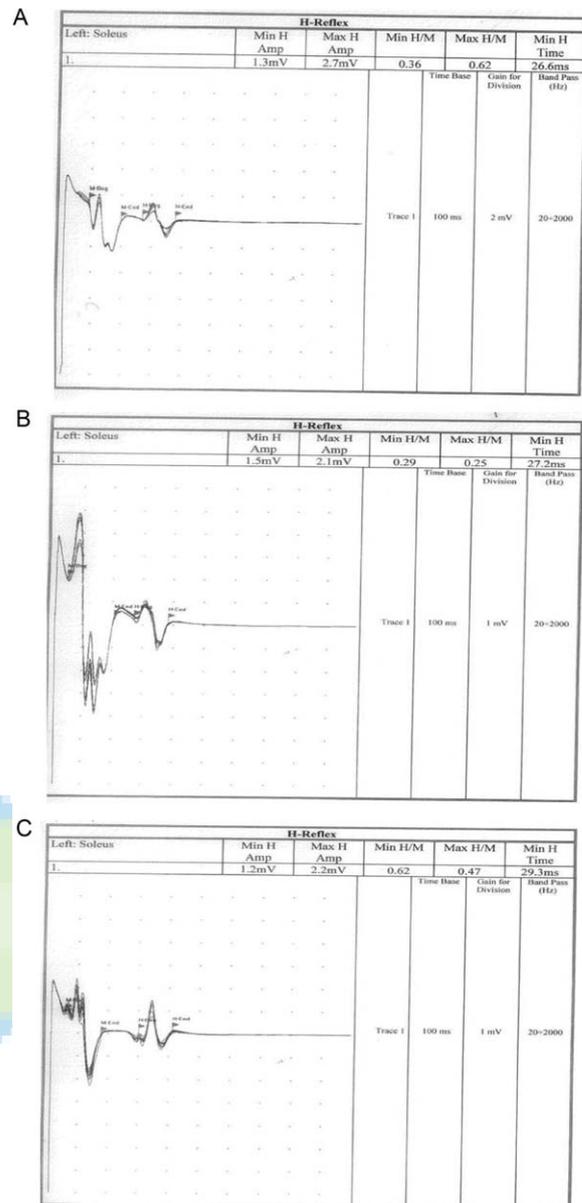
Soleus H-reflex measurements representative of the study group. (a) Before WBV application, (b) 0 min after application, and (c) 30 min after application. H-reflex, Hoffman reflex; WBV, whole-body vibration.

spastic diplegia [4], and improves mobility and muscle force in bilateral spastic cerebral palsy children [27]. Those improvements were accompanied by a reduction in spasticity that might be associated with a suppression of Ia afferent transmission [4].

Previous studies suggested that the mechanisms underlying the vibration-induced H-reflex depression are likely due to an increased firing threshold of Ia afferent fibers and presynaptic inhibition of Ia terminals with primary afferent depolarization and postactivation depression due to repetitive activation of the Ia motor neuron synapse followed by reduced probability of transmitter release [22].

The results of this study disagreed with those of previous studies [28–31]. The differences in results might probably be due to differences in the mechanical characteristics of the devices (such as amplitude, frequency, and duration of exposures), differences in the study population (age, sex, and health status), differences in acute or training effects and/or treatment protocols (acute or training effects),

Figure 7



Soleus H-reflex measurements representative of the control group. (a) Before WBV application, (b) 0 min after application, and (c) 30 min after application. WBV, whole-body vibration.

and differences in the position of the knee, whether relaxed or flexed. These factors might influence the effects of WBV on the neuromuscular system of the human body.

The most frequently cited mechanism by which WBV increases muscle activity is the TVR. However, TVR has been well proven for locally applied vibration over the muscle belly or its tendon, but there is no conclusive evidence until now that the TVR is applicable to WBV too [19].

This study has some limitations: first, participants comprised only healthy men. Thus, the generalizability

of the findings may be compromised. Future studies should address this matter and study the effects in different age groups and in the female population. Second, this study investigated the acute effects of WBV with a single bout. Therefore, a study conducted over a long period is needed. Further studies should investigate the use of WBV with the same parameters used here in patients with neurological disorders.

The findings of the current study imply that WBV might be an option for decreasing motor neuron excitability and thus may have therapeutic implications for cases with upper motor neuron lesions to normalize muscle tone.

## Conclusion

The present study showed that WBV under the current study protocol is effective in decreasing the motor neuron excitability in healthy male adults immediately and 30 min after its application.

## Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Nil.

## Conflicts of interest

There are no conflicts of interest.

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