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Original article

Various performance-enhancing effects from the same intensity of whole-body vibration training

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Abstract

Purpose: The purpose of this study was to compare the effects of an 8-week whole-body vibration training program in various frequency and amplitude settings under the same acceleration on the strength and power of the knee extensors.

Methods: Sixty-four young participants were randomly assigned to 1 of 4 groups with the same acceleration (4 *g*): high frequency and low amplitude ($n = 16$, 32 Hz, 1 mm) group, medium frequency and medium amplitude ($n = 16$, 18 Hz, 3 mm) group, low frequency and high amplitude ($n = 16$, 3 Hz, 114 mm) group, and control ($n = 16$, no vibration) group. All participants underwent 8 weeks of training with body mass dynamic squats, 3 sessions a week.

Results: The results showed that the high frequency and low amplitude group increased significantly in isometric contraction strength and 120°/s isokinetic concentric contraction strength; the medium frequency and medium amplitude group increased significantly in 60°/s and 120°/s isokinetic strength of both concentric and eccentric contraction; and the low frequency and high amplitude group increased significantly in 60°/s and 120°/s isokinetic eccentric contraction strength.

Conclusion: All frequency and amplitude settings in the 8-week whole-body vibration training increased muscle strength, but different settings resulted in various neuromuscular adaptations despite the same intensity.

Keywords: Isokinetic contraction strength; Muscle contraction speed; Neuromuscular adaptation; Vibration acceleration; Vibration amplitude; Vibration frequency

1. Introduction

Numerous reviews and meta-analyses indicated that acute vibration stimulation and/or chronic whole-body vibration (WBV) training could enhance muscle maximal strength and power.[1–4] The chronic effect of vibration has shown benefits in maximal voluntary contraction strength,[1] 1-repetition maximum,[4] and countermovement jump (CMJ) performances.[1,4] Vibration stimulation used in combination with other training methods, rather than vibration stimulation alone, was also considered to conduct more neuromuscular excitations and show more efficient training effects.[5–7] However, a previous study demonstrated that only the higher frequency of 50 Hz showed an increase of maximum muscle strength at an amplitude of 3 mm;[8] consequently, if the amplitude was increased to 10 mm, all frequencies of 30 Hz, 40 Hz, and 50 Hz showed a significant increase in electromyography (EMG) value for the vastus lateralis; the frequency of 30 Hz showed the greatest increase.[9] The greater EMG value could also be found with the greater amplitude at the fixed frequency of 30 Hz.[10] It seemed that WBV training had led to a better training effect for muscle strength with the greater amplitude but not necessarily with the higher frequency.[2,3]

The effects of WBV training could be determined by the vibration volume and intensity, which comprised the frequency,

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the amplitude, the duration of vibration stimulation, the rest interval, and the stiffness of muscle or joint of those who undertook vibration stimulation.[11–14] Furthermore, the acceleration of WBV training could represent the vibration intensity, which was dependent on the frequency and amplitude of the vibrating platform.[15] A previous study showed that if the acceleration ranged from 0.2 g to 9.0 g, the high-amplitude vibration was always associated with the greater EMG activity, and the effect of frequency was most marked at the higher amplitude with a moderately linear relationship with EMG activity.[16] Although the acceleration could be determined by the interaction between the vibration frequency and the amplitude of the platform, each of them induced a different mechanism of the neuromuscular system.

Higher frequency or greater amplitude, which represented the change in the number of stimulations or the muscle length, respectively, induced greater acceleration for increasing muscle activation, and, consequently, a better chronic training effect would be expected.[1,12] Nevertheless, acceleration was provided as only 1 of the characteristics of vibration platform use in most previous studies. One previous study indicated that the specific neuromuscular adaptation was possibly induced by different WBV training settings,[17] but there was no evidence showing whether it would relate to the strength and power of muscle contraction. Two serial studies determined that a setting of low frequency and high amplitude (15–30 Hz, 10 mm) with 4 min of vibration stimulation could temporarily enhance isometric contraction strength of the knee extensors, body balance, and CMJ performances; the effects were more significant than those in the high frequency and low amplitude (25–40 Hz, 2 mm) setting.[18,19] However, these studies did not control the same acceleration of vibration stimulation among the groups, and no chronic training effect was reported.

Therefore, the purpose of this study was to compare the effects of an 8-week WBV training period in various frequency and amplitude settings under the same acceleration on concentric and eccentric contraction strength and power of the knee extensors. The hypothesis was that the muscle strength and power of the knee extensors would increase significantly after an 8-week WBV training period, and different training effects would be expected owing to the different stimulated mechanisms of vibration frequency and amplitude on neuromuscular adaptations.

2. Materials and methods

2.1. Participants

Sixty-four healthy young people were recruited in this study (32 males and 32 females; age 20.1 ± 1.1 years; height 167.7 ± 9.5 cm; body mass 61.8 ± 11.6 kg). The inclusion criteria were age between 18 and 22 years and lack of WBV training experience. The exclusion criteria were a muscle or bone injury of the lower extremities and regular use of resistance training within the previous 6 months (to avoid any other training effects). The participants were required to be informed and to provide written consent before enrollment into this study. This study was approved by the Institutional Review Board of Taipei Medical University, Taiwan, China.

2.2. Study design

This study had a randomized controlled experimental design. A 4-group pre- and post-test design was used to examine the effects of an 8-week WBV training period with various frequency and amplitude settings under the same acceleration on concentric and eccentric contraction strength and power of the knee extensors. The 4 groups included a high frequency and low amplitude (HFV) group, a medium frequency and medium amplitude (MFV) group, a low frequency and high amplitude (LFV) group, and a control (CON) group. The intensity of WBV training in the HFV, MFV, and LFV groups was controlled at the same acceleration. An isokinetic dynamometer (System 3 Pro; Biodex, New York, NY, USA) was used to measure muscle strength of maximal voluntary isometric contractions and low and high isokinetic concentric and eccentric contractions of the knee extensors. The acceleration time of muscle contraction during each test was used to evaluate the power of the knee extensors.

All participants were assigned to 1 of the 4 groups randomly. Each group had the same number of men and women (n = 16, 8 men and 8 women). Ten participants dropped out because they were unable to participate in 2 or more consecutive training sessions. The final number of participants was 54 (13 in the HFV group, 15 in the MFV group, 15 in the LFV group, and 11 in the CON group). No significant differences were found in the anthropometric characteristics among the 4 groups (Table 1).

2.3. Training procedures

The HFV, MFV, and LFV groups underwent an 8-week WBV training period on a vibration platform with dynamic squat sessions 3 times per week. The same acceleration (4 g) was applied for each group, and various frequency and amplitude settings were calculated by the formula $g = A(2\pi f)^2/9.81$, where g is acceleration of vibration platform output, A is the amplitude, and f is the frequency.[15] To control the different frequency and amplitude settings with the same acceleration load, 3 different commercial models of WBV training platforms were used in this study: (1) HFV group: frequency, 32 Hz; amplitude, 1 mm;

Table 1
Participants anthropometric characteristics (mean ± SD).

	HFV (n = 13)	MFV (n = 15)	LFV (n = 15)	CON (n = 11)
Age (year)	20.6 ± 1.4	20.6 ± 1.3	19.3 ± 0.5	19.6 ± 0.5
Height (cm)	168.0 ± 12.3	167.6 ± 9.9	167.4 ± 8.2	167.7 ± 12.0
Body mass (kg)	62.5 ± 10.5	62.9 ± 9.4	61.3 ± 12.9	60.8 ± 16.3

Abbreviations: CON = control; HFV = high frequency and low amplitude; LFV = low frequency and high amplitude; MFV = medium frequency and medium amplitude.