Acute Effects of Different Whole-Body Vibration Frequencies and Amplitudes on Muscle Activity in Rowers

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ABSTRACT

Purpose: To investigate the effects of an acute whole-body vibration (WBV) on the muscle activity and performance during the 30-s Wingate test on a rowing ergometer. **Methods**: Fourteen elite male rowers (height, 175.6±4.7 cm; body mass, 76.4±5.2 kg) were administered in a randomized cross-over design into four experiments including the high-frequency high-amplitude (HFHA, 30 Hz and 0.6 mm), low-frequency low-amplitude (LFLA, 15 Hz and 0.375 mm), high-frequency low-amplitude (HFLA, 30 Hz and 0.375 mm) and non-vibration exercise (CON). Maximum voluntary contraction (MVC) of knee extensors was collected before the treatments, and then the athletes completed the 30-s Wingate test on the rowing ergometer immediately after the vibration or no vibration stimulation (10×1 min, 1 min rest interval). The muscle activities of the thigh were measured via the surface electromyography (EMG) and the power output was recorded by the rowing ergometer. The repeated one-way ANOVA for four treatments was calculated to determine the statistical differences. **Results:** There were no significant differences on the root-mean-square EMG (EMGrms) of the dominant leg among the treatments ($p > .05$). However, the HFLA had significantly higher EMGrms in the vastus lateralis of the non-dominant leg at the peak power output than the HFHA and CON treatments ($p < .05$). Moreover, the quotient of EMGrms/peak mechanical power had no significant difference among the treatments ($p > .05$). **Conclusion:** This study suggested that a single bout of WBV could not improve the anaerobic exercise performance, and the HFLA treatment might reduce the efficiency of recruited motor units on the non-dominant leg during the anaerobic power test in elite male rowers.

Key Words: electromyography, Wingate anaerobic power test, rowing

INTRODUCTION

It has been shown that mechanical vibrations applied to the muscle or tendon stimulates sensory receptors, mainly length-detecting muscle spindles (Hagbarth & Eklund, 1966). The activation of these muscle spindles facilitates the activation of alpha-motoneurons, leading to reflex muscle contractions (tonic vibration reflex) (Cardinale & Lim, 2003). This response is mediated by monosynaptic and polysynaptic pathways and results in increased motor unit activation (Cardinale & Bosco, 2003; Martin & Park, 1997), and it also changed the response of muscle activities on surface electromyography (EMG).

A few studies have demonstrated the acute whole-body vibration (WBV) could improve the dynamic muscle performance, such as the counter movement jump with arm swing (Cochrane & Stannard, 2005), one repetition-maximum test (Liebermann & Issurin, 1997), vertical jump height (Cormie, Deane, Triplett, & McBride, 2006), and endurance time (squatting on platform with load till exhaustion) (Rittweger, Mutschelknauss, & Felsenberg, 2003). In addition, Bosco, Cardinale, and Tsarpela (1999a) conclude that a single vibration bout resulted in a significant temporary increase in muscle strength of the lower extremities and arm flexors (Bosco et al., 1999b). Issurin and Tenenbaum (1999) showed that maximal power during concentric elbow flexion were enhanced significantly by vibration, and they found that the vibration induced a significantly larger increase in maximal power for elite athletes (10.4 % increase), than for amateurs (7.9 % increase) consisting of participants in club or college sports.

Therefore, acute WBV may improve the anaerobic power in athletes. However, the responsiveness of different frequencies and amplitudes on EMG follow by WBV in rower has not been studies, specifically in 30 seconds exercise on an ergormeter. In addition to, despite the above noted preliminarily positive findings and wide use of different vibration devices among athletes and activity person, conclusive evidence on the efficacy and safety of vibration stimulation is lacking, and there were no studies to verify the effects of WBV on the anaerobic exercise performance that using the glycolytic system (about 30 seconds). This lack of data is especially clear concerning the acute exercise performance and different whole-body vibration frequencies and amplitudes effects.

This study was to investigate the acute effects of different whole-body vibration on the surface EMG activity of the quadriceps and performance during the 30-s Wingate test on a rowing ergometer.

METERIALS AND METHODS

Subjects

Fourteen elite male rower (height, 175.6 ± 4.7 cm; body mass, 76.4 ± 5.2 kg; training year: 6.1 ± 2.9 yrs) volunteered to participate in this study and they were administered in a randomized cross-over design into four managements, each of the four test sessions were least separated by 2 days and included maximum voluntary contraction (MVC) test, WBV exercise and the 30 seconds Wingate anaerobic power test. All subjects were asked to avoid alcohol-containing beverages, 24 h before the first pre-treatment whole-body vibration. The procedures used were approved by a departmental committee for ethics in research, and all participants provided written informed consent.

EMG Analysis

The surface electromyography (EMG) signals were collected by Biovision system (Biovision®, Wehrheim, Germany, differential input impedance: 10 MΩ , common mode rejection ratio: 120 db) and then was sent to an A/D card and was analyzed using DASYLab software (Version 6.0, National Instruments, Germany). EMG of the rectus femoris, vastus lateralis, vastus medialis, and biceps femoris muscles of the dominant leg and non-dominant were recorded by bipolarly disposable 2-cm disc electrodes (Ag/AgCl ECG Electrodes, MSB Monitrace, Unomeidcal Ltd., Great Britain). The electrodes were fixed lengthwise over the middle of the muscle belly with an interelectrode (center-to-center) distance of 1-cm. A meter stick was placed the proper location of muscle in every subject for accurate measurement in four treatments. The reference electrode was attached to the right and left upper thigh. The preamplified EMG signals were amplified (×1,000), bandpass filtered (10 Hz low cut-off, 500 Hz high cut-off), and sampled at 1,000 Hz for analysis. Electromyography cables were fastened to prevent the cables from swinging and from movement artefact.

Treatment Protocol

After positioning of the electrodes, the experimental session undertook a standardized warm-up consisting of 10 minutes of stretch and 5 minutes of rowing on an ergometer without resistance. Before the WBV test protocol was started, muscle activity was recorded during performance of isolated MVC of knee extensors and flexors. Those involving the rectus femoris, vastus lateralis, and vastus medialis muscles of the dominant leg and non-dominant were recorded during an isolated leg extension at knee angles of 90 degree with the subjects sitting and lying position on a therapy table with knees hanging and erect gesture of the table.

Each subject was instructed to stand in the center of the vibration platform (AV-001 Elite Personal Trainer, B. Green Technology Co., Ltd, Taiwan) in standard postures (knee angles 100° and hip angles 90°) during four different treatments. Posture was strictly controlled during all exercises by standardizing knee and hip joint angles. The four treatments include the high-frequency high-amplitude (HFHA, 30 Hz and 0.6 mm), low-frequency low-amplitude (LFLA, 15 Hz and 0.375 mm), high-frequency low-amplitude (HFLA, 30 Hz and 0.375 mm,) and non-vibration exercise (CON). Loading was carried out in a half-squat position with individual foot spacing held constant throughout the ten times 1-minute exposure with 1-min interval. The sham intervention consisted of the subject standing on the vibration platform in the same position with the vibration plate inactivated.

All subjects were performed the 30 seconds Wingate anaerobic power test on a rowing ergometer (Concept Π system, Morrisville, VT, USA) immediately after WBV exercise, and the EMG recordings started when the subjects stood in the regulatory posture on a rowing ergometer till carried out the Wingate test. Total power values displayed by the ergometer were recorded with specific software.

Data Analysis

The amplified raw EMG signal was converted to an average root-mean-square (rms) signal. The mean EMGrms values was computed at the peak power output during the 30 seconds Wingate anaerobic test for each test in each muscle group after the four WBV treatments.

For leg extension and flection motion, quadriceps muscle (rectus femoris, vastus lateralis, and vastus medialis) were expressed relative to muscle activity at the peak power output during the 30 seconds Wingate anaerobic test. In addition, the EMG/peak mechanical power (EMG/$\dot{W}$) was recorded on the rowing ergometer for evaluation of neural potential. The data are reported as mean ± SD.

Statistical Analysis

The repeated one-way ANOVA for four treatments was calculated to determine the statistical differences and the criterion alpha level was set at $p < .05$. All statistical analyses were performed through the use of a statistical software package (SPSS, Version 11.0; SPSS Inc., Chicago, IL).

RESULTS

Anaerobic exercise performance

These subjects carried out the 30-s Wingate test after different WBV of frequencies and amplitudes, and the power output was recorded by JVC camera during the test. As can be seen in Figure 1, there were no significant differences on the peak power among the treatments ($p > .05$). Moreover, the vibration effect in average power output was not significant difference among the treatments (HFHA vs. LFLA vs. HFLA vs. CON; 625.1±63.3 W vs. 635.4±52.3 W vs. 628.3±55.0 W vs. 636.9±52.7 W, $p > .05$).

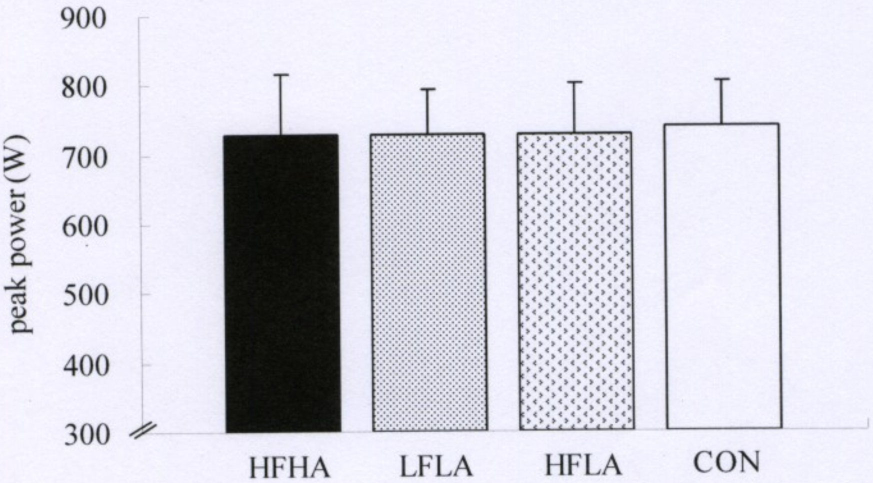

Figure 1. The peak power output of the 30-s Wingate anaerobic power test during a rowing ergometer after different frequencies and amplitudies WBV exercises. HFHA = high-frequency high- amplitude = 30 Hz and 0.6 mm, LFLA = low-frequency low-amplitude = 15 Hz and 0.375 mm, HFLA = high-frequency low-amplitude = 30 Hz and 0.375 mm, CON = non-vibration.

EMG activity of the quadriceps and neural efficiency

The EMGrms of the RF and quadriceps were noticeably higher than HFHA in dominant leg followed the LFLA ($p < .05$). After the HFLA, the EMGrms was significantly higher in VL than HFHA and CON ($p < .05$), and the total EMGrms of the quadriceps was also higher in HFLA than HFHA ($p < .05$). Furthermore, the VM was not significant difference within the four treatments (see Table 1).

Table 1. Muscle activity of the rectus femoris (RF), vastus lateralis (VL), and vastus medialis (VM) of non-dominant leg at power output during 30-s Wingate test after the HFHA, LFLA, HFLA, and CON treatments presented in relative value as a percentage of the muscle activity during an isolated MVC (100%). Values are mean ± SD.

	RF				VM				VL				Quadriceps			
	HFHA	LFLA	HFLA	CON	HFHA	LFLA	HFLA	CON	HFHA	LFLA	HFLA	CON	HFHA	LFLA	HFLA	CON
EMGrms (%)	66.6 ± 16.5	83.1* ± 24.8	75.1 ± 19.3	69.7 ± 21.1	82.7 ± 21.0	89.2 ± 25.5	93.9 ± 29.1	96.0 ± 37.5	80.6 ± 15.6	82.2 ± 22.6	95.7*† ± 24.7	79.4 ± 12.4	75.5 ± 15.0	84.6* ± 14.7	86.8* ± 18.6	78.3 ± 15.4

HFHA = high-frequency high- amplitude = 30 Hz and 0.6 mm, LFLA = low-frequency low-amplitude = 15 Hz and 0.375 mm, HFLA = high-frequency low-amplitude = 30 Hz and 0.375 mm, CON = non-vibration exercise. EMGrms = EMG root-mean-square. MVC = maximum voluntary contraction. * Significant increase in HFLA or in HFLA than HAHA ($p < .05$). †Significant increase in HFLA than LFLA and CON ($p < .05$).

The EMGrms detected in the quadriceps, RF, VL, and VM muscle of non-dominant leg demonstrated no statistically significant differences among the treatments ($p > .05$) (see Table 2).

Table 2. Muscle activity of the rectus femoris (RF), vastus lateralis (VL), and vastus medialis (VM) of non-dominant leg at power output during 30-s Wingate test after the HFHA, LFLA, HFLA, and CON treatments presented in relative value as a percentage of the muscle activity during an isolated MVC (100%). Values are mean ± SD.

	RF				VM				VL				Quadriceps			
	HFHA	LFLA	HFLA	CON	HFHA	LFLA	HFLA	CON	HFHA	LFLA	HFLA	CON	HFHA	LFLA	HFLA	CON
EMGrms (%)	65.8 ± 15.1	63.6 ± 18.2	68.2 ± 14.6	66.3 ± 19.1	97.0 ± 35.6	95.2 ± 33.3	83.7 ± 28.0	82.4 ± 16.7	100.3 ± 27.9	95.3 ± 24.7	94.0 ± 21.9	85.5 ± 26.4	74.5 ± 11.9	77.7 ± 13.2	83.2 ± 15.4	77.4 ± 12.9

HFHA = high-frequency high- amplitude = 30 Hz and 0.6 mm, LFLA = low-frequency low-amplitude = 15 Hz and 0.375 mm, HFLA = high-frequency low-amplitude = 30 Hz and 0.375 mm, CON = non-vibration exercise. EMGrms = EMG root-mean-square. MVC = maximum voluntary contraction.

The neural efficiency had no significant differences in the legs at peak power output on rowing ergometer among the treatments (p > .05) (see Figure 2).

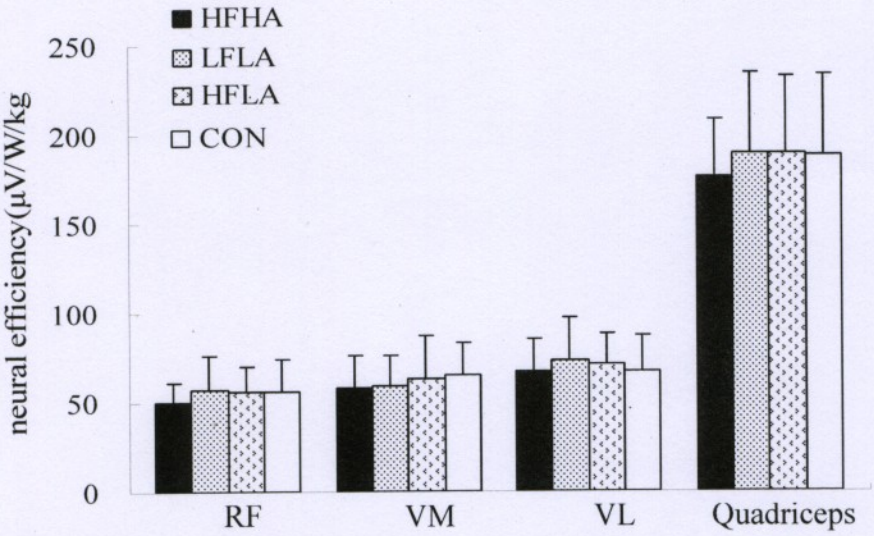

Figure 2. The neural efficiency recorded at the anaerobic peak power output during a rowing ergometer after different frequencies and amplitudies WBV exercises. HFHA = high-frequency high-amplitude = 30 Hz and 0.6 mm, LFLA = low-frequency low-amplitude = 15 Hz and 0.375 mm, HFLA = high-frequency low-amplitude = 30 Hz and 0.375 mm, CON = non-vibration. rectus femoris = RF, vastus lateralis = VL, and vastus medialis = VM.

DISCUSSION

This is the first study that focuses on the WBV-induced increase in activity of the leg muscles during the 30-s Wingate anaerobic power test. The first hypothesis of the study was confirmed because the previous researches showed that the one repetition maximum (Liebermann and Issurin, 1997), maximal power and mean power (Issurin and Tenenbaum, 1999), maximal voluntary contraction force (Curry and Clelland, 1981), and IEMG of forearm flexor (Kihlberg S, 1995) were notably improve by the acute WBV exercise. Therefore, in this present study, we try to detect the optimum frequency and amplitude of WBV for training in athletes. Although the Wingate anaerobic power performance and neural efficiency had no significant differences in both upper thighs at peak power output on a rowing ergometer among the treatments, one thing is interesting that the EMGrms had a significant increase in HFLA in non-dominant leg than the LFHA and CON. It's important to note that the anaerobic power was not improved after different WBV exercise in this study, and the HFLA recruited more motor units to do the same workload. Therefore, we suggested that the HFLA may be unfavourable to 30-s anaerobic exercise. Unfortunately there is no study investigate the dynamic muscle performance by acute effects of vibration since present. According to the author's experience, subject will feel uncomfortable if the intensity of WBV over 2.5 g (gravity), therefore, we choice the intensity of WBV under the 2.5g. Because of the anaerobic power performance was not improved by acute WBV exercise, we suggested that the acute WBV may not ergogenic on per motor unit during the 30-s anaerobic exercise. In addition, the HFLA vibration may increase the recruitment of motor unit due to impairment of muscle activity.

Unlike the previous study, this study presented that neural efficiency had no significant difference among the four treatments. (Bosco et al., 2000) reported that the acute WBV influences proprioceptive feedback mechanisms and specific neural components, leading to an improvement of neuromuscular performance. Moreover, Bosco et al. (1999b) showed that the ration of EMG/$\dot{W}$ decreased because of an enhancement of neural efficiency. We suggest that the efficiency of neural potential may not affect by acute WBV exercise through the strictly cross-over design in elite male rower.

The WBV exercise has been reported to increase both peak and mean power output during counter movement vertical jumps (Cochrane & Stannard, 2005) and static jumps (Torvinen, Kannus et al., 2002a). Dissimilar improvements in power performance were reported by this present study. However, some studies evidenced the opposite consequences. (de Ruiter, van der Linden, van der Zijden, Hollander, & de Haan, 2003) investigate that twelve untrained students (seven males) performed the maximal knee extensor force with one standard WBV exercise session 5 × 1 minute vibration (2 minutes rest in between).

Maximal knee extensor force reduced 90 seconds after vibration and the maximal rate of isometric force raise was not affected by WBV exercise. (Torvinen, Sievanen et al., 2002b) examined that sixteen young health subjects (eight males) were randomized cross-over design to different treatment with 4 minutes WBV exercise on muscle performance and body balance. They reported no change in muscle performance or balance at 2 and 60 minutes after the exercise session.

We suggested that first reason is the frequency and/or amplitude may not enough for stimulation of each muscle and then the performance could not improve by acute WBV exercise; second reason are the duration of WBV exercise and/or the whether cross-over design, because the intensity, duration, and method of experiment are very important to performance. Last explanation is the level of physical activity. (Rehn, Lidstrom, Skoglund, & Lindstrom, 2007) reported that the untrained people may have a greater benefit form long-term vibration exercise than physically active people.

In conclusion, the different intensities of a bout WBV could not improve anaerobic power performance during maximal rowing sprint test in elite male rowers, and the HFHA gave a better insight in the responsiveness of the neuromuscular system. This information will help professionals involved in the health and fitness to determine the potential of WBV programs in revalidation and training.

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