
WHOLE-BODY VIBRATION APPLIED DURING UPPER BODY EXERCISE IMPROVES PERFORMANCE

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ABSTRACT

Marín, PJ, Herrero, AJ, Milton, JG, Hazell, TJ, and García-López, D. Whole-body vibration applied during upper body exercise improves performance. *J Strength Cond Res* 27(7): 1807–1812, 2013—Whole-body vibration (WBV) training has exercisers perform static and dynamic resistance training exercises on a ground-based platform. Exposure to WBV exposure has demonstrated benefits and no effect on lower body strength, power, and performance. The aim of this study was to determine if WBV exposure (50 Hz, 2.51 mm) has any potentiating effects postexercise by measuring the kinematic variables of a set of upper body elbow-extensor exercise (70% one-repetition maximum [1RM]) to volitional exhaustion. Sixteen recreationally active students (12 male and 4 female) performed 3 different experimental conditions on separate days. Each condition had the subjects perform 1 set of elbow-extension exercise to fatigue with 1 of 3 WBV treatments: WBV simultaneously during the set (AE); 60 seconds after application of WBV for 30 seconds (RE); and no WBV (CTRL). Kinematic parameters of each repetition were monitored by linking a rotary encoder to the highest load plate. The mean velocity and acceleration throughout the set and perceived exertion were analyzed. A significant increase ($p < 0.05$) was observed in the mean velocity for the whole set in the AE condition vs. the CTRL condition. The mean acceleration was significantly higher ($p < 0.05$) in the AE condition in comparison with RE (increased by 45.3%) and CTRL (increased by 50.4%) conditions. The positive effect induced by WBV on upper-limb performance is only achieved when the stimulus is applied during the exercise.

However, WBV applied 60 seconds before upper body exercise results in no benefit.

KEY WORDS vibration exercise, performance, kinematics, elbow extension

INTRODUCTION

The kinematic aspects of resistance exercises (e.g., velocity and acceleration) have been proposed as one of the most important stimuli for strength and resistance training-induced adaptations (19). Consequently, athletes and coaches are continually looking for new methods that will be helpful in improving kinematics. Recently, whole-body vibration (WBV), which has exercisers perform static and dynamic movements on a ground-based platform, has garnered much interest in the fitness and rehabilitation realms. It is theorized that the WBV stimulus causes short and rapid changes in muscle fiber length that result in skeletal muscle reflex contractions (9,24). These reflexive contractions result in an increased neuromuscular load placed on the muscle (1,10,12,26). This increased neuromuscular load with WBV has also demonstrated improvements in lower body strength and power capabilities after acute (21,23) and chronic exposures (5,6,14,15,22,28,31). However, the fact that ground-based WBV stimulus can affect the upper body is not well established. Hazell et al. (10) demonstrated that WBV stimuli of varied frequencies (25–45 Hz) and amplitudes (2–4 mm) resulted in no effect on upper body (biceps brachii, triceps brachii) skeletal muscle electromyography (EMG) in healthy young men. However, we recently demonstrated that similar WBV stimuli (30 Hz, 2.5 mm and 46 Hz, 1.1 mm) resulted in significant increases in upper body (biceps brachii) EMG in healthy older adults (16).

To determine whether the WBV stimulus increases upper body strength and power, Marín et al. (13) compared the effects of a WBV stimulus of high magnitude vibration (50 Hz, 2.51 mm, $98.55 \text{ m}\cdot\text{s}^{-2}$) vs. that of low magnitude vibration (30 Hz, 1.15 mm, $20.44 \text{ m}\cdot\text{s}^{-2}$) during elbow-extension exercise performed to failure (70% of 1 repetition

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maximum [1RM]). The results demonstrated that the high magnitude stimulus significantly increased the average velocity of the contractions suggesting that higher magnitude WBV generates more neuromuscular facilitation than the lower magnitude stimuli, which can improve upper body resistance exercise performance. However, no study to date has examined if the improvements in velocity of contractions during upper body exercise are present postexercise with WBV exposure. Thus, the aim of this study was to analyze the potential post-exercise effects of WBV by measuring acceleration and velocity 60 seconds after WBV exposure (30-second duration) to determine if WBV exposure has a residual effect on upper body performance. It was hypothesized that WBV would potentiate the neuromuscular system by improving kinematic aspects (velocity and acceleration of contractions) of a resistance exercise. Potential improvements to the speed of the contractions could have important effects on performance during or subsequent training adaptations.

METHODS

Experimental Approach to the Problem

Each subject performed 3 sets of elbow-extension exercise on a WBV platform under 3 conditions (independent variables): (a) acute effect, the elbow-extension exercise was performed during WBV on a vibration platform (AE); (b) residual effect, the WBV stimulus (30 seconds) during the semisquat position was applied 60 seconds before the elbow-extension exercise (RE); control, the elbow-extension set was performed on a vibration platform without WBV (CTRL). The initial experimental session determined the subject's 1RM for the elbow-extension exercise on a pulley cable machine (Telju, Toledo, Spain). Each of the 3 exercise sessions was performed as 1 set of repetitions until muscular failure on the pulley cable machine. All the experimental sessions (including the 1RM measurement) were performed on the platform to avoid a setting-related bias. Thus, at the end of the experimental phase, all the participants had been tested for the 3 conditions. Testing sessions were carried out on the same day of the week and in all cases at the same time of the day.

Subjects

Sixteen recreationally active students (12 male and 4 female) participated in this study. The participants' mean ($\pm SD$) age, height, body mass, and elbow-extension 1RM were 19.1 ± 1 years, 176.3 ± 10.4 cm, 73.4 ± 13.2 kg, and 39 ± 12.9 kg. The participants were physically active, and all of them had at least 3 months' experience with free-weight resistance exercises and training to failure. Their normal workouts typically lasted just <90 minutes and entailed training of multiple body parts and exercises. However, at the time of the study and from 2 months before, none was engaged in any regular or organized resistance training program(s). All data were collected between April and May 2010. Exclusion criteria were diabetes, epilepsy, gallstones, kidney stones, cardiovascular diseases, joint implants, recent thrombosis, and musculoskeletal prob-

lems. Before any participation, the experimental procedures and potential risks were explained to the subjects, and all the subjects provided written informed consent. The study received local ethics committee approval. Moreover, the participants did not allow their sleeping, eating, and drinking habits to change throughout study participation.

Vibration Equipment

The vibration stimulus of the platform used in this study consisted of uniform vertical oscillations (synchronous) Power Plate Next Generation (Power Plate North America, Northbrook, IL, USA). The vertical components of the acceleration, frequency, and amplitude were measured using an accelerometer in accordance with ISO2954 (Vibration meter, VT-6360, Hong Kong, China). The peak-to-peak amplitude of the vibration was 2.51 mm when the platform vibration frequency was 50 Hz. The acceleration was $98.55 \text{ m} \cdot \text{s}^{-2}$ with 70 kg on the platform. During all the sessions, the participants wore the same athletic shoes to standardize the damping of the vibration resulting from the footwear (12).

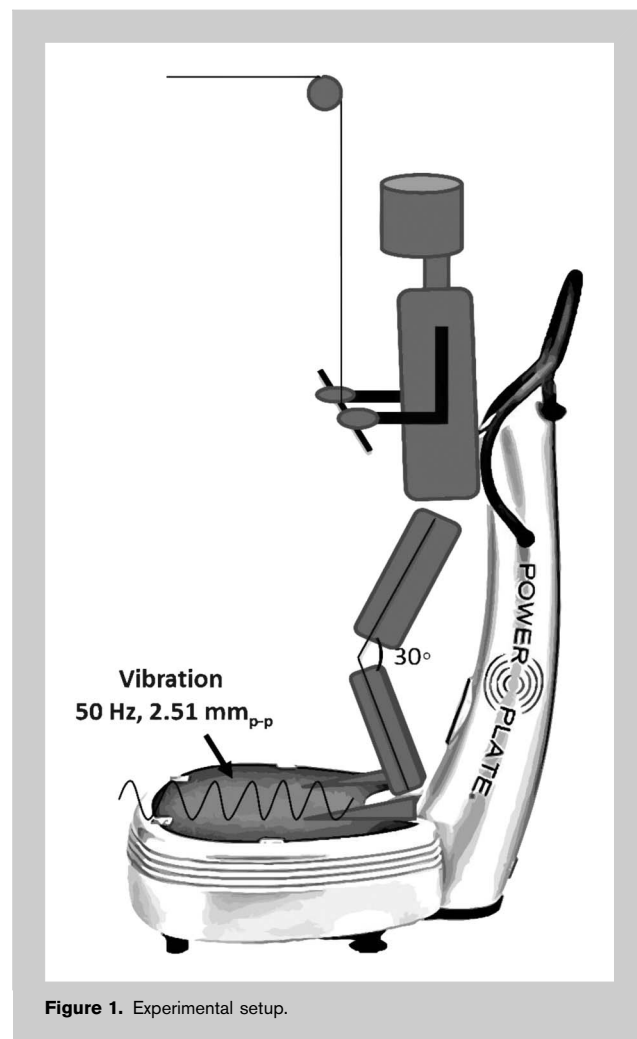


Figure 1. Experimental setup.

Maximal Strength Measurement

The 1RM elbow extension was estimated from a 1RM to 3RM effort using the equation described by Wathan (32). Each subject carried out 3–5 attempts with progressively increasing weights to achieve a 1–3 RM. Three minutes of rest was allowed between attempts. Although direct 1RM testing is more reliable, the direct 1RM test may present safety issues for subjects; thus, the chosen protocol was used to limit risk of injury (30). For elbow-extension repetitions, the participants lowered the bar until the elbows were completely extended. Hand spacing at the handle was shoulder width, and the cable was perpendicular to the floor when the elbow was flexed 90°. Throughout each repetition, the elbows were flexed and extended equally with the upper back remaining in contact with the control tower of the platform (Figure 1). Feet spacing was also shoulder width, and a 30° knee flexion was maintained during the exercise for all the conditions. No bouncing or arching of the back was allowed. Elbow-extension technique and settings were maintained throughout the whole experimental phase.

Elbow-Extension Sets to Failure

Each elbow-extension protocol consisted of performing 1 set to volitional exhaustion, with a load equivalent to the subject's 70% of 1RM. The load used (70% of 1RM) was selected because a previous study focused on the effects of vibration used a similar load (13,23). In all the conditions, the participants began with a warm-up consisting of 5 minutes of low-resistance cycling on an ergometer (50 and 75 W for women and men, respectively), followed by 2 sets of elbow extension comprising 15 repetitions at 6 kg and 1 set of 10 repetitions at 40% of the 1RM, allowing 1 minute of rest between sets. Experimental exercise sets (AE, CTRL) began 1 minute after the specific warm-up. In the RE condition, the WBV stimulus began 1 minute after the warm-up with the elbow-extension exercise set beginning immediately upon

cessation of the WBV stimulus (30 seconds; 50 Hz, 2.51 mm). The participants were asked to move the cable handle as fast as possible during the concentric phase of each repetition, until volitional exhaustion. The elbow-extension range of motion was performed completely, starting from maximal flexion to avoid compensation by the shoulders and trunk. Failure was defined, according to a previously established criterion (7), as the time point when either the handle ceased to move, or the subject paused >1 second when the arms were in the extended position, or the subject was unable to reach the full extension position of the arms. During the set, one examiner encouraged the participants to execute the exercise properly, with verbal orientations to avoid alterations in posture.

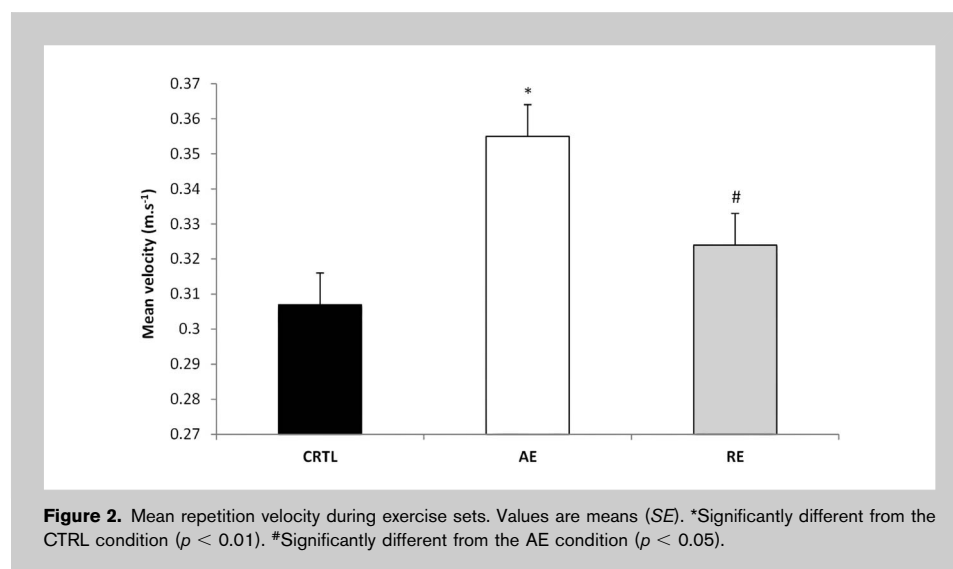
Kinematic parameters of each repetition were monitored by linking a rotary encoder (Globus Real Power, Globus, Codogno, Italy) to the highest load plate. The rotary encoder recorded the position of the load plate within an accuracy of 0.1 mm and time events with an accuracy of 0.001 seconds. The mean velocity and acceleration throughout the set and perceived exertion were analyzed. Velocity and acceleration were determined using software provided by the rotary encoder as described previously (8).

Immediately after the fifth repetition, the OMNI-RES perceived exertion scale (25) was verbally administered. The OMNI-RES consists of 10 reporting options between 1 (extremely easy) and 10 (extremely hard). All the participants had previous experience using the OMNI-RES scale, a written copy of the OMNI-RES scale with the following instructions was given to the participants: "At fifth repetition, we want you to rate the intensity of effort perceived during the exercise, using the scale shown above. By perceived exertion we mean how heavy and strenuous the exercise feels to you, depending mainly on the strain and fatigue in your muscles and on your general feeling. The value of "1" corresponds to feeling of exertion during seated rest while

the value of "10" corresponds to feelings at maximal exertion. You should use the verbal anchors (e.g. extremely easy, extremely hard, etc...) to assist you in giving your perceptions a numeric rating."

Statistical Analyses

The normality of the dependent variables was checked and subsequently confirmed using the Kolmogorov-Smirnov test. Comparisons of dependent variables between treatment conditions (i.e., AE vs. RE vs. CTRL) were analyzed with a 1-way analysis of variance. When a significant *F* value was achieved,



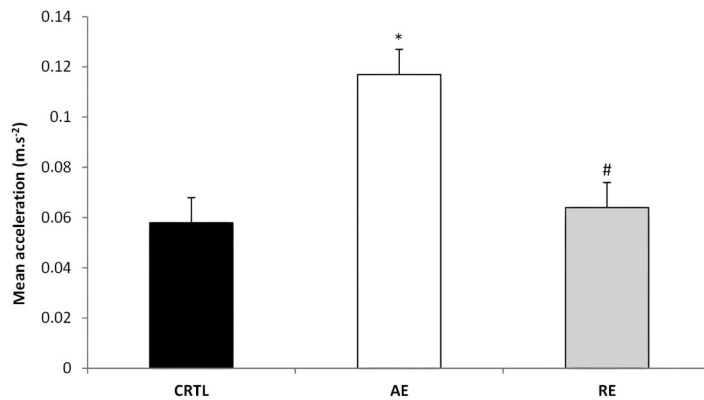


Figure 3. Mean repetition acceleration during exercise sets. Values are means (SE). *Significantly different from the CTRL condition ($p < 0.01$). # Significantly different from the AE condition ($p < 0.05$).

pairwise comparisons were performed using a Scheffe post hoc procedure. From the 2-familiarization trials, the intraclass correlation coefficients were calculated for each dependent variable to determine test-retest reliability (>0.91). Statistical significance was set at $p \leq 0.05$. Effect sizes (d) were analyzed to determine the magnitude of an effect independent of sample size. *Small* effect sizes are considered $d < 0.2$, *moderate* effect sizes $d = 0.2-0.8$, and *large* effects sizes $d \geq 0.8$ (29). A sample size of 16 was determined to be necessary to detect a 16% increase in the mean velocity between AE and CTRL, at a significance level of 0.05 with a power of 80%. Values are expressed as mean \pm SD in the text, and as mean \pm SE in the figures.

RESULTS

Mean Velocity Throughout the Set

There was a significant increase ($p < 0.05$; $d = 1.33$) in the mean velocity for the whole set in the AE condition vs. that in the CTRL condition (Figure 2). No significant condition effects ($p > 0.05$; $d = 0.47$) related to velocity pattern were observed between the RE and CTRL.

Mean Acceleration Throughout the Set

A statistically significant condition effect ($p < 0.05$) was observed concerning the mean acceleration for the whole set (Figure 3). Post hoc analyses revealed a significant increase ($p < 0.05$) in the AE condition vs. that in the RE condition (increased by 45.3%; $d = 1.33$) and CTRL (increased by 50.4%; $d = 1.48$). There was no statistically significant difference ($p > 0.05$; $d = 0.15$) between the RE and CTRL.

Subjects' Perceived Exertion

Perceived exertion (OMNI-RES value) at the fifth repetition was 8.1 ± 1.2 in the AE condition, 8.3 ± 1.2 in the RE condition, and 8.3 ± 0.9 in the CTRL condition. Although

CTRL was perceived as slightly harder than the AE condition (2.5%), no statistically significant condition effect was observed related to perceived exertion ($p > 0.05$).

DISCUSSION

The primary finding of this study was that WBV applied during a set of elbow-extension exercise at 70% 1RM increased the mean acceleration of the repetitions performed. However, when the WBV exposure was applied 60 seconds before performing the exercise set, there was no benefit. These results suggest that WBV

applied during upper body exercise performance is beneficial but performing WBV immediately before upper body performance has no effect. To the best of our knowledge, this is the first study that analyzes the effects of WBV before and during elbow-extension performance that mimics a typical strength-training session with WBV.

Previous WBV research on exposure immediately before exercise or performance has demonstrated positive results. Cormie et al. (4) demonstrated that 30 seconds of synchronous WBV (30 Hz, 2.5 mm) during a static squat resulted in a significantly greater jump height during a countermovement jump immediately after the WBV treatment but not 5–30 minutes post WBV. Rhea and Kenn (23) have also reported a short 30-second synchronous WBV exposure at 35 Hz, 4 mm during significantly increased power output in subsequent squat exercise. Armstrong et al. (2) reported that 60 seconds of synchronous WBV (30–50 Hz, 2–4 or 4–6 mm) during a static squat significantly increased vertical jump height for up to 5 minutes post exposure. Further, Ronnestad (27) demonstrated that superimposing the WBV stimulus during squat and countermovement jumps results in significant increases in peak average power in untrained subjects. These studies illustrate the potential benefit of a single WBV exposure before and during lower body performance. However, our current study concerned the effects of WBV both during and before upper body performance. Our results demonstrate that although WBV applied during upper body exercise is beneficial, applying WBV immediately before a set of elbow-extension exercises did not increase the subsequent performance.

Marin et al. (16) have recently demonstrated that WBV applied via a ground-based platform can result in significant increases in upper body EMG. Although the potential mechanism(s) by which WBV improves neuromuscular performance are not well understood, there are few theories on how WBV can stimulate the neuromuscular system. It is theorized that the WBV platform could induce the tonic vibration reflex (TVR) in

several muscles because it is theorized that the oscillations of the WBV platform stimulate Ia afferents via muscle spindles, resulting in facilitating homonymous α -motoneurons (17). The mechanical oscillations of the WBV platform induce an involuntary reflex contraction (akin to the TVR) (21,24) in both primary and secondary muscles involved in the movement being performed (10–12,26). This results in a neuromuscular potentiating effect (postactivation potentiation) where the WBV-induced increases in muscle activity enhance force output via increased motor neuron excitability or the phosphorylation of muscle contractile elements (3,18). Further, increases in corticospinal excitability with WBV has been demonstrated by Mileva et al. (20) who applied WBV (30 Hz, 1.5 mm) during static squat exercise, which resulted in increased corticospinal excitability and altered intracortical processes suggesting that the facilitatory effects of vibration in healthy subjects may influence the excitatory state of the peripheral and central structures of the brain facilitating subsequent voluntary movements. This could explain how WBV applied to the lower limbs could benefit upper-limb muscle performance seen in our previous work (13) and in the present results. Our data support that there is an effect of WBV applied via a ground-based platform on upper body muscle contractions though a limited window during which contraction velocity will be enhanced after an acute bout of WBV exists. This limited effect could occur by a decrease in cortical and spinal activity because of an inadequate dose of stimulus and rest.

In conclusion, WBV applied to the body via a ground-based platform during but not before upper body resistance exercise at 70% 1RM was effective in increasing the average velocity of repetitions throughout a set at 70% 1RM performed until muscular failure. The current results also demonstrate that 60 seconds of WBV performed immediately before upper body resistance exercise results in no performance benefit.

PRACTICAL APPLICATIONS

These data suggest that a vibration stimulus applied to the feet can result in positive improvements in upper body resistance exercise performance. They also demonstrate that WBV superimposed during exercise results in greater effects than 60 seconds of WBV exposure performed immediately before upper body resistance exercise. Exercise and fitness professionals can employ WBV via a ground-based platform simultaneously during the set to improve muscular performance in the upper body. The use of WBV while performing upper body exercises may increase the intensity of the effort as contractions are being performed at a higher velocity, the resulting training stimulus may result in a greater training adaptation than performing the same upper body exercise without WBV. The current findings also suggest that 60 seconds of WBV exposure immediately before upper body resistance exercise do not confer the same positive benefit.

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