Effect of Direct Whole-Body Vibration on Upper-Body Muscular Power in Recreational, Resistance-Trained Men

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Abstract

Jones, MT, Martin, JR, Jagim, AR, and Oliver, JM. Effect of direct whole-body vibration on upper-body muscular power in recreational, resistance-trained men. *J Strength Cond Res* 31(5): 1371–1377, 2017—To determine the acute effect of whole-body vibration (WBV) on upper-body power, 15 men (mean ± *SD*; age 21.5 ± 2.3 years; height 173.1 ± 6.5 cm; and weight 77.2 ± 13.8 kg) with ≥1-year resistance training experience and a bench press (BP): body mass ratio ≥1.25 participated in a repeated-measures crossover design. Session 1 included body composition ([Bod Pod] 15.76 ± 6.7% body fat), 3 repetition maximum BP, and familiarization with: seated medicine ball throw (SMBT), plyometric push-up (PPU) on a force plate, and vertical WBV platform. Sessions 2–5 were randomly ordered across condition and test, separated by 24 hours, and consisted of a warm-up followed by 4 × 30-second push-up holds (2 × elbows at 90° and 2 × arms extended) performed on the vibration platform with WBV (frequency: 30 Hz, amplitude: 2–4 mm, 1:1 work: relief ratio) or no WBV. Seated medicine ball throw and PPU were tested immediately, 1, 5, and 10 minutes post. Standardized magnitude-based inferences were used to define outcomes. A likely positive effect of WBV was observed for SMBT at 10 minutes post. A likely negative effect of WBV resulted at 1 minute in time-to-peak force. A possibly positive effect was observed 10 minutes post. A possibly negative effect was observed 10 minutes post for peak power, and a likely negative effect of WBV was observed on time-to-peak power immediate post. Incorporating a 10-minute rest period is recommended when implementing power exercises after upper-body static-hold exercises during WBV exposure.

Key Words bench press, plyometric push-up, seated medicine ball throw, time-to-peak force, time-to-peak power

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Introduction

Whole-body vibration (WBV), a mechanical stimulus that is characterized by oscillatory motion, has been hypothesized to increase neuromuscular stimulation (16,24,25,31). Originally a therapeutic modality, WBV has been used as a treatment for certain chronic diseases (5,13,31), muscle soreness (32), and injury rehabilitation (11). The timing of WBV application has included before (4,9,33,36) and during (14,35) muscular activity.

As an example, a landmark study by Cormie et al. (9) investigated the effect of using WBV as a warm-up activity for subsequent direct (isometric squat [IS]) and indirect measures (countermovement jump [CMJ]) of lower-body strength and power in recreational, resistance-trained men. A single 30-second bout of WBV was administered while subjects performed a half-squat static hold. Testing of CMJ and IS occurred immediately post (IP), 5 minutes, 10 minutes, and 20 minutes after WBV exposure. The CMJ height at IP was significantly greater for the WBV condition compared with that of the no WBV (NWBV) condition (9). It was concluded that WBV could serve as a potential warm-up before strength and power activities.

Although exposure to WBV has been shown to increase lower-body muscular strength (12,34,35) and power (1,9,36) in athletes (4,7,12,19,33), recreationally resistance-trained men (34), and the elderly (11,21), a paucity of research exists on the effect of WBV on the upper-body musculature. Furthermore, the results have been inconclusive. This may be due to differences in methodology. For example, methods have included direct application of upper-body WBV with subjects seated while gripping a vibrating dumbbell (2,6,17,28) or kneeling on the floor with hands placed directly on the WBV platform (7), and indirect application with subjects standing on the WBV platform while performing elbow extension resistive exercise (22,23) or static holds with an elbow joint angle of 90° (14,26). These methods have produced mixed results with none emerging as the most effective in eliciting gains in upper-body muscular strength and power.

As with studies of WBV and the lower body, the timing of WBV application has included before (6,7) and during (2,14,17,22,23,28) muscular activity, and its effects have been assessed by a variety of laboratory (2,14,17,22,23,28) and field tests (6,7). Again, results have been inconclusive across timing of WBV application and testing methods. Furthermore, most of the research has consisted of WBV administration during muscular activity, and few studies have included measures past immediately posttreatment.

Given the positive results of WBV as a warm-up for the lower body in the study by Cormie et al. (9), this study used a similar protocol to investigate the effect of using WBV as a warm-up activity for subsequent laboratory and field measures of upper-body power in recreational, resistance-trained men from immediately posttreatment to 10 minutes post. It was hypothesized that direct WBV exposure to the upper body, as a warm-up activity, would result in significantly improved performance measures of upper-body power.

Methods

Experimental Approach to the Problem

This study used a repeated-measures crossover study design to determine whether an acute bout of upper-body WBV would enhance upper-body power in recreational, resistance-trained men. All data were collected over the same 3-month period. Under the direct supervision of an NSCA–Certified Strength and Conditioning Specialist (CSCS), subjects underwent 5 data collection sessions, all of which were conducted at the same time of day. Session 1 consisted of body composition assessment, 3 repetition maximum (RM) bench press (BP) testing, and familiarization with the: (a) seated medicine ball throw (SMBT) field test, (b) plyometric push-up (PPU) on a force platform, and (c) vertical WBV platform. After 48 hours, subjects returned to the laboratory for experimental trials (sessions 2–5) each separated by 24 hours. Each testing session consisted of the same 10-minute dynamic warm-up followed by WBV (frequency: 30 Hz, amplitude: 2–4 mm, 1:1 work: relief ratio) or NWBV treatment. Both the WBV and NWBV conditions consisted of performing 4 × 30-second push-up static holds; 2 with the elbows at a joint angle of 90° and 2 with the arms fully extended, on a vibration platform. Seated medicine ball throw or PPU measures were completed immediately post (IP), 1-minute, 5-minute, and 10-minute posttreatment. The combination of treatments and measures resulted in a total of 4 testing sessions (e.g., WBV+PPU, NWBV+PPU, WBV+SMBT, and NWBV+SMBT), performed randomly.

Subjects

Fifteen recreational, resistance-trained men (mean ± *SD*; age 21.5 ± 2.3 years [range: 18–30]; height 173.1 ± 6.5 cm; and weight 77.2 ± 13.8 kg) with ≥1-year resistance training experience and a BP to body mass ratio ≥1.25 participated in this study. All subjects had the risks and benefits explained to them before voluntarily signing an institutionally approved consent form to participate. The Institutional Review Board for Human Subjects approved all procedures. The inability to complete a PPU, chronic pain in the upper body, or severe musculoskeletal injuries of the upper body within 6 months before the study were grounds for exclusion from the study. Physical characteristics are included in Table 1.

Procedures

Session 1: Baseline Testing and Familiarization. Session 1 consisted of body composition assessment, 3RM BP testing, and familiarization with the: (a) SMBT field test, (b) PPU on the force platform, and (c) vertical WBV platform. Forty-eight hours separated sessions 1 and 2.

Body Composition. Subjects were instructed to drink only water and not to eat or exercise for the preceding 2 hours. On arrival to the laboratory, height and body mass were recorded to the nearest 0.01 cm and 0.02 kg, respectively, using a stadiometer and digital scale (Bod Pod; Cosmed, Chicago, IL, USA) calibrated according to manufacturer guidelines with subjects' bare foot. Body composition was then assessed using air displacement plethysmography (Bod Pod; Cosmed) calibrated according to manufacturer guidelines. Lycra and swim caps were worn during testing, and all jewelry was removed before in accordance with standard operating procedures to reduce air displacement. A trained technician performed Bod Pod testing. Previous studies indicate air displacement plethysmography to be an accurate and reliable means to assess changes in body composition (29). Body mass and body volume were then used to estimate body fat percentage based on the Brozek equation (3).

Estimated Maximum Upper-Body Strength. After body composition determination, upper-body strength was assessed on the Olympic/"free bar" BP with a 3RM test using previously described procedures (19). Briefly, subjects completed a 10-minute dynamic whole-body warm-up followed by supervised (CSCS) warm-up sets for the BP test. A timed rest of 3 minutes was taken before each maximal

Table 1. Subject physical characteristics.*†

Measure	Mean ± *SD*
Age	21.5 ± 2.3
Height (cm)	173.1 ± 6.5
Body mass (kg)	77.2 ± 13.8
Fat percentage	15.7 ± 6.7
1RM bench press (kg)	108.3 ± 20.4
1RM bench: body mass ratio	1.41 ± 0.14

*1RM = 1 repetition maximum.
†*N* = 15. Data are mean values ± *SD*.

effort set. Weight was increased based on the performance of the previous attempt, and the subject continued to perform sets of 3 repetitions until failure or until it was determined that he could no longer perform the BP safely with proper form. After 2 failures, testing was stopped, and the best lift was recorded. If fewer than 3 repetitions were completed with proper form, that number was used to estimate 1RM. Once the 3RM was established, a 1RM was calculated from the prediction equation of Mayhew et al. (27).

Sessions 2–5: Experimental Protocol. Forty-eight hours after session 1, subjects returned to the laboratory at the same time of day on 4 separate occasions, each separated by 24 hours, to perform 4 randomly ordered experimental trials (e.g., WBV+PPU, NWBV+PPU, WBV+SMBT, and NWBV+SMBT). On the day of each experimental trial, subjects arrived having refrained from upper-body resistive exercise since the previous experimental trial. After a supervised, standardized, 10-minute warm-up identical to that performed before testing during session 1, subjects performed 4 × 30-second push-up static-hold exercises in the WBV or NWBV condition. Each WBV or NWBV exercise set was followed by a 30-second rest period. On completion of the condition, subjects performed either an SMBT or PPU immediately post, 1 minute, 5 minutes, and 10 minutes after exercise. The SMBT and PPU protocols were identical to those used during the familiarization session, and the same procedure was followed for experimental sessions 2–5. Power, force, and time-to-peak power were determined from the PPU, which is a direct measure. Distance thrown was measured in the SMBT, which is a commonly used field test and an indirect measure of upper-body power.

Plyometric Push-up. The PPU was performed on a portable force platform (Advanced Medical Technology, Inc.; Watertown, MA, USA). The subjects began a push-up with hands placed in the middle of the platform shoulder width apart and elbows at full extension. A level box of the same height as the force platform supported the subject's feet and was placed at the appropriate distance to ensure that the subject's hands were directly under the shoulders. The subjects lowered their upper body to the force platform bending at the elbows (tucking toward the ribs) while keeping the back and hips inline until elbow flexion reached 90°. The subjects then applied force through the hands and extended the elbows with as much force and speed as possible. The PPU required the subject to produce enough force to cause his hands to leave the force platform surface.

Force, Power, Time-to-Peak Force, and Time-to-Peak Power. During each PPU repetition, ground reaction force and center of mass velocity data were collected using the force plate and were sampled at a rate of 500 Hz using an analog-to-digital converter (Sewell Direct; Provo, UT, USA). Signals were filtered through a zero-lag low-pass Butterworth filter. Force-time and center of mass velocity-time data files were exported into Microsoft Excel (Microsoft Corp., Redmond, WA, USA). Power was calculated from the product of force and the center of mass velocity. Graphs were created from the raw data to determine time-to-peak force and time-to-peak power. Both time-to-peak force and time-to-peak power were determined during the concentric portion of the PPU, this included the time from the initiation of the upward phase of the motion until the subject broke contact with the force platform at the top of the PPU movement.

Seated Medicine Ball Throw. The SMBT was used as a field test of upper-body power and administered according to previously published methods, and has been shown to be a reliable and valid measure of upper-body power (18). Each subject sat on the floor with his back against a wall and the legs fully extended. A 2-kg medicine ball (First Place; Perform Better, Warwick, RI, USA) was held with both hands in front of the chest. The hands were placed on either side of the ball without fingers touching. On the "go" command, the subject lifted the ball to his chest and threw it forward for maximum distance using a "basketball style" chest pass. The angle of ball release was approximately 45°. The same test administrator measured the distance the ball traveled on each throw on landing, whereas another ensured that the subject's back remained in contact with the wall.

Whole-Body Vibration Protocol. Whole-body vibration was administered through a vibration platform (Pro5 AIRdaptive; Power Plate, Irvine, CA, USA) that produced vertical sinusoidal vibrations with a frequency range of 25–50 Hz and a vertical displacement range of 2–4 mm (i.e., amplitude). After completion of the Bod Pod and 3RM testing in session 1, each subject was introduced to the 2 push-up static-hold positions, which were (a) the elbows at a joint angle of 90° and (b) the arms fully extended.

All WBV sets were 30 seconds in duration followed by a 30-second rest (1:1 work-to-relief ratio). Whole-body vibration protocol exercises did not use an external load, only body weight, and the frequency (30 Hz) and amplitude (2–4 mm) remained constant for both WBV sessions. During the NWBV protocol, subjects completed the same volume and duration of push-up static holds selected for the WBV protocol without the inclusion of WBV. Loading was performed in the up and down position of a push-up with hands placed on the vibration platform and feet placed on a box with the height parallel to the vibration platform. Hands were placed in the middle of the WBV platform shoulder width apart. Arms were fully extended on the WBV platform in the "up phase" of a push-up. For the second exercise, arms were at 90°, thereby simulating the "down phase" of the push-up. Total WBV exposure time was limited to 2 minutes in a single session.

Table 2. Effect of WBV treatment on SMBT distance compared with NWBV treatment.*

	SMBT			
Time	NWBV (cm)	WBV (cm)	Mean difference†	Inference‡
IP	613.2 ± 104.4	611.1 ± 63.5	−2.0; ±25	Unclear
1 min	621.3 ± 98.6	623.5 ± 77.7	2.2; ±18	Likely trivial
5 min	637.2 ± 100.6	637.5 ± 79.7	0.34; ±22	Unclear
10 min	630.8 ± 93.3	657.6 ± 78.2	27; ±27	Likely positive

*WBV = whole-body vibration; SMBT = seated medicine ball throw; NWBV = no WBV.
†±90% CL, the 90% confidence limits for the effect of WBV.
‡The probabilistic inference is the chance that the true (large-sample) effect of WBV is substantially different from no WBV, where the threshold for the smallest substantial effect was calculated as 0.2 time baseline *SD* for the NWBV treatment.

Statistical Analyses

Normality of data was assessed by the Kolmogorov–Smirnov test of normality, which determined all outcome measures of interest to be normally distributed. Estimates and uncertainty (90% CI) on the subsequent performance of the PPU and SMBT were derived from a repeated-measures analysis of variance with 2 factors: treatment (2 levels) and performance outcome. The resultant model was then used to make probabilistic magnitude-based inferences about the true (large-sample) values of outcomes by qualifying the likelihood that the true effect represents a "substantial" change. This was performed on all primary outcome measures. The smallest substantial threshold was estimated as the standardized (8) change of 0.2 times the average between subjects' SD for the performance outcome after NWBV. The probability (likelihood) of a substantial increase or decrease in any one of the primary performance outcome variables was calculated from the 2-tailed Student's *t* distribution and classified according to Hopkins et al. (15).

Results

The aim of this study was to determine the acute effect of WBV on upper-body power in recreational, resistance-trained men. No discomfort, side effects, or injuries were reported for the 15 subjects who participated in the study.

Table 3. Effect of WBV treatment on peak force and time-to-peak force during the PPU compared with NWBV treatment.*

	PPU peak force			
Time	NWBV (N)	WBV (N)	Mean difference†	Inference‡
IP	338.9 ± 49.0	330.6 ± 48.7	−8.2; ±11	Possibly trivial
1 min	340.8 ± 47.1	340.8 ± 52.6	0.77; ±11	Unclear
5 min	340.3 ± 52.7	347.4 ± 53.3	7.2; ±15	Possibly trivial
10 min	347.1 ± 54.8	342.1 ± 49.7	−4.9; ±11	Likely trivial
	PPU time-to-peak force			
Time	NWBV (s)	WBV (s)	Mean difference†	Inference‡
IP	0.044 ± 0.036	0.047 ± 0.029	−0.003; ±0.012	Unclear
1 min	0.028 ± 0.026	0.043 ± 0.026	−0.014; ±0.013	Likely negative
5 min	0.039 ± 0.023	0.040 ± 0.047	−0.001; ±0.023	Unclear
10 min	0.041 ± 0.024	0.035 ± 0.022	0.006; ±0.008	Possibility positive

*WBV = whole-body vibration; PPU = plyometric push-up; NWBV = no WBV.
†±90% CL, the 90% confidence limits for the effect of WBV.
‡The probabilistic inference is the chance that the true (large-sample) effect of WBV is substantially different from no WBV, where the threshold for the smallest substantial effect was calculated as 0.2 time baseline *SD* for the NWBV treatment.

Table 4. Effect of WBV treatment on peak power and time-to-peak power during the PPU compared with NWBV treatment.*

	PPU peak power			
Time	NWBV (W)	WBV (W)	Mean difference†	Inference‡
IP	1,529.1 ± 452.2	1,504.0 ± 369.9	−25; ±89	Likely trivial
1 min	1,448.0 ± 447.3	1,471.1 ± 366.4	23; ±100	Likely trivial
5 min	1,517.4 ± 351.9	1,453.1 ± 467.1	−64; ±110	Possibly trivial
10 min	1,560.0 ± 390.3	1,460.9 ± 427.0	−99; ±84	Possibly negative
	PPU time-to-peak power			
Time	NWBV (s)	WBV (s)	Mean difference†	Inference‡
IP	0.317 ± 0.067	0.331 ± 0.078	−0.14; ±0.13	Likely negative
1 min	0.309 ± 0.073	0.319 ± 0.070	−0.01; ±0.02	Possibly trivial
5 min	0.283 ± 0.058	0.290 ± 0.090	−0.01; ±0.03	Unclear
10 min	0.285 ± 0.065	0.272 ± 0.082	0.01; ±0.02	Possibly trivial

*WBV = whole-body vibration; PPU = plyometric push-up; NWBV = no WBV.
†±90% CL, the 90% confidence limits for the effect of WBV.
‡The probabilistic inference is the chance that the true (large-sample) effect of WBV is substantially different from no WBV, where the threshold for the smallest substantial effect was calculated as 0.2 time baseline *SD* for the NWBV treatment.

Seated Medicine Ball Throw

A likely positive effect of WBV was observed for SMBT distance at 10 minutes after treatment (Table 2). However, all other effects (IP, 1 minute, and 5 minutes) were unclear or trivial.

Plyometric Push-up

Peak force during the PPU was minimally affected by the WBV treatment as all observed effects were trivial or unclear for the 4 time points tested (Table 3). In contrast, the time to achieve peak force was affected by WBV. We observed a likely negative effect of WBV at 1 minute after treatment, whereas a possibly positive effect was observed 10 minutes after treatment (Table 3).

Similar to that which was observed in peak force, most time points tested resulted in trivial effects in regard to peak power (Table 4). However, a possibly negative effect was observed 10 minutes after treatment. Furthermore, we observed a likely negative effect of WBV on time to achieve peak power immediately after treatment (Table 4). All other effects were unclear or trivial.

Discussion

This is the first study to examine the effect of acute WBV exposure directly to the upper-body musculature (through the hands) on both laboratory and field measures of upper-body power at immediately post, 1 minute, 5 minutes, and 10 minutes after WBV exposure. Given previous reports of improved performance as a warm-up for lower-body musculature (9), it was hypothesized that direct WBV exposure to the upper body, as a warm-up activity, would result in improved performance measures of upper-body power in recreational, resistance-trained men. However, in contrast to Cormie et al. (9), we did not observe a positive effect of WBV on upper-body power immediately after treatment. The overall findings from this study supported a positive effect of WBV exposure at 10 minutes after treatment for the SMBT and time-to-peak force in the PPU. The effect of WBV exposure on SMBT and peak force at immediately post, 1-minute, and 5-minute posttreatment was trivial. However, the effect of WBV immediately after treatment was likely negative on time-to-peak power as was the 1-minute post-treatment on time-to-peak force with both eliciting lower values than the NWBV condition.

Because of the limited research on the effect of WBV as a warm-up activity for upper-body exercise, this study was modeled after the landmark study by Cormie et al. (9), in which 30 seconds of acute WBV immediately before exercise was shown to increase CMJ height compared with NWBV immediately after treatment. Recreationally resistance-trained men performed standing, static holds during WBV for 30 seconds (30 Hz, 2.5 mm amplitude), and it was concluded that WBV is a plausible warm-up for increasing CMJ height (9). Results from this study did not show positive effects on field or laboratory tests at immediately post, 1 minute or 5 minutes after WBV, only at 10 minutes post. Therefore, the response of the upper body to WBV, as a warm-up activity, was not similar to that of the lower-body musculature, which was previously reported (9).

Our results from the immediate posttest period are in agreement with those of others who used differing methodologies and used upper-body WBV as a warm-up activity (6,7). Cochrane and Hawke (6) used a vibrating dumbbell to apply WBV at a preselected tempo for 5 minutes (26 Hz, 3 mm) during 5 upper body exercises. Acute WBV did not improve subsequent performance on immediate field-based measures of the SMBT and grip strength. The authors suggested that the lack of significant results might have been due to the field-based measures (SMBT, grip strength) or the WBV protocol. In addition, when acute WBV (26 Hz, 6 mm) was applied for 1 minute to subjects kneeling on the floor with hands placed directly on the WBV platform, no improvement was reported in immediate postmeasures of grip strength (7).

In this study, the WBV exposure resulted in a positive effect at 10 minutes after treatment for the SMBT and time-to-peak force in the PPU. It is possible that a longer rest period is necessary for the upper-body musculature to recover from the acute WBV exposure.

The smaller muscle mass in the upper body, compared with that of the lower body, may experience a higher level of initial muscular fatigue, and thereby require a longer recovery period to realize any potentiation effects of the WBV treatment. Research of rest periods after WBV exposure in the lower body has reported strong individual differences in the optimal rest interval (10,30) and has varied with the type of performance assessment (30). It is not unreasonable to expect that the upper body might respond in a similar fashion.

Others have used indirect application of WBV during upper body exercise with subjects standing on the WBV platform while performing dynamic (22,32) or static-hold (14) upper-body exercises. Marin et al. (22) applied WBV (50 Hz, 2.5 mm) through a ground-based platform either 60 seconds before exercise or during the elbow extension exercise set. Subjects performed increased reps in the set to failure with WBV applied during the exercise set. Whole-body vibration exposure before exercise did not have a residual effect on subsequent performance. Another study of indirect WBV application at multiple frequencies (30, 46 Hz) and amplitudes (2–4 mm, 4–6 mm) reported increased upper-body muscle activity in older adults while performing isometric bicep curl exercises when standing on the WBV platform (26).

Although research addressing acute WBV exposure on the upper-body musculature remains inconclusive, it does seem that the upper body responds differently from the lower body. Interestingly, this finding is in agreement with previous research that investigated the response of the lower-body and upper-body musculature to the same strength training protocol in older adults (20). Results from WBV studies have been mixed with no method or protocol emerging as the most effective in eliciting gains in upper-body muscular strength and power. Therefore, further research is warranted that addresses the type (indirect or direct) and time (pre-exercise or during exercise) of WBV exposure as well as the type of assessment (field or laboratory).

We acknowledge some study limitations. First, the exercise selection consisted of 2 push-up static-hold positions (i.e., the elbows at a joint angle of 90°, arms fully extended) while WBV was applied directly to the upper body through the hands. We attempted to mimic the body position of the PPU in our selection of the 2 push-up static-hold positions. Since, the PPU is a dynamic movement, the inclusion of an additional dynamic exercise may have elicited a different response. Second, subjects in this study were recreationally trained men with ≥1-year resistance training experience and a BP to body mass ratio ≥1.25, and all were unfamiliar with WBV. Given the reported individual differences in response to WBV protocols (10,30), it is recommended that future studies include subjects who are known to respond favorably to WBV exposure.

In conclusion, direct WBV exposure to the upper body does not seem to be a plausible warm-up activity for improving performance measures of upper-body power. In addition, the specific protocol and application method for applying WBV to the upper body remain unclear.

Practical Applications

The results of this study suggest the following in recreational, resistance-trained men:

(a) Unlike the lower body's response, acute WBV applied directly to the upper body is most likely not a viable warm-up when used immediately before strength and power activities.
(b) A 10-minute rest period is recommended in between completion of isometric upper-body WBV exercise and subsequent performance of activities that require high levels of upper-body power.
(c) It is recommended that the strength and conditioning practitioner uses an extended rest between WBV stimulation and the initiation of upper-body strength training activities.

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