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Acute Effects of Whole-Body Vibration on Muscle Activity, Strength, and Power

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Abstract. Cormie, P., R.S. Deane, N.T. Triplett, and J.M. McBride. Acute effects of whole-body vibration on muscle activity, strength, and power. *J. Strength Cond. Res. 20(2):257–261. 2006.*—The purpose of this study was to investigate the effects of a single bout of whole-body vibration on isometric squat (IS) and countermovement jump (CMJ) performance. Nine moderately resistance-trained men were tested for peak force (PF) during the IS and jump height (JH) and peak power (PP) during the CMJ. Average integrated electromyography (IEMG) was measured from the vastus medialis, vastus lateralis, and biceps femoris muscles. Subjects performed the 2 treatment conditions, vibration or sham, in a randomized order. Subjects were tested for baseline performance variables in both the IS and CMJ, and were exposed to either a 30-second bout of whole-body vibration or sham intervention. Subjects were tested immediately following the vibration or sham treatment, as well as 5, 15, and 30 minutes posttreatment. Whole-body vibration resulted in a significantly higher ($p \leq 0.05$) JH during the CMJ immediately following vibration, as compared with the sham condition. No significant differences were observed in CMJ PP; PF during IS or IEMG of the vastus medialis, vastus lateralis, or biceps femoris during the CMJ; or IS between vibration and sham treaments. Whole-body vibration may be a potential warm-up procedure for increasing vertical JH. Future research is warranted addressing the influence of various protocols of whole-body vibration (i.e., duration, amplitude, frequency) on athletic performance.

Key Words. electromyography, vertical jump, squat

Introduction

The focus of this investigation was to determine the acute impact of a bout of whole-body vibration on athletic performance. The implications for the use of vibration as an exercise intervention have been reviewed recently (4). Longitudinal research has shown that whole-body vibration training is effective in producing strength and countermovement jump (CMJ) height improvements over 3–4 months vs. standard weight training alone (6, 15, 17, 22). Additionally, acute exposure to whole-body vibration ranging from 4–10 minutes has been shown to induce transient increases in strength, CMJ height (1, 2, 21), and power (1, 2).

Neuromuscular stimulation as a result of whole-body vibration is the likely source of previously observed changes in athletic performance. The tonic vibration reflex is a response elicited from vibration directly applied to a muscle belly or tendon (9, 19). This reflex is characterized by activation of muscle spindles primarily though Ia afferents (9, 16) and activation of extrafusal muscle fibers through α-motor neurons. The application of vibration to an active muscle recently has been shown to cause a shift in electromyography (EMG) patterns (10). Vibration also has been shown to stimulate transient increases in certain hormones, such as growth hormone and IGF-I (2). These mechanisms may indicate the use of vibration as a viable warm-up before athletic competition.

Several studies have examined the possible use of whole-body vibration as a warm-up procedure before strength and power activities. Vibration has been shown to acutely increase norepinephrine levels (8) and to increase power output in an arm flexion movement (1). Performance enhancement immediately following vibration has been shown in the leg press as well (1). However, several studies have indicated no acute effect of vibration (5, 7). Cochrane et al. (5) indicated no significant effect of vibration on vertical jump, sprint, or agility performance. In that study, though, the performance variables were not measured until 2 days after the last exposure to vibration (5). Therefore, the vibration stimulus was not utilized in the same context as that used in the previously mentioned studies (1, 8). Yet de Ruiter et al. (7) measured immediately after the vibration exposure and found no effect of vibration on isometric knee extensor maximal force or rate of force development. Thus, there appears to be some contradiction in the results of past investigations. Protocols for the vibration stimulus in previously mentioned studies have utilized various frequencies and amplitudes ranging from 10–50 Hz and 0.1–10 cm, respectively, making interpretation of the effectiveness of vibration difficult.

The purpose of this study was to address the issue of using whole-body vibration as a viable warm-up before strength and power activities. Because changes in muscle activity seem to be the most plausible mechanism for possible increases in performance following vibration, EMG was measured from select involved muscles.

Methods

Experimental Approach to the Problem

The subjects completed four testing sessions; countermovement jump—vibration (CMJ-V), CMJ—sham (CMJ-S), isometric squat—vibration (IS-V), and IS—sham (IS-S). The sessions were completed in a randomized order, with at least 2 days between each session. Following a 5-minute bicycle ergometer warm-up, baseline measurements were determined with either a CMJ or an IS test, depending on the experimental session. At least 2 trials were conducted in order to establish an accurate baseline; additional tests were administered if the trials were not within 5% of each other. Adequate rest (3 minutes) was allowed between each effort. Following 5 minutes of quiet sitting, the participants underwent 30 seconds of whole-body vibration or sham treatment immediately before performing a CMJ or an IS. Performance on the CMJ and

IS was measured again 5, 15, and 30 minutes after the vibration or sham stimulus.

Subjects

This study involved 9 men between the ages of 19 and 23 (height: 176.4 ± 7.8 cm; weight: 80.0 ± 11.2 kg; percentage body fat: 12.35 ± 4.5%; isometric squat [IS] peak force [PF]: 1,815.61 ± 415.81 N). Subjects were involved in resistance training and some type of recreational sporting activities. The volunteers were notified about the potential risks involved and gave their written informed consent, approved by the Institutional Review Board at Appalachian State University.

Whole-Body Vibration

The application of the vibration treatment was conducted using a Power Plate body vibration platform (Power Plate North America Inc., Northbrook, IL). Cardinale and Lim (3) noted that the EMG signal of the vastus lateralis reached its highest activity during vibration at 30 Hz; thus, the frequency in the current study was set to 30 Hz. The peak-to-peak amplitude of the vibration platform was 2.5 mm, which was similar to previous studies (10–12). Loading was carried out in a half-squat position with individual foot spacing and knee angle (100°) held constant throughout the 30-second exposure and across all experimental conditions. The sham intervention consisted of the subject standing on the vibration platform in the same position with the vibration plate inactivated.

Isometric Squat

The IS was performed by having the subject stand on a force platform (BP6001200, AMTI, Watertown, MA) under a fixed bar position at a 100° knee angle (20) while performing a maximal isometric contraction for 3 seconds. Each individual's bar height and foot placement remained constant during and between testing sessions. The force-time curve was recorded using a shielded BNC adapter chassis (BNC-2090, National Instruments, Austin, TX) and an A/D card (NI PCI-6014, National Instruments). LabVIEW (Version 7.1, National Instruments) was used for recording and analyzing the data. PF of the whole 3-second contraction and average rate of force development for the first 400 ms of the force-time curve were calculated.

Countermovement Jump

Participants set up for the CMJ in a standing position on a portable force platform (Quattro Jump Portable Force Plate 9290AD, Kistler Instruments Corp., Amherst, NY) with their hands placed on their hips. After instruction, subjects initiated the jump via a downward countermovement to a visually monitored knee angle of approximately 100°. Participants were instructed to keep their hand position constant throughout the jump and were encouraged to reach a maximum jump height with every attempt. Variables analyzed during the CMJ included peak power (PP) and jump height (JH) as outlined by Sayers et al. (18). Reliability data for jump testing in this laboratory is reported in McBride et al. (13).

Electromyography

EMG of the vastus lateralis, vastus medialis, and biceps femoris muscles was collected at 1,000 Hz using a telemetry transmitter (8-channel, 12-bit analog to digital converter; Noraxon USA Inc., Scottsdale, AZ). A disposable surface electrode (Noraxon USA) with a 2-cm interelectrode distance and a 1-cm circular conductive area, was attached to the skin over the belly of each measured muscle, distal to the motor point and parallel to the direction of the muscle fibers. The exact location of the electrode was marked following the first testing session to ensure consistent placement in subsequent tests. The amplified myoelectric signal, recorded during each of the CMJ and IS performances, as well as during the first and last 5 seconds of the vibration and sham treatments, was detected by the receiver-amplifier (Telemyo 900, Noraxon USA; gain = 2,000, differential input impedance = 10 MΩ, bandwidth frequency 10–500 Hz, common mode rejection ratio = 85 dB) and then was sent to an A/D card (KPCMCIA-12AI-C, Keithley, Cleveland, OH) and was analyzed using MyoResearch software (Version 4.0; Noraxon USA). The signal was full-wave rectified and filtered (6-pole Butterworth, notch filter 60 Hz, band-pass filter 10–200 Hz). The integrated value ($mv\cdot s^{-1}$) was calculated and then was averaged over the 3-second isometric contraction, the eccentric-concentric phase of the CMJ, or the recorded 5-second vibration/sham exposure (mV; integrated electromyography [IEMG]).

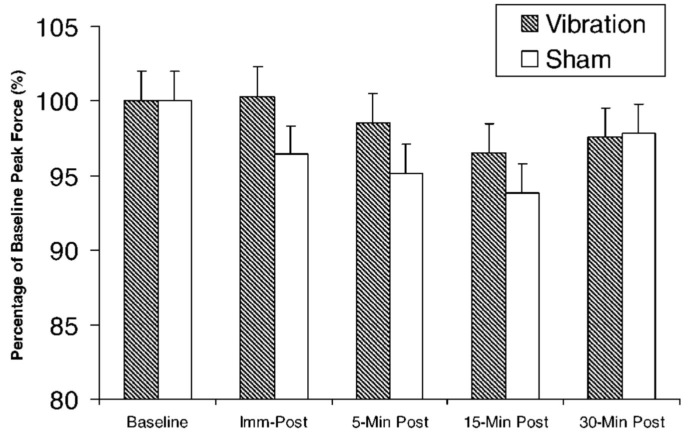

FIGURE 1. Change in isometric squat peak force following vibration and sham stimuli; expressed as a percentage of baseline values.

Statistical Analyses

A general linear model repeated measures analysis of variance was used for analysis. The criterion alpha level was set at $p \leq 0.05$. All statistical analyses were performed through the use of a statistical software package (SPSS, Version 11.0; SPSS Inc., Chicago, IL).

RESULTS

PF during the IS slightly decreased from baseline following both vibration and sham stimuli (Figure 1; Table 1). Although not significant, subjects' PF decreased less immediately, 5 minutes, and 15 minutes postvibration. A similar pattern was observed for JH and PP (Figures 2 and 3; Table 1). Furthermore, a significant ($p < 0.05$) difference between treatments was observed in JH from baseline immediately posttreatment: subjects jumped higher following exposure to whole-body vibration, compared with the sham intervention. No significant differ-

TABLE 1. Mean values ± standard deviation of peak force (PF) during the isometric squat (IS) and countermovement jump (CMJ) height (JH) and peak power (PP).

	IS	CMJ	
	PF (N)	JH (cm)	PP (W/kg)
Vibration			
Baseline	1830.12 ± 444.73	49.02 ± 7.58	55.00 ± 6.81
Immediate	1817.39 ± 401.80	49.34 ± 7.17	54.74 ± 7.03
5 min	1800.36 ± 431.81	48.82 ± 6.86	53.51 ± 7.80
15 min	1764.95 ± 450.67	46.54 ± 8.14	51.49 ± 7.54
30 min	1770.94 ± 428.44	45.92 ± 8.30	51.68 ± 7.75
Sham			
Baseline	1801.11 ± 393.90	50.67 ± 7.13	55.54 ± 6.62
Immediate	1718.57 ± 418.69	49.34 ± 6.90	53.98 ± 8.22
5 min	1714.22 ± 401.69	49.01 ± 7.24	52.91 ± 6.55
15 min	1687.16 ± 370.72	48.02 ± 7.98	51.48 ± 7.08
30 min	1754.77 ± 408.52	47.16 ± 8.16	49.68 ± 7.21

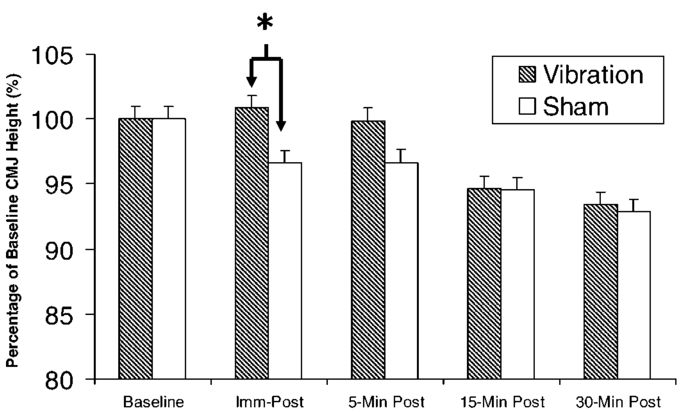

FIGURE 2. Change in countermovement jump (CMJ) height following vibration and sham stimuli; expressed as a percentage of baseline values. * = significant ($p < 0.05$) difference between vibration and sham stimuli.

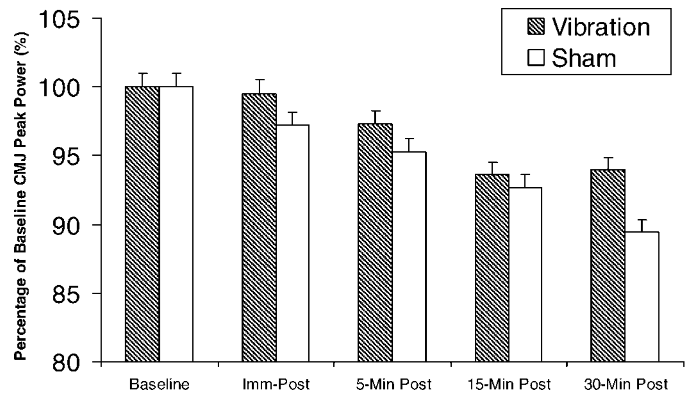

FIGURE 3. Change in countermovement jump (CMJ) peak power following vibration and sham stimuli; expressed as a percentage of baseline values.

ences were observed in IEMG throughout testing (Tables 2 and 3).

DISCUSSION

The most significant finding in this investigation was that an acute bout of whole-body vibration led to an increase in vertical JH, in comparison with the sham condition. However, no other performance variables (i.e., peak IS force, CMJ PP) were affected. In addition, no detectable differences in EMG activity were observed during either the IS or CMJ. EMG activity of the measured muscles during the treatment of whole-body vibration did not appear to be different when compared with the sham condition.

Muscle activity changes with whole-body vibration have been shown previously in 2 studies (2, 10). As previously mentioned, tonic vibration reflex may be a physiological mechanism by which muscle activity is altered as a result of vibration (9, 19). However, in the current investigation, no statistically significant changes in EMG amplitude were observed. It is possible that changes in other physiological parameters that were not measured, such as hormone release, could have influenced the outcome of the performance measures. Acute increase in norepinephrine levels, for example, in response to vibration

TABLE 2. Average integrated electromyography mean values ± standard deviation of the vastus lateralis (VL), vastus medialis (VM), and biceps femoris (BF) for the vibration and sham treatment conditions during countermovement jump (CMJ) and isometric squat (IS) tests.

	CMJ			IS		
	VL (μV)	VM (μV)	BF (μV)	VL (μV)	VM (μV)	BF (μV)
Vibration						
Baseline	180.59 ± 62.59	190.73 ± 71.46	50.78 ± 29.36	206.28 ± 49.58	254.77 ± 117.29	21.16 ± 17.81
Immediate	194.86 ± 98.04	186.58 ± 89.18	45.72 ± 16.63	196.21 ± 60.93	266.98 ± 134.67	22.40 ± 21.14
5 min	188.88 ± 104.01	154.96 ± 98.61	41.81 ± 29.75	180.39 ± 44.73	255.29 ± 140.01	12.65 ± 12.32
15 min	198.41 ± 116.24	177.70 ± 78.85	42.76 ± 24.46	190.43 ± 81.00	226.32 ± 121.83	23.46 ± 18.97
30 min	208.14 ± 121.25	198.13 ± 95.53	44.67 ± 35.88	184.71 ± 47.23	195.09 ± 83.80	22.32 ± 18.00
Sham						
Baseline	215.67 ± 73.34	189.31 ± 70.20	57.77 ± 30.92	190.70 ± 93.72	234.99 ± 147.73	27.78 ± 18.09
Immediate	201.73 ± 38.31	209.83 ± 129.26	56.69 ± 33.44	186.80 ± 96.27	209.59 ± 131.35	27.91 ± 16.88
5 min	200.62 ± 85.68	189.76 ± 62.51	41.00 ± 20.79	185.05 ± 93.94	221.70 ± 130.65	23.50 ± 13.21
15 min	176.03 ± 64.53	157.03 ± 56.48	49.87 ± 40.42	158.87 ± 84.89	217.03 ± 121.70	27.21 ± 12.51
30 min	250.61 ± 148.53	159.11 ± 89.87	50.48 ± 34.05	126.29 ± 40.67	219.81 ± 113.28	22.49 ± 14.14

Table 3. Average integrated electromyography mean values ± standard deviation of the vastus lateralis (VL), vastus medialis (VM), and biceps femoris (BF) during the first and last 5 seconds of vibration and sham stimuli.

	Countermovement jump			Isometric squat		
	VL (μV)	VM (μV)	BF (μV)	VL (μV)	VM (μV)	BF (μV)
First 5 s						
Vibration	35.76 ± 22.41	43.97 ± 31.53	10.73 ± 5.85	31.44 ± 10.18	35.47 ± 22.01	11.29 ± 17.42
Sham	31.99 ± 22.66	27.30 ± 28.87	9.01 ± 4.48	31.36 ± 12.86	28.92 ± 22.71	6.31 ± 12.94
Last 5 s						
Vibration	37.29 ± 12.54	43.05 ± 13.52	11.86 ± 12.59	27.57 ± 23.50	31.59 ± 17.78	10.13 ± 6.17
Sham	35.58 ± 26.20	26.51 ± 10.42	10.67 ± 12.77	35.85 ± 27.99	32.67 ± 18.58	6.56 ± 6.62

has been shown (8), and thus may have been a mitigating factor in the current investigation, as well.

The vertical JH during the CMJ in the current investigation increased slightly and was significantly different from the JH observed immediately after the sham condition. This is in contrast to the results obtained by Rittweger et al. (14) who reported a significant decrease in vertical JH of approximately 9.1% after vibration. However, it must be noted that the vibration was applied until volitional exhaustion of the subjects. In addition, Rittweger et al. (14) reported that in certain individuals, JH actually increased. Bosco et al. (2) reported an increase in JH after a nonfatiguing vibration protocol more similar to the protocol used in the current investigation. This study utilized ten 60-second bouts of whole-body vibration with 60-second rest intervals and observed an increase in JH of approximately 3.9%. The current study only utilized a single bout of whole-body vibration lasting 30 seconds. The jump increase in the current investigation was only 0.7%. Torvinen et al. (21) used a whole-body vibration protocol of 1 single bout for 4 minutes and observed an increase in JH of approximately 2.2%. Thus, there may be an ideal dose–response paradigm by which a certain amount of vibration can result in increasing performance (current investigation: 1 bout of 30 seconds, 0.7% increase in JH; Torvinen et al. [21]: 1 bout of 4 minutes, 2.2% increase in JH; Bosco et al. [2]: 10 bouts of 60 seconds, 3.9% increase in JH; Rittweger et al. [14]: 1 bout to volitional exhaustion, 9.1% decrease in JH).

In conclusion, it appears that whole-body vibration may be a plausible warm-up procedure for increasing vertical JH. However, the optimal dose of vibration is still unclear. The findings of this study are specific to the vibration settings used (frequency, 30 Hz; amplitude, 2.5 mm). It appears that vibration can have a potentiating effect on JH and can induce fatigue, as well. The exact mechanism for the effect of vibration on increasing vertical JH needs further investigation, because changes in muscle activity levels were not observed in the current investigation.

Practical Applications

The use of whole-body vibration as a warm-up procedure should be considered for coaches, and for strength and conditioning coaches in particular. However, the expected influence of vibration on performance increase can be expected to be small at best. The exact protocol to be used for its practical application is still unclear, as is the precise nature of the possible usefulness of vibration in field-based settings.

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