OPTIMAL FREQUENCY, DISPLACEMENT, DURATION, AND RECOVERY PATTERNS TO MAXIMIZE POWER OUTPUT FOLLOWING ACUTE WHOLE-BODY VIBRATION

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ABSTRACT

Adams, JB, Edwards, D, Serviette, D, Bedient, AM, Huntsman, E, Jacobs, KA, Del Rossi, G, Roos, BA, and Signorile, JF. Optimal frequency, displacement, duration, and recovery patterns to maximize power output following acute whole-body vibration. *J Strength Cond Res* 23(1): 237–245, 2009—Power is an important component of general health, fitness, and athletic performance. Traditional overload techniques require considerable time, intensity, and volume of training. Whole-body vibration (WBV) is a potentially less time-consuming method for increasing power performance than traditional training. However, the exact protocols that can maximize power output have not yet been identified. Eleven healthy men, aged 32.3 ± 4.1 years, and 9 healthy women, aged 29.1 ± 3.5 years, performed countermovement jumps (CMJs) of maximal volition to assess peak power pre and post (immediately and at 1, 5, and 10 minutes) randomized WBV stimuli set at different frequency (30, 35, 40, and 50 Hz), displacement (2–4 vs. 4–6 mm), and duration (30, 45, and 60 seconds) combinations. Repeated-measures analysis of variance on peak power normalized to initial power (nPP) revealed no significant effects attributable to duration of stimulus. However, high frequencies were more effective when combined with high displacements, and low frequencies were more effective in conjunction with low displacements ($p < 0.05$). Additionally, the greatest improvements in nPP occurred at 1 minute posttreatment, with significant improvements lasting through 5 minutes posttreatment ($p < 0.05$). Optimal acute effects can be attained using as little as 30 seconds of WBV, and they are highest from 1 to 5 minutes posttreatment. Additionally, high frequencies were most effective when applied in conjunction with high displacements, whereas low frequencies were most effective when applied in conjunction with low displacements.

KEY WORDS WBV, protocols, countermovement jump-immediate effects

INTRODUCTION

Power is an important component of athletic performance. In fact, power training techniques are currently used to prepare athletes for such diverse sports as hockey (15), skiing (27), baseball (16), and football (14). Additionally, power is a major component of general health, fitness, and independence (2,18). Overload techniques such as weight training (24) and plyometrics (29) have traditionally been used to improve power (1,17,35), and specific protocols using these methods to optimize power have been studied extensively (1,17,19). Although the benefits of these traditional training methodologies are well established (14–16,21), they are often quite time consuming and require considerable training intensity and volume, making them unattractive to the majority of the population seeking to improve their health and fitness. In addition, time constraints placed on collegiate and professional athletes by controlling agencies and competitive schedules also argue for the development of more effective and efficient training techniques.

Within the past 25 years, a relatively new method of neuromuscular overload, whole-body vibration (WBV), has been slowly emerging that may address these concerns. Recent research suggests that mechanical vibrations that incorporate low amplitudes and frequencies are a safe and effective method of exercising the neuromuscular system (6). In fact, mechanical vibrations have been shown to induce nonvoluntary muscle contractions (20), so the application of vibration to a limb or entire body may be an appropriate

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treatment for sport training (20). Whole-body vibration is starting to be used as an alternative form of strength and power training (6,30,32). It elicits neuromuscular training in a short time period without a great deal of effort (30).

Many studies have reported acute (10,11,22,30,31,36) and chronic (6,9,12,26,32,37) increases in power after WBV training; however, a limited number of studies have reported no effect (9) or even a decline (30). The divergent results in these studies may have been attributable to the variations in the frequency, displacement, and duration of the WBV stimulus applied as well as variations in populations tested and WBV devices. Target populations included men (10,33), women (32), and trained (3–5,10,12,21,22,27,30) and untrained (11,32) individuals. Because of the varied target populations, a specific group most sensitive to the acute effects of WBV has not yet been identified.

We have selected healthy untrained adults in a low-risk age group because we feel that this is an important target group, given their propensity to use exercise as a fitness and wellness tool.

Among the devices examined are triplanar devices that apply the vibratory stimulus in anterior/posterior, lateral, and vertical directions and uniplanar devices that either tilt on a central axis or move solely in a vertical direction.

Potential Mechanisms

The exact mechanism that regulates how the body reacts to vibratory stimulus is currently unknown; however, several potential mechanisms have been proposed.

Neuromuscular Facilitation

Initial strength and power gains during weight training are attributable to neuromuscular facilitation (32). The neuromuscular facilitation that maximizes muscular performance during weight training has also been shown with WBV training (6). Improvements in strength and power may be attributable to neural factors including increased recruitment, synchronization, muscular coordination, and proprioceptor response (6).

Tonic Vibration Reflex

Mechanical stimuli are transmitted from the vibration device through the body, where they stimulate sensory receptors, most likely muscle spindles. This activates alpha motoneurons, initiating reflexive muscle contractions–this is referred to as the tonic vibration reflex (6,13,32). Monosynaptic and polysynaptic pathways mediate this response, resulting in an increased activation of motor units (33). The tonic vibration reflex is probably dependent on the frequency of vibration, muscle length, and body position (23). Voluntary muscle contractions may be enhanced by the tonic vibration reflex when used in conjunction with strength-training protocols (23).

Increased Gravitational Forces on Muscle

Under normal gravitational conditions, muscles can maintain their performance. During conditions of decreased gravitational load, microgravity, a decrease in force capability, occurs. An increase in gravitational load, hypergravity, increases the cross-sectional area and force-generating capability of the muscles (6). Mechanical vibrations applied to the whole body can produce changes in gravitational conditions during the intervention (4,6). The vibrations produce fast and short changes in the length of the muscle-tendon complex. Sensory receptors, probably muscle spindles, call on a reflex muscular activity in an attempt to dampen the vibratory waves (6). Additionally, conditions of hypergravity have been shown to increase hormone levels, including androgens and growth hormones in the blood (6).

Types of Whole-Body Vibration Devices

The effects of WBV have been studied using vibrating plates that produce sinusoidal vibrations (7). During WBV training, the subject may stand or move on a platform that generates vibrations with frequencies ranging from 25 to 40 Hz and amplitudes from 2 to 10.5 mm (13,32). This study uses a triple-plane WBV device (Power Plate). The platform simultaneously oscillates up and down, left to right, and front to back. The potential amplitudes are low (2–4 mm) and high (4–6 mm). The frequency options for this device include 30, 30, 40, and 50 Hz.

A key reason for inconsistencies in scientific data regarding the effects of WBV may be that protocols vary from study to study. Different frequencies and amplitudes have been applied to different populations with varying recovery periods. Each of these parameters has the potential to impact biological response to vibration training and, therefore, the effects of vibration training on strength and power performance.

In exercises geared toward increasing strength and power, the specific loading parameters must be carefully determined, applied, and controlled to ensure the desired training effect. Application of different training protocols would yield varying results, just as varying vibration training protocols is likely to yield variable physiological responses (23).

Whole-body vibration is currently used as an exercise program in many fitness and rehabilitation facilities, but the current knowledge on effective exercise protocols is limited (7). Currently, the sport industry is producing various devices for WBV; therefore, it is important to determine appropriate training protocols (20).

Although studies using WBV have been shown to elicit positive acute and chronic responses on strength and power, the exact intensity, duration, and postexercise recovery time that would optimize these benefits are not known. For WBV to be an effective and efficient tool for increasing muscular performance, the appropriate protocols for targeting muscular strength and muscular power must be established (10).

Once effective protocols are developed, WBV may provide a less time-consuming alternative for improving power compared with traditional training methods (6,26). In addition, it has been shown that perceived exertion is lower during WBV compared with standard training techniques eliciting similar results 12,13,20,25). This may encourage sedentary individuals to participate in an exercise program and add to the options currently available to both recreationally active individuals and athletes seeking to improve their health, fitness, and performance.

To our knowledge, no work has examined the frequency, displacement, and work-recovery duty cycle that would maximize power development during WBV, and there has been little research examining the duration of the acute effects of WBV (10). Additionally, there is a paucity of information addressing the acute effects of triplanar WBV, such as that provided by the Power Plate vibration platform (Power Plate North America Inc., Northbrook, Ill), on the power of healthy untrained adults. Therefore, the objective of this study was to identify the WBV protocols that would elicit the greatest improvement in power performance after a single exposure and to determine the duration of these effects.

METHODS

Experimental Approach to the Problem

Exposure to WBV has been shown to elicit variable power output changes immediately after WBV exposure. The divergent results in these studies may have been caused by the variations in the frequency, displacement, and duration of the WBV stimulus applied as well as variations in populations tested and WBV devices. The goal of this study was to identify the immediate effects of specific combinations of frequency, displacement, and duration of WBV stimulus on the power output of a healthy, untrained, low-risk population. In accordance with Sayers et al. (34), we felt that a jump pad was appropriate to assess power because we were monitoring pre-post exposure change in power. Each subject served as his or her own control. Additionally, jump pads have been shown to be highly correlated with 3D jump height analysis, with a Pearson *r* of 0.967 (25).

Subjects

Twenty-two untrained individuals, 23–39 years of age, volunteered to participate in this study. Two subjects withdrew from the study–one because of time constraints, the other because of discomfort during WBV treatment. Characteristics of the 20 subjects who completed the study are presented in Table 1. Exclusion criteria included any chronic medical condition or medications that could affect skeletal muscle performance, or any contraindications to WBV use. Contraindications included unhealed fresh wounds, serious heart or vascular disease, recent hip or knee replacement, pregnancy, acute hernia, discopathy, spondylolysis, severe diabetes, epilepsy, tumors, acute inflammation, acute migraine, pacemaker or recently placed IUD, or fixation devices such as metal pins, bolts, or plates. This study was approved by the subcommittee for the use and protection of human subjects at the University of Miami.

Procedures

We developed specific protocols using different combinations of frequency (30, 35, 40, and 50 Hz), displacement (low, 2–4 mm; or high, 4–6 mm), and work duration (30, 45, and 60 seconds). Before testing, we randomized the protocols for each subject to reduce the potential for an order effect. Subjects came to the laboratory for 9 visits. During the first visit, each subject completed a health status questionnaire to confirm study eligibility. If inclusion criteria were met, procedures and risks were thoroughly explained to the subject, and his or her written informed consent was obtained. During this visit, the subject was also familiarized with WBV platform use. For this familiarization session, the subject stood on the plate in a half-squat position with the knees held at a 2.27-rad angle. The exposure time was 30 seconds at a frequency of 30 Hz and low displacement. The subject was also familiarized with the hands-on-hips countermovement jump (CMJ) used to assess power.

The treatment protocols used during days 2–9 are presented in Table 2. On each of the testing days, subjects completed the 3 randomized treatment protocols, which were determined during the initial randomization process. Subjects were instructed to stand in a half-squat position with the knees shoulder width apart. The knee angle was set at 2.27 rad using a handheld goniometer. A minimum of 24 hours and a maximum of 1 week separated testing days.

Testing

Subjects were instructed to refrain from training for 24 hours before testing. The impact of the specific WBV protocols on peak leg power was assessed using the CMJ to determine power (7,16). The starting position for the CMJ was feet shoulder width apart, hands on the hips, and knees at 2.27 rad. Subjects were instructed to keep hand position constant and were encouraged to give a maximal effort for each jump.

TABLE 1. Subject characteristics (mean ± *SD*).

Gender	*N*	Age (y)	Height (cm)	Weight (kg)	Body mass index
Women	9	29.1 ± 3.5	165.4 ± 6.8	64.4 ± 10.2	23.5 ± 2.7
Men	11	32.3 ± 4.1	180.3 ± 6.0	88.2 ± 8.9	27.2 ± 3.1
Sample	20	30.9 ± 4.1	173.6 ± 9.8	77.5 ± 9.8	25.5 ± 3.4

TABLE 2. Whole-body vibration (WBV) treatment protocols.

Frequency (Hz)	Displacement (mm)	Duration (s)
30	Low, 2–4	30
		45
		60
	High, 4–6	30
		45
		60
35	Low, 2–4	30
		45
		60
	High, 4–6	30
		45
		60
40	Low, 2–4	30
		45
		60
	High, 4–6	30
		45
		60
50	Low, 2–4	30
		45
		60
	High, 4–6	30
		45
		60

On hearing the word "go," the subject performed 3 jumps with a slight delay between jumps to reduce the potential impact of the previous jump on stored elastic energy. All jumps were performed on a pressure-sensitive mat interfaced with a laboratory computer containing an assessment program (Axon Bioingeneria Deportiva, version 2.01, 2005). The Bioingeneria program used time off the mat to compute jump height. We selected the CMJ because it measures the combined effects of contractile, neural, and elastic elements, each of which could have adapted acutely to the WBV stimulus.

Power for the 3 jumps was computed using the formula presented by Sayers et al. (34):

$$\begin{aligned}\mathrm{PP\,(W)} &= 51.9 \times \mathrm{CMJ\,height\,(cm)} \\ &\quad + 48.9 \times \mathrm{BM\,(kg)} - 2007\end{aligned}$$

where PP = peak power and BM = body mass.

This formula was specific to the CMJ and has been successfully used to compute power for the hands-on-hips jump technique employed in our study (8). The highest of the 3 jump heights recorded was used to calculate the power used for statistical analysis. Because each subject served as his or her own control to compare pre- vs. post-WBV jump heights, we determined jump technique consistency through visual observation.

Because the effects of WBV are extremely time sensitive (3,10,36), CMJ data were collected immediately after and at 1, 5, and 10 minutes after each WBV bout. Subjects were instructed to remain seated after each testing session. This procedure allowed comparison of the effects of each protocol over time. All testing sessions were preceded by a 5-minute warm-up on a cycle ergometer at 50 W.

Statistical Analyses

The response variable for this study was the peak leg power achieved by the subject. This was calculated using CMJ height and body mass (34). The peak power score was then normalized as a percentage of the pretest jump score (nPP) according to the method of Cormie et al. (10) to account for intersubject variation. This was necessary because our subject population consisted of men and women of varying athletic abilities.

A repeated-measures analysis of variance was used to assess the impact of frequency, displacement, work duration, and recovery time on nPP. The criterion alpha level was set at $p \leq 0.05$. This analysis revealed that the greatest increase in power occurred at 1 minute posttreatment, no significant differences were identified as attributable to duration, and there were no interactions among other independent variables and duration; for these reasons, we performed a second repeated-measures analysis using frequency, displacement, and time (pretest and 1 minute posttreatment) as the independent variables. Bonferroni tests for multiple comparisons were used for all post hoc analyses.

RESULTS

Repeated-measures analyses revealed a significant time × displacement × frequency interaction ($p \leq 0.018$). The graphs for the low-displacement (Figure 1) and high-displacement (Figure 2) conditions illustrate that increases in nPP were greatest for the low-displacement conditions at lower frequencies and at high displacement for high-frequency conditions. Post hoc tests revealed significantly different patterns of change between pretest and immediately posttreatment and between immediately posttreatment and 1 minute posttreatment for low vs. high displacements ($p =$ 0.015 and 0.044, respectively). Trends were also seen for patterns of change from immediately posttreatment to 1 minute posttreatment and from 5 minutes posttreatment to 10 minutes posttreatment for high vs. low displacements ($p = 0.062$ and 0.056, respectively). Actual PP values are provided in Table 3.

Our analysis also revealed a significant frequency × displacement interaction ($p \leq 0.012$). Post hoc analysis identified that the source of this significant difference was the pattern of change from 40 to 50 Hz, with the high-displacement condition showing an increase in performance and the low-displacement condition showing a decrease ($p \leq 0.038$) (see Figure 3).

Finally, the analysis showed a significant effect by time ($p \leq 0.001$). Post hoc analyses showed significant differences at various time points. Figure 4 illustrates that significant

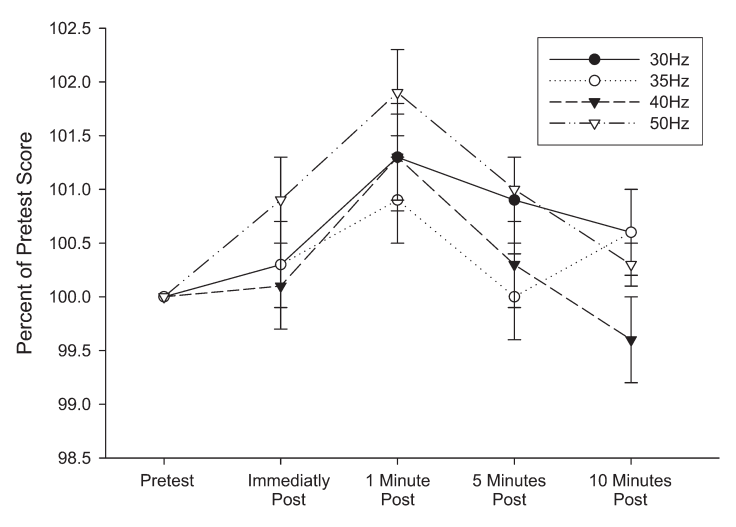

Figure 1. Countermovement jump (CMJ) peak power normalized to baseline values for various frequencies across time at low amplitude.

increases in nPP were seen between pretest values and those recorded at 1 and 5 minutes posttreatment. The figure also shows that there was a significant decline in nPP by 10 minutes posttreatment.

The results of our analysis removing duration as an independent variable revealed a time × frequency × displacement interaction ($p \leq 0.002$). Post hoc analysis demonstrated that, at low displacement, there was a decline in nPP when the 30-Hz condition was compared with 40 Hz, whereas high displacement showed the opposite pattern.

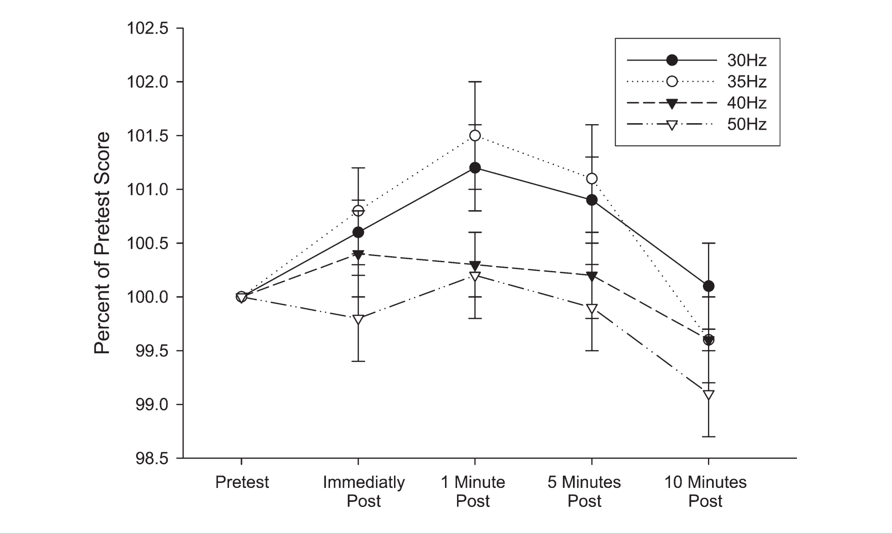

Figure 2. Countermovement jump (CMJ) peak power normalized to baseline values for various frequencies across time at high amplitude.

This analysis also showed a time × displacement interaction, with high displacements producing greater nPP values than low displacements ($p \leq 0.05$).

DISCUSSION

Three significant findings resulted from this investigation. First, an interaction between time, frequency, and displacement was detected, where higher displacements elicited greater power increases at higher frequencies, whereas lower displacements elicited greater power increases at lower frequencies. Our second finding was that an acute bout of WBV led to a transient increase in power that peaked at 1 minute posttreatment, remained significantly elevated at 5 minutes posttreatment, and declined below significant levels by 10 minutes posttreatment. Finally, we found that varying the duration of exposure within the range of 30–60 seconds had no impact on subsequent power measurements.

To our knowledge, these are the first data that have shown a frequency-displacement relationship; however, the results from previous studies that examined Power Plate and other devices support our results to some degree. It should be recognized that these comparisons are confounded by the use of a vast array of frequencies, displacements, training protocols, and WBV devices. The Power Plate device used in this study vibrated in 3 planes and provided low (2–4 mm) and high (4–6 mm) displacement. In contrast, studies using the Galileo platform applied displacements as high as 10 mm (4,8,10,29), but this platform oscillates by pivoting laterally about a central axis. Additionally, 2 studies examined vertical vibration devices using frequencies from 24 to 40 Hz and displacements of 2–4 mm (5,38).

In the only study evaluating the impact of a single bout of WBV on explosive power using a Power Plate, Cormie et al. (10) found that applying low-frequency (30 Hz) and low-amplitude (2.5 mm) WBV

Table 3. Actual peak power values for various frequencies at low and high amplitudes.

		Displacement	
		Low	High
Time	Frequency (Hz)	Peak power (W), mean ± *SE*	Peak power (W), mean ± *SE*
Pretest	30	3224.0 ± 213.8	3228.4 ± 214.5
	35	3216.1 ± 208.5	3218.6 ± 212.9
	40	3234.4 ± 213.5	3248.9 ± 213.9
	50	3242.4 ± 212.6	3225.6 ± 214.0
Immediately post	30	3239.8 ± 212.4	3239.7 ± 216.7
	35	3243.8 ± 212.6	3224.6 ± 211.0
	40	3246.8 ± 213.9	3247.4 ± 210.9
	50	3231.5 ± 210.0	3245.6 ± 211.0
1 minute post	30	3257.7 ± 213.4	3263.9 ± 213.8
	35	3260.9 ± 212.1	3238.4 ± 211.8
	40	3245.1 ± 215.2	3283.0 ± 212.2
	50	3247.5 ± 213.2	3279.6 ± 213.6
5 minutes post	30	3246.3 ± 211.5	3256.2 ± 215.8
	35	3253.1 ± 213.8	3220.5 ± 214.2
	40	3248.1 ± 218.1	3253.7 ± 213.5
	50	3240.3 ± 214.4	3253.2 ± 214.0
10 minutes post	30	3232.4 ± 218.1	3240.4 ± 213.3
	35	3210.3 ± 213.0	3218.1 ± 213.7
	40	3227.6 ± 216.5	3238.0 ± 215.6
	50	3221.0 ± 216.4	3234.4 ± 214.0

for 30 seconds significantly increased normalized CMJ height immediately after treatment. Roelants et al. (32) has reported a significant increase in muscle activity and force production after a 30-second bout at 2.5 mm and 35 Hz on the Power Plate. The results of these studies support our finding that matching low frequencies with low displacement can positively affect neuromuscular performance. However, they provide no comparisons with other frequency and displacement interactions.

The results from studies using horizontal displacement WBV devices can also be compared with our results; however, it should be recognized that these comparisons are affected by the differences in the patterns of displacement. In a study using a Kuntatory vibration platform at a displacement of 2 mm and frequencies of 25, 30, 35, and 40 Hz for each minute of a 4-minute protocol, Torvinen et al. (38) found no significant increase in vertical jump measured at 2 and 60 minutes after exposure. Because the final minute of the protocol employed

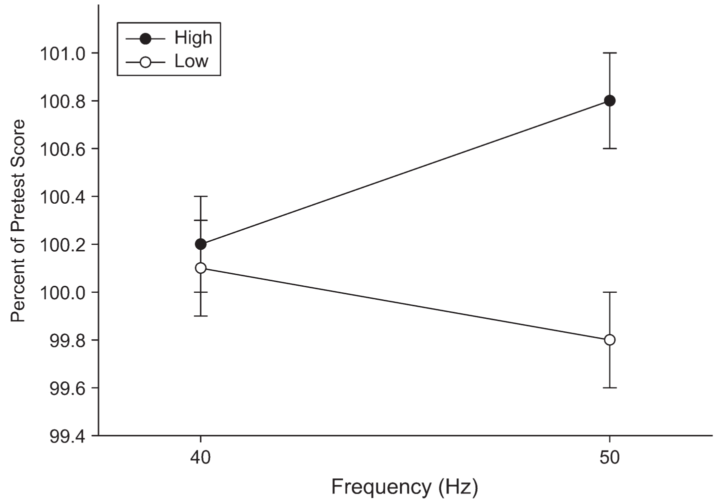

Figure 3. Countermovement jump (CMJ) peak power normalized to baseline values showing different patterns of change for high and low amplitudes across 40 and 50 Hz.

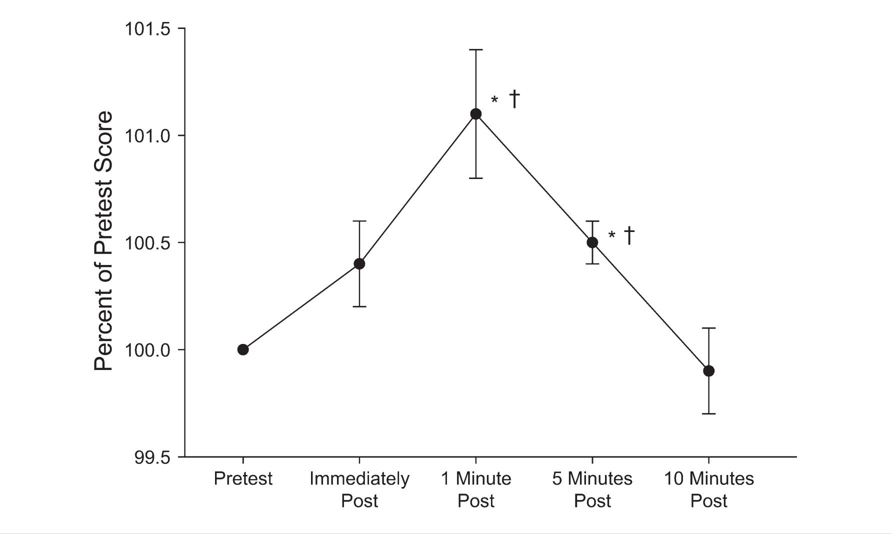

Figure 4. Changes in countermovement jump (CMJ) peak power over time, normalized to baseline values.

a low-displacement, high-frequency combination and no significant improvements were seen, it may be argued that these data support our findings. However, the nature of the vibratory stimulus, the duration of the treatment, and the use of multiple frequencies make these results difficult to compare with our findings. In contrast, Bosco et al. (5) have reported a significant improvement in jump height after 60 seconds at 26 Hz at a 4-mm displacement on a vertical displacement plate. Once again, these data are difficult to compare with ours because the frequency employed was lower than any we investigated, and the displacement levels fell between those used in the current study.

The results of studies examining the acute impact of WBV on the Galileo platform are more difficult to compare with our results. The Galileo works by tilting on a central axis to produce a vibratory stimulus. Because this is quite different from both the Power Plate and the vertical displacement devices reviewed above, the frequencies and displacements used also differ considerably. The frequencies range from 5 to 30 Hz, and the displacements range from 0 to 13 mm. In one study, Rittweger et al. (31) examined the effect of loaded squatting exercises on a Galileo WBV platform at a frequency of 26 Hz and a displacement of 6 mm. The stimulus was applied until exhaustion as assessed by each subject's rating of perceived exertion. Durations ranged from 150 to 500 seconds. This protocol produced no changes in serial jump heights or isometric knee extension. In a second study, Rittweger et al. (30) examined the impact of WBV at a frequency of 26 Hz and a displacement of 11 mm. Once again, the subjects remained on the platform until self-reported fatigue. The durations of these exposures ranged from 200 to 475 seconds. This protocol produced a significant decline in CMJ performance. Finally, de Ruiter et al. (11) examined the impact of WBV at 30 Hz and 8-mm displacement for five 60-second repetitions with a 120-second recovery interval. This protocol produced no change in CMJ performance. The lack of acute improvements using the Galileo may be specific to this mode of vibration, or it may reflect the exhaustive nature of these protocols. Regardless of the underlying causes, comparing frequency/displacement patterns between WBV on the Galileo and the Power Plate seems inappropriate.

As indicated in the summary above, our second finding was that an acute bout of WBV led to a transient increase in power that peaked at 1 minute after WBV and declined to baseline levels by 5 minutes posttreatment. This finding is in agreement with the results of a number of studies that examined acute responses to WBV (5,10,21). For example, Cormie et al. (10) found a significant increase in CMJ height immediately after WBV (30 Hz, low displacement, 30 seconds), but this increase fell below baseline by 5 minutes posttreatment (10). Bosco et al. (4) also found that a single vibration bout (26 Hz, 10 mm) showed temporary increases (lasting 10 minutes) in muscle average force, average velocity, and average power with all loads used on the treated leg. This resulted in an increase in both velocity and power post WBV for the treated leg at all external loads tested during the leg press test (4). The control legs showed no changes from pre to post WBV tests (4). These results support our findings that there is a limited window during which power performance will be maximized after an acute bout of WBV. Unfortunately, they do not allow comparison with our findings that this window seems to be maximized 1 minute after the stimulus ends.

Finally, we found that varying the duration of exposure within the range of 30–60 seconds had no impact on power. Once again, comparisons with other studies are difficult, because acute responses have not been previously compared within the 30- to 60-second range; however, results of previous studies do lend support to our findings. Bosco et al. (4) found that 10 WBV exposures lasting 60 seconds with 60 seconds of recovery between exposures on a Galileo increased average power as well as peak power in women volleyball players. This WBV treatment was applied at a frequency of 26 Hz and displacement of 10 mm. Cormie et al. (10) found significant increases in CMJ height immediately after a 30-second exposure to the triple-plane WBV device, Power Plate, at a frequency of 30 Hz and

2.5-mm displacement. The fact that both studies reported significant improvements when the duration of the WBV varied by 30 seconds supports our findings.

In contrast, prolonged exposures to WBV have been shown to elicit power decrements (11,30). Rittweger et al. (30) found decreased power after exhaustive exposures (200–475 seconds) on a Galileo WBV platform at a frequency of 26 Hz and a displacement of 11 mm with additional external loads between 35 and 40% of body weight. De Ruiter et al. (11) reported a significant decrease in both maximum voluntary contraction and electrically stimulated maximum force-generating capacity of the knee extensors after five 1-minute bouts on a Galileo 200 at 30 Hz and 8-mm displacement. These declines in performance may have been the result of fatigue resulting from the application of WBV until exhaustion or an ineffective work/recovery duty cycle. We suggest that our data indicating similar responses with WBV bouts of 30, 45, and 60 seconds, and our data indicating transient power increases lasting between 1 and 5 minutes, may help when designing WBV programs to maximize power gains.

Practical Applications

Short bouts of WBV used for warm-up before explosive efforts have been shown to improve neuromuscular performance (3,22). Therefore, WBV may prove effective as a precompetition or pretraining warm-up activity for both individual and team sports where power is a dominant factor. However, our results indicate that if WBV is to be used acutely as either a precompetition or pretraining warm-up, coaches should consider combining high displacements with high frequencies or low displacements with low frequencies. Additionally, preparatory bouts should be temporally positioned so that they precede the competitive performance by 1–5 minutes. The fact that we found no differences between 30, 45, and 60 seconds of stimulation indicates that the time required to generate a positive impact on performance is relatively short, but that durations of up to 1 minute will still generate positive results.

The greater time efficiency and lower training volume and intensity associated with WBV compared with traditional training methodologies may make it an effective training tool for athletes (6,27), especially during tapers when reduced volume and intensity are used to prepare athletes for competition (24). Whole-body vibration may be an effective tool for providing the benefits of a taper while further stimulating neuromuscular adaptations for power. Our data also suggest that WBV may be an effective warm-up preceding plyometric training.

We suggest that these results be considered when designing the proper work-recovery duty cycles when WBV is used as a training tool to maximize power; however, further studies must be conducted to determine the optimal duration of recovery, the optimal number of cycles, and the frequency and duration interactions necessary to maximize power gains in both competitive athletes and other special populations, whose responses may vary because of age, gender, body composition, and training status.

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