EFFECT OF DIFFERENT REST INTERVALS AFTER WHOLE-BODY VIBRATION ON VERTICAL JUMP PERFORMANCE

NICOLE C. DABBS,[1] COLLEEN X. MUÑOZ,[1] TAI T. TRAN,[1] LEE E. BROWN,[1] AND MARTIM BOTTARO[2]

[1]Kinesiology Department, Human Performance, Laboratory, California State University, Fullerton, California; and [2]College of Physical Education, University of Brasília, Brasília, Brazil

ABSTRACT

Dabbs, NC, Muñoz, CX, Tran, TT, Brown, LE, and Bottaro, M. Effect of different rest intervals after whole-body vibration on vertical jump performance. *J Strength Cond Res* 25(3): 662–667, 2011—Whole-body vibration (WBV) may potentiate vertical jump (VJ) performance via augmented muscular strength and motor function. The purpose of this study was to evaluate the effect of different rest intervals after WBV on VJ performance. Thirty recreationally trained subjects (15 men and 15 women) volunteered to participate in 4 testing visits separated by 24 hours. Visit 1 acted as a familiarization visit where subjects were introduced to the VJ and WBV protocols. Visits 2–4 contained 2 randomized conditions per visit with a 10-minute rest period between conditions. The WBV was administered on a pivotal platform with a frequency of 30 Hz and an amplitude of 6.5 mm in 4 bouts of 30 seconds for a total of 2 minutes with 30 seconds of rest between bouts. During WBV, subjects performed a quarter squat every 5 seconds, simulating a countermovement jump (CMJ). Whole-body vibration was followed by 3 CMJs with 5 different rest intervals: immediate, 30 seconds, 1 minute, 2 minutes, or 4 minutes. For a control condition, subjects performed squats with no WBV. There were no significant ($p > 0.05$) differences in peak velocity or relative ground reaction force after WBV rest intervals. However, results of VJ height revealed that maximum values, regardless of rest interval (56.93 ± 13.98 cm), were significantly ($p < 0.05$) greater than the control condition (54.44 ± 13.74 cm). Therefore, subjects' VJ height potentiated at different times after WBV suggesting strong individual differences in optimal rest interval. Coaches may use WBV to enhance acute VJ performance but should first identify each individual's optimal rest time to maximize the potentiating effects.

KEY WORDS time, countermovement, warm-up

INTRODUCTION

Enhancing performance in athletes and recreationally trained individuals has become increasingly common for sport performance today. Traditional techniques to train for sport performance are still prevalent (25,26,29), but an increasing number of options have been identified. Traditional training techniques, such as strength training, plyometrics, and weightlifting, may benefit from the inclusion of nontraditional techniques to further enhance performance (8,14,16,32).

One of the more recent nontraditional techniques is whole-body vibration (WBV), which has been shown to increase performance in upper and lower body muscular activity in both trained and untrained populations (4,7,10,12,15,17,22). Current research has shown that WBV exposure at a moderate intensity is safe and effective in stimulating the neuromuscular system (8) and has been shown to induce nonvoluntary muscle contractions (20), which may be beneficial in sport performance. Whole-body vibration has also shown an increase in power production by facilitation of an explosive strength effort (4,21,30) leading to enhancement of performance via muscular strength and motor function (5,6). Also, sprinting and jumping performance has been shown to increase after bouts of WBV (2,3,7,14). This enhancement of acute performance is accomplished with little or no effort by the subject (31). In contrast, WBV has also been shown not to increase performance but to only have similar effects as traditional techniques (12,14–16,24).

Whole-body vibration is increasingly being used as a warm-up for its potentiating effect before performance. Warm-up before performance is often recommended to prevent injury and to prepare the body for activity. Whole-body vibration has been used as active passive warm-up instead of traditional active warm-up methods (13,14,31) because of its reported acute performance effects. The acute lower body neuromuscular activation from WBV (1,2) may be beneficial in many power sports.

Whole-body vibration exposure variables such as frequency, amplitude, duration, and rest intervals need to be considered to optimize performance. Rest intervals after WBV have been shown to effect performance outcomes with too short a rest possibly over stimulating the neuromuscular

Address correspondence to Lee E. Brown, leebrown@fullerton.edu.

25(3)/662–667

Journal of Strength and Conditioning Research

system and too long a rest may be allowing any effect to dissipate (2). Therefore, optimal rest intervals are crucial to the use of WBV to enhance sport performance. Previously researched, rest intervals after acute bouts of WBV have been used from immediately post to 10 minutes (2,3,7,12,14,27,33) and have demonstrated conflicting results.

Therefore, the purpose of this study was to investigate the effect of different rest intervals after WBV on vertical jump (VJ) performance. If optimal rest intervals are determined after WBV in maximizing VJ performance then individual performance may increase. This implies the impact WBV may have on individuals before a single explosive maximal performance and the importance of examining optimal rest intervals in individuals to optimize performance outcomes and can be prescribed by professionals working with individuals seeking to enhance VJ performance. To our knowledge, no work has been previously reported examining different rest intervals before maximal VJ using this specific pivotal WBV platform.

METHODS

Experimental Approach to the Problem

We were interested in acute performance potentiation after WBV exposure as might be used in a modified warm-up procedure. Therefore, this study used a repeated measures design by having subjects perform 5 different rest interval conditions and comparing VJ performance to a control condition without WBV. Rest intervals ranged from immediate post to 4 minutes post.

Subjects

Thirty recreationally trained individuals (15 men age: 23.6 ± 1.72 years, height: 175.59 ± 6.97 cm, body mass: 80.98 ± 9.63 kg; 15 women age: 23.4 ± 2.23 years, height: 156.59 ± 27.53 cm, body mass: 60.12 ± 8.06 kg) volunteered to participate in 4 testing visits. The participants were selected at random from responders to fliers distributed over the university campus, and by word of mouth.

Subjects who were recreationally trained were defined as individuals who within the last year participated in lower body strength and power activities about 3 times a week; highly trained athletes were excluded from this study because of their training status. Subjects were asked to refrain from any physical activity 24 hours before testing and were excluded if they reported any lower body orthopedic injury or musculoskeletal injury within the past year. Each visit was within plus or minus 1 hour from initial to all proceeding visits, separated by at least 24 hours during the spring season in a controlled laboratory setting. Subjects were asked to wear comfortable clothing and the same shoes for each visit. Diet and hydration were not recorded, but subjects were asked to keep consistent throughout the duration of the study. Each subject read and signed a university Institutional Review Board approved informed consent form before participation.

TABLE 1. The VJ height, rGRF, and PV maximum values and values for each condition.*†

	Control	Immediately post	30 s	1 min	2 min	4 min	Max value
VJ height (cm)	54.44 ± 13.74	54.99 ± 13.88	55.20 ± 14.24	54.94 ± 14.19	55.41 ± 13.57	55.11 ± 13.66	56.93 ± 13.98‡
rGRF (N·kg^{-1})	14.09 ± 4.88	13.42 ± 3.15	13.04 ± 2.87	13.46 ± 2.96	13.57 ± 3.12	13.63 ± 3.21	14.30 ± 3.09
PV (m·s^{-1})	2.36 ± 0.40	2.35 ± 0.39	2.31 ± 0.40	2.31 ± 0.35	2.33 ± 0.37	2.30 ± 0.35	2.42 ± 0.42

*VJ = vertical jump; rGRF = relative ground reaction force; PV = peak velocity.
†Values are given as mean ± *SD*.
‡Significantly ($p < 0.05$) greater than control.

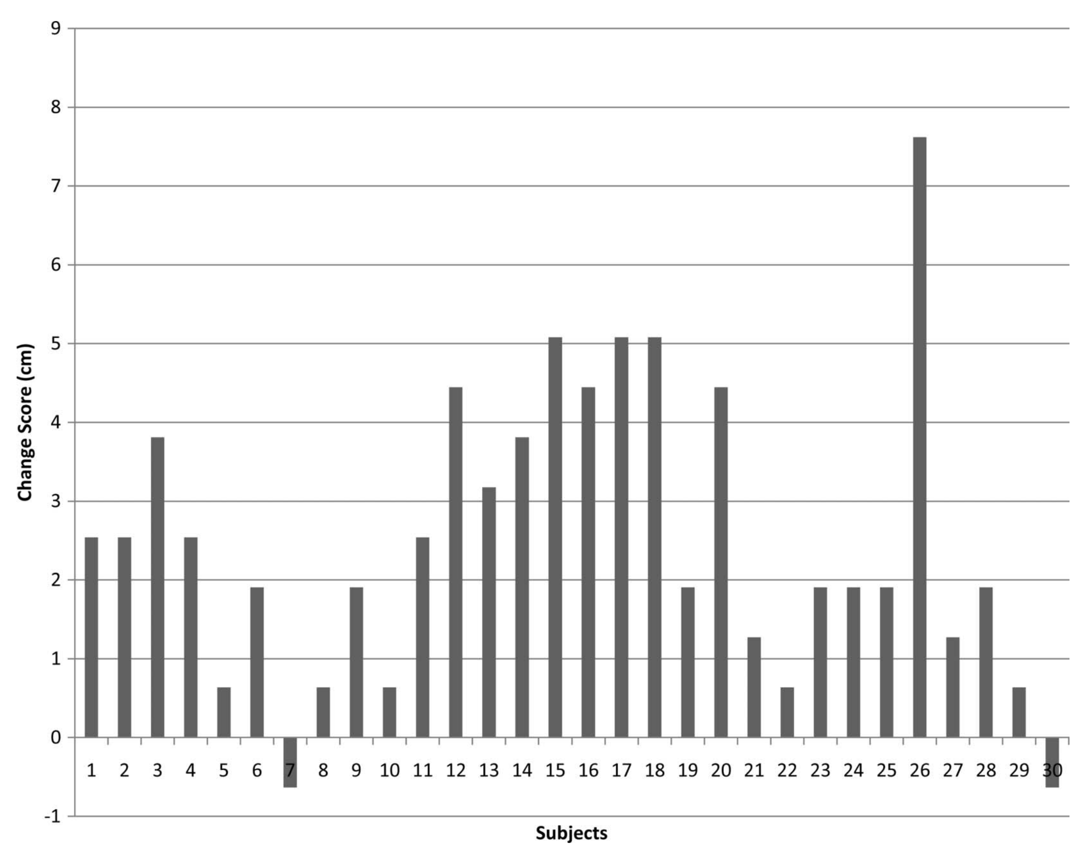

Figure 1. Individual differences between control and maximal vertical jump height.

Procedures

Visit 1 served as a familiarization session, which included completing the informed consent, anthropometric measurements, familiarization with the countermovement jump (CMJ) and WBV protocol. During the familiarization session, each subject completed 3 CMJs to assess variability; if the 3 CMJs exceeded 5% difference in jump height, they were asked to return to the laboratory on a subsequent day to complete another 3 jumps until the criterion was met. Subjects then performed 6 experimental conditions in 3 days with 2 conditions per day (3) separated by a 10-minute rest period. This rest period was deemed sufficient because previous literature has shown that WBV is ineffective after 10 minutes of exposure (2). The order in which the conditions were performed was randomized and separated by at least 24 hours.

Whole-body vibration was performed on a MedVibe NitroFit Deluxe vibration platform (Scottsdale, AZ, USA), which administered a pivotal vibration frequency at 30 Hz (2,14) with a vertical amplitude of 6.5 mm. Amplitude was controlled by having subjects place their feet at the widest point on the plate. Whole-body vibration sessions entailed 4 bouts of 30 seconds (3) for a total of 2 minutes of vibration with 30 seconds rest between bouts. During WBV, subjects performed quartersquats (3,11) every 5 seconds while also simulating the arm swing used in a CMJ. Subjects were instructed to step off the plate during the rest time. After WBV exposure, subjects were instructed to walk quickly to the force plate (~15 ft) at which point they stood quietly until their rest interval for that condition was completed and then performed 3 CMJs.

One condition served as a control during which the subjects stood on the vibration platform with no vibration, completed the squatting protocol then immediately performed 3 CMJs. The other 5 conditions used rest intervals of either immediately post, 30 seconds, 1 minute, 2 minutes, or 4 minutes followed by 3 CMJs (2). In addition, each subject's max value for each variable, regardless of rest interval, was analyzed as another condition, thereby making 7 conditions overall.

During all conditions, subjects were instructed to begin with their arms at a 90° angle and then perform a CMJ to a self-selected depth with arm swing and jump as high and as explosively as possible. Fifteen seconds of rest separated each jump, and all jumps were performed on an AMTI force plate

(Advanced Mechanical Technology, Inc., Watertown, MA, USA). An EPIC VJ tester (EPIC Athletic Performance Inc., Colorado Springs, CO, USA) was used to measure jump height to the nearest quarter inch and was positioned next to the force plate. Data were sampled at 1,000 Hz and maximum values from the peak velocity (PV) repetition for each condition were analyzed. The force plate was connected to a desktop computer running custom LabVIEW data collection and analysis software (version 7.1, National Instruments Corporation, Austin, TX, USA), which analyzed force and velocity. Peak velocity was determined by subtracting body weight from the force–time curve, dividing by body mass, and integrating with respect to time using the trapezoidal rule for numerical integration. Peak velocity ($m \cdot s^{-1}$) was recorded as the maximum velocity value before take-off. Relative ground reaction force (rGRF in $N \cdot kg^{-1}$) was determined by dividing peak GRF by body weight. After completing 1 condition, subjects sat in a chair with no active movement for 10 minutes and then completed the second condition for that visit.

Statistical Analyses

All statistical procedures were conducted using the Statistical Package for the Social Sciences (PASW 18.0 for Windows, SPSS, Inc., Chicago, IL, USA). An a priori alpha was set at 0.05 to determine significance. Differences in VJ height, rGRF, and PV between conditions were analyzed with a 2×7 (sex by condition) mixed factor analysis of variance.

RESULTS

No significant ($p > 0.05$) interaction of sex by condition was found for any variable. There was a main effect for sex for all variables demonstrating greater values for men when compared to women. There were no main effects for condition for either rGRF or PV (Table 1). However, there was a main effect for condition for VJ height. This was followed up with an least significant difference (LSD) pairwise comparison demonstrating that maximum values, regardless of rest interval, were significantly ($p < 0.05$) greater than the control condition (power = 0.45, effect size = 0.39) (Table 1). Individual results are shown in Figure 1.

DISCUSSION

This study sought to determine the optimal rest interval after bouts of WBV to increase VJ height, PV, and rGRF. The major finding was that after WBV VJ height increased at different individual rest intervals, whereas there was no change in PV or rGRF. Because the rest interval eliciting increased VJ height was variable across this subject population, it suggests strong individual differences in optimal rest interval.

Previous research has stated that 1-minute rest post WBV and a frequency of 30 Hz were optimal for potentiation, which supports our present findings. Although frequency was the same in this and previous studies, our study did differ in the time exposure of WBV. Bedient and coworkers (2,3) exposed subjects to 1 bout of 30 seconds of WBV and found an increase in CMJ resulting in a homogenous optimal rest interval of 1 minute post when compared to immediate post, 5 minutes or 10 minutes. In contrast, our study exposed subjects to 4 bouts of 30 seconds of vibration with a 1:1 rest ratio and found individual optimal rest intervals.

The findings of our study are partially supported by Cormie et al. (14), who found that 2.5 mm of displacement at 30 Hz significantly increased VJ height after 30 seconds of WBV exposure, whereas our present study used 4 bouts of 30 seconds of exposure with 6.5-mm displacement. Similar to our present investigation, McBride et al. (27) found that WBV exposure of 30 seconds at 30 Hz while performing bilateral body weight squats resulted in a significant increase in peak GRF for WBV compared to control. Additionally, they found these results both immediately post and 8 minutes post WBV. They concluded that their protocol may have induced postactivation potentiation (PAP) (27). Postactivation potentiation is induced by a voluntary contraction and has consistently been shown to increase both peak force and rate of force development during subsequent muscle actions (34). However, the voluntary action might also induce fatigue, and it is the balance between PAP and fatigue that will determine the net effect on performance of a subsequent activity. The PAP fatigue relationship appears to be affected by several variables including recovery period after the voluntary action (28). Also, PAP occurrence may be highly individualized (9). Some individuals may have a greater PAP effect than fatigue effect, whereas others may have a greater fatigue effect than PAP effect for the same rest interval (28). In the present study, we found no differences between the rest interval; we found that WBV within 0–4 minutes before performance increased VJ height. Thus, we suspect PAP may also partially explain the results of our study. The protocol we used may have been sufficient to induce PAP but conservative enough not to induce fatigue.

In our current study, VJ height increased with no differences in PV or rGRF, which may be because of our use of the EPIC to measure VJ height instead of using the force plate to estimate it. Using the EPIC to measure VJ height does not control for changes in arm reach or trunk twist from jump to jump, which may alter scores (18). The force plate estimates VJ height and does not control for differences in landing mechanics, which could alter VJ height estimation (18). In addition, our results demonstrated no differences in PV or rGRF between rest intervals, which may be explained by the use of recreationally trained individuals and their lack of high velocity training as compared to elite athletes (19).

It is possible that VJ height in our study may also have been influenced by our testing protocol. After each set of CMJs, subjects performed 3 jumps separated by 15 seconds. Our data reflect the maximum VJ height for each condition, and it is possible that prior jumps affected subsequent VJ performance. However, previous research analyzing the kinetics of complex training intervals and their effect on VJ performance demonstrated no significant difference between 5 trials across rest time intervals of 10 seconds, 1 minute, 2 minutes, 3 minutes, and 4 minutes (23). Another important factor is the WBV platform used. Our present study used a pivotal platform, whereas others (2,3,27) have used other types (e.g., vertical, sliding horizontal, and triplanar), which may elicit different muscular mechanisms thereby resulting in different performance outcomes.

Practical Applications

The current investigation indicates that using 4 sets of 30-second bouts of WBV before performance may increase VJ height in recreationally trained subjects, albeit at different individual rest times. Therefore, it is recommended that each individual's optimal WBV rest time be determined before jumping to elicit the greatest potentiating effects for performance. To acquire individual optimal rest times prior to performance, we would recommend that individuals to be assessed before their competition phase. Determining optimal rest times would allow individuals to incorporate WBV into their prejump routine for a single explosive movement during competition. For example, a high jumper could use WBV before a single explosive jump during competition to maximize performance. These acute effects may apply to athletes in sport performance. Any long-term performance gains have not yet been investigated but should be studied in future research.

References

1. Abercromby, AF, Amonette, WE, Layne, CS, McFarlin, BK, Hinman, MR, and Paloski, WH. Variation in neuromuscular responses during acute whole-body vibration exercise. *Med Sci Sports Exerc* 39: 1642–1650, 2007.
2. 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: 237–245, 2009.
3. Bedient, AM, Adams, JB, Edwards, D, Serviette, D, Huntsman, E, Mow, SE, Roos, BA, and Signorile, JF. Displacement and frequency for maximizing power output resulting from a bout of whole-body vibration. *J Strength Cond Res* 23: 1683–1687, 2009.
4. Bosco, C, Cardinale, M, and Tsarpela, O. Influence of vibration on mechanical power and electromyogram activity in human arm flexor muscles. *Eur J Appl Physiol Occup Physiol* 79: 306–311, 1999.
5. Bosco, C, Cardinale, M, Tsarpela, O, Colli, R, Tihanyi, J, VonDuvillard, S, and Viru, A. The influence of whole body vibration on jumping performance. *Bio Sports* 15: 157–164, 1998.
6. Bosco, C, Colli, R, Introini, E, Cardinale, M, Tsarpela, O, Madella, A, Tihanyi, J, and Viru, A. Adaptive responses of human skeletal muscle to vibration exposure. *Clin Physiol* 19: 183–187, 1999.
7. Bullock, N, Martin, DT, Ross, A, Rosemond, CD, Jordan, MJ, and Marino, FE. Acute effect of whole-body vibration on sprint and jumping performance in elite skeleton athletes. *J Strength Cond Res* 22: 1371–1374, 2008.
8. Cardinale, M and Bosco, C. The use of vibration as an exercise intervention. *Exerc Sport Sci Rev* 31: 3–7, 2003.
9. Chiu, LZ, Fry, AC, Weiss, LW, Schilling, BK, Brown, LE, and Smith, SL. Postactivation potentiation response in athletic and recreationally trained individuals. *J Strength Cond Res* 17: 671–677, 2003.
10. Cochrane, DJ and Hawke, EJ. Effects of acute upper-body vibration on strength and power variables in climbers. *J Strength Cond Res* 21: 527–531, 2007.
11. Cochrane, DJ, Legg, SJ, and Hooker, MJ. The short-term effects of whole-body vibration training on vertical jump, sprint, and agility performance. *J Strength Cond Res* 18: 828–832, 2004.
12. Cochrane, DJ and Stannard, SR. Acute whole body vibration training increases vertical jump and flexibility performance in elite female field hockey players. *Br J Sports Med* 39: 860–865, 2005.
13. Cochrane, DJ, Stannard, SR, Sargeant, AJ, and Rittweger, J. The rate of muscle temperature increase during acute whole-body vibration exercise. *Eur J Appl Physiol* 103: 441–448, 2008.
14. Cormie, P, Deane, RS, Triplett, NT, and McBride, JM. Acute effects of whole-body vibration on muscle activity, strength, and power. *J Strength Cond Res* 20: 257–261, 2006.
15. Dabbs, NC, Brown, LE, Coburn, JW, Lynn, SK, Tran, TT, and Biagini, MS. Effect of whole-body vibration warm-up on bat speed in women softball players. *J Strength Cond Res* 24: 2296–2299, 2010.
16. de Ruiter, CJ, van der Linden, RM, van der Zijden, MJ, Hollander, AP, and de Haan, A. Short-term effects of whole-body vibration on maximal voluntary isometric knee extensor force and rate of force rise. *Eur J Appl Physiol* 88: 472–475, 2003.
17. Di Loreto, C, Ranchelli, A, Lucidi, P, Murdolo, G, Parlanti, N, De Cicco, A, Tsarpela, O, Annino, G, Bosco, C, Santeusanio, F, Bolli, GB, and De Feo, P. Effects of whole-body vibration exercise on the endocrine system of healthy men. *J Endocrinol Invest* 27: 323–327, 2004.
18. Ferreira, LC, Schilling, BK, Weiss, LW, Fry, AC, and Chiu, LZ. Reach height and jump displacement: Implications for standardization of reach determination. *J Strength Cond Res* 24: 1596–1601, 2010.
19. Gullich, A and Schmidtbleicher, D. MVC-induced short-term potentiation of explosive force. *New Stud Athl* 11: 67–81, 1996.
20. Issurin, VB. Vibrations and their applications in sport: A review. *J Sports Med Phys Fitness* 45: 424–436, 2005.
21. Issurin, VB and Tenenbaum, G. Acute and residual effects of vibratory stimulation on explosive strength in elite and amateur athletes. *J Sports Sci* 17: 177–182, 1999.
22. Jacobs, PL and Burns, P. Acute enhancement of lower-extremity dynamic strength and flexibility with whole-body vibration. *J Strength Cond Res* 23: 51–57, 2009.
23. Jensen, RL and Ebben, WP. Kinetic analysis of complex training rest interval effect on vertical jump performance. *J Strength Cond Res* 17: 345–349, 2003.
24. Kelly, SB, Alvar, BA, Black, LE, Dodd, DJ, Carothers, K, and Brown, L. The effect of warm-up with whole body vibration versus cycle ergometry on isokinetic dynamometry. *J Strength Cond Res* 24: 3140–3143, 2010.
25. Kraemer, WJ, Nindl, BC, Ratamess, NA, Gotshalk, LA, Volek, JS, Fleck, SJ, Newton, RU, and Häkkinen, K. Changes in muscle hypertrophy in women with periodized resistance training. *Med Sci Sports Exerc* 36: 697–708, 2004.
26. Kraemer, WJ and Ratamess, NA. Fundamentals of resistance training: Progression and exercise prescription. *Med Sci Sports Exerc* 36: 674–688, 2004.
27. McBride, JM, Nuzzo, JL, Dayne, AM, Israetel, MA, Nieman, DC, and Triplett, NT. Effect of an acute bout of whole body vibration exercise on muscle force output and motor neuron excitability. *J Strength Cond Res* 24: 184–189, 2010.
28. McCann, MR and Flanagan, SP. The effects of exercise selection and rest interval on postactivation potentiation of vertical jump performance. *J Strength Cond Res* 24: 1285–1291, 2010.

29. Newton, RU, Kraemer, WJ, and Häkkinen, K. Effects of ballistic training on preseason preparation of elite volleyball players. *Med Sci Sports Exerc* 31: 323–330, 1999.
30. Poston, B, Holcomb, WR, Guadagnoli, MA, and Linn, LL. The acute effects of mechanical vibration on power output in the bench press. *J Strength Cond Res* 21: 199–203, 2007.
31. Rittweger, J, Beller, G, and Felsenberg, D. Acute physiological effects of exhaustive whole-body vibration exercise in man. *Clin Physiol* 20: 134–142, 2000.
32. Ronnestad, BR. Comparing the performance-enhancing effects of squats on a vibration platform with conventional squats in recreationally resistance-trained men. *J Strength Cond Res* 18: 839–845, 2004.
33. Ronnestad, BR. Acute effects of various whole-body vibration frequencies on lower-body power in trained and untrained subjects. *J Strength Cond Res* 23: 1309–1315, 2009.
34. Tillin, N and Bishop, D. Factors modulating post-activation potentiation and its effect on performance of subsequent explosive activities. *Sports Med* 39: 147–166, 2009.