Open Access Journal of Sports Medicine

Dovepress
open access to scientific and medical research

Open Access Full Text Article

ORIGINAL RESEARCH

What is the most effective posture to conduct vibration from the lower to the upper extremities during whole-body vibration exercise?

This article was published in the following Dove Press journal:
Open Access Journal of Sports Medicine
6 January 2016
Number of times this article has been viewed

Yuka Tsukahara
Jun Iwamoto
Kosui Iwashita
Takuma Shinjo
Koichiro Azuma
Hideo Matsumoto

Institute for Integrated Sports Medicine, Keio University School of Medicine, Tokyo, Japan

Background: Whole-body vibration (WBV) exercise is widely used for training and rehabilitation. However, the optimal posture for training both the upper and lower extremities simultaneously remains to be established.

Objectives: The objective of this study was to search for an effective posture to conduct vibration from the lower to the upper extremities while performing WBV exercises without any adverse effects.

Methods: Twelve healthy volunteers (age: 22–34 years) were enrolled in the study. To measure the magnitude of vibration, four accelerometers were attached to the upper arm, back, thigh, and calf of each subject. Vibrations were produced using a WBV platform (Galileo 900) with an amplitude of 4 mm at two frequencies, 15 and 30 Hz. The following three postures were examined: posture A, standing posture with the knees flexed at 30°; posture B, crouching position with no direct contact between the knees and elbows; and posture C, crouching position with direct contact between the knees and elbows. The ratio of the magnitude of vibration at the thigh, back, and upper arm relative to that at the calf was used as an index of vibration conduction.

Results: Posture B was associated with a greater magnitude of vibration to the calf than posture A at 15 Hz, and postures B and C were associated with greater magnitudes of vibration than posture A at 30 Hz. Posture C was associated with a vibration conduction to the upper arm that was 4.62 times and 8.26 times greater than that for posture A at 15 and 30 Hz, respectively.

Conclusion: This study revealed that a crouching position on a WBV platform with direct contact between the knees and elbows was effective for conducting vibration from the lower to the upper extremities.

Keywords: whole-body vibration exercise, upper extremities, lower extremities

Introduction

Whole-body vibration (WBV) exercise, which is used for training and rehabilitation, is becoming a popular training option for subjects ranging from elite athletes to elderly patients.[1–8] WBV exercise originated based on an observation of Jean-Martin Charcot, a French neurologist, who showed that the symptoms of a patient with Parkinson's disease had improved, possibly as a result of the vibrations produced by railway carriages.[9] Strong evidence suggests that acute WBV exercise can enhance upper- and lower-body muscle power, and there is some indication that longer-term WBV exercise can augment muscle power of the upper and lower body extremities.[10] WBV exercise has also been reported to improve chronic back pain,[11,12] to reduce pain and improve function in patients with knee osteoarthritis,[13] and to be a promising option for preventing bone fracture and osteoporosis.[14] WBV exercise is a safe modality for

Correspondence: Yuka Tsukahara
Institute for Integrated Sports Medicine, Keio University School of Medicine,
35 Shinanomachi, Shinjuku-ku,
Tokyo 160-8582, Japan
Tel +81 3 3353 1211
Fax +81 3 5269 9054
Email yuka.voila@gmail.com

submit your manuscript | www.dovepress.com
Dovepress
http://dx.doi.org/10.2147/OAJSM.S93047

increasing the physiological responses of reflex and muscle activity and the muscle function of athletes, the elderly, and individuals with compromised health.[10]

Thus, WBV exercise has been acknowledged as a potential modality in sports, exercise, and health sectors. WBV exercise is performed while the subject stands with bent knees and hips on a platform. Because vibrations conducted to the head are thought to induce headaches, some authors have claimed that the subject's knees should be semiflexed to reduce vibration to the head.[15] Most studies regarding this type of exercise have focused on the lower extremities and back,[1,3,5–8] and little has been studied regarding the optimal posture for training the upper extremities. Although positioning the upper arm directly on the platform may improve the neuromuscular function of the upper extremities, it may cause headaches or benign vertigo because of the conduction of vibrations to the head.[16] Dumbbell training is another option, but an amplitude of 2 mm is recommended and gloves should be worn to prevent blisters, according to previous studies.[17] Thus, it appears hard to train the upper extremities using WBV exercise. Direct contact between the elbows and knees has been hypothesized to conduct vibration efficiently from the lower to the upper extremities. Such a posture could make it possible to simultaneously train the upper and lower extremities. The objective of this study was to search for an effective posture to conduct vibration from the lower to the upper extremities while performing WBV exercise without causing any of the above-mentioned side effects.

Methods

Ethical approval

The study protocol was approved by the Keio University Human Ethics Committee (the registration number: 20120327). Written informed consent was obtained from all the participants.

Study subjects

Twelve healthy volunteers (six men and six women), aged 22–34 years, were enrolled in the study. All the subjects were physically active, but none had previous experience performing WBV exercise. None of the subjects had a serious past medical history, including cardiovascular diseases, liver diseases, kidney dysfunction, diabetes, and musculoskeletal diseases, and none of the subjects had metallic implants of any kind. None of the female participants were pregnant.

Whole-body vibration

Instructions were given on how to assume correct positions on the platform, and the study was started after confirming that the subjects fully understood the procedures and potential risks associated with the study. Shoes of the same design were provided to each subject.

Vibration was produced using a WBV platform (Galileo 900; Novotec Medical GmBH, Pforzheim, Germany). The Galileo machine is a unique device for applying WBV/oscillatory muscle stimulation. The subjects were positioned at the center of the platform with their feet shoulder-width apart and placed completely on the platform; the subjects were asked not to hold on to any item during the study. The subjects were asked to stand with bent knees and hips on a rocking platform with a sagittal axle, which alternately thrusts the right and left legs upwards and downwards, thereby promoting the lengthening of the extensor muscles of the lower extremities. This type of training provides reflex muscle stimulation with no serious adverse events. A chain of rapid muscle contractions during the exercise directly activates the neuromuscular system in the lower extremities. The amplitude of the vibration was set to 4 mm, and the frequency was set to 15 or 30 Hz.

Postures on WBV platform

Three postures were used (Figure 1): posture A (standard), standing posture with the knees flexed at 30°; posture B, crouching position (like a downhill posture in skiing) with no direct contact between the knees and elbows; and posture C, crouching position with direct contact between the knees and elbows.

Assessment of magnitudes of vibration

Accelerometers (MVP-RF8-GC; Microston Co, Ltd, Nagano, Japan) were attached to the calf over the lateral gastrocnemius, to the thigh over the rectus femoris, to the back over the latissimus dorsi, and to the upper arm over the triceps brachii of each subject on the right side (Figure 2).

The WBV platform was run for 13 seconds, and data from 5 to 10 seconds after the start were recorded while the magnitude of the vibration was kept constant (Figure 3). The orders of position and frequency were randomized, and the ratio of the magnitude of vibration at the thigh, back, and upper arm relative to that at the calf was used as an index of vibration conduction. Effective postures for use with the WBV system were investigated by analyzing the vibration conduction to each part of the body while the subject was in each of the three postures.

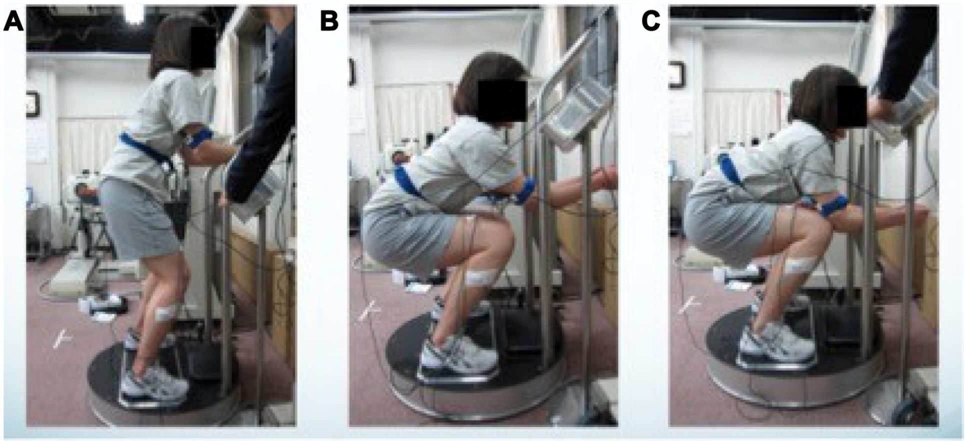

Figure 1 Three postures on WBV platform.
Notes: Posture (**A**) (standard), standing posture with the knees flexed at 30°; posture (**B**), crouching position (like a downhill posture in skiing) with no direct contact between the knees and elbows; and posture (**C**), crouching position with direct contact between the knees and elbows.
Abbreviation: WBV, whole-body vibration.

Statistical analysis

Data were expressed as the mean ± standard deviation. The Friedman test and the Bonferroni post hoc test were used to compare the data using SPSS software (IBM Japan, Tokyo, Japan). The significance level was set at $P<0.05$.

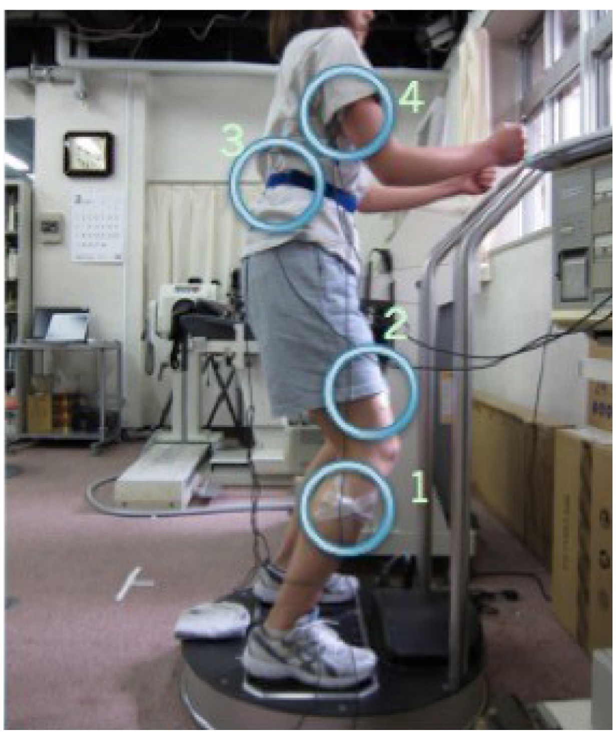

Figure 2 Assessment of magnitudes of vibration.
Notes: Accelerometers were attached to the following body parts: 1 – the calf over the lateral gastrocnemius, 2 – the thigh over the rectus femoris, 3 – the back over the latissimus dorsi, and 4 – the upper arm over the triceps brachii of each subject on the right side.

Results

Characteristics of study subjects

The mean ± standard deviation values of the subjects' age, height, weight, and body mass index were 28.6±3.9 years (range: 22–34 years), 1.69±0.06 m, 62.8±11.6 kg, and 21.9±3.0 kg/m^2, respectively.

Magnitudes of vibration recorded at each region

Table 1 lists the magnitudes of vibration recorded at each region (calf, thigh, back, and upper arm).

Calf: posture B was associated with a greater magnitude of vibration than posture A at 15 Hz, and posture C had a smaller magnitude of vibration than posture B. Postures B and C were associated with a greater magnitude of vibration than posture A at 30 Hz. Thigh: posture C was associated with

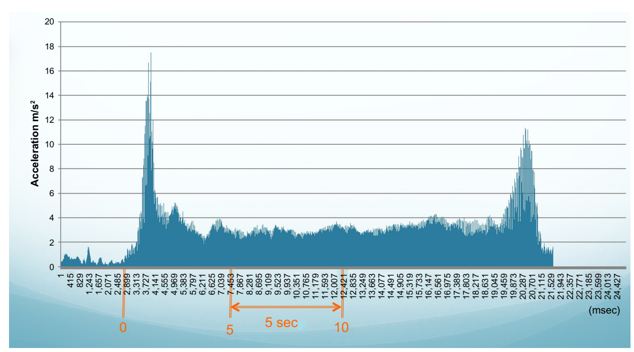

Figure 3 Collection of magnitude of vibration.
Note: The WBV platform was run for 13 seconds, and data from 5 to 10 seconds after the start were recorded while the magnitude of the vibration was kept constant.
Abbreviation: WBV, whole-body vibration.

Table 1 Magnitudes of vibration recorded at each region

Position	Posture A		Posture B		Posture C	
Frequency	**15 Hz**	**30 Hz**	**15 Hz**	**30 Hz**	**15 Hz**	**30 Hz**
Calf	51.9±19.1	58.0±26.5	66.7±17.9*	81.4±35.2**	54.8±16.4***	79.1±29.7**
Thigh	29.2±10.5	31.2±10.9	31.4±8.2	24.5±8.9	27.5±7.0	25.2±10.8
Back	6.22±2.23	6.56±3.40	4.09±1.79**	4.4±1.98**	4.24±1.82**	4.30±1.95**
Upper arm	2.47±1.10	1.07±0.44	2.91±1.27**	1.56±0.67	11.4±5.0*,#	8.81±4.89**,***

Notes: Data are expressed as the mean ± SD. *$P<0.01$, **$P<0.05$ vs posture A, ***$P<0.05$, #$P<0.01$ vs posture B by Friedman's test and Bonferroni's post hoc test.
Abbreviation: SD, standard deviation.

a smaller magnitude of vibration than posture B at 15 Hz, but no significant differences were found among the three postures at 30 Hz. Back: postures B and C were associated with a smaller magnitude of vibration than posture A at 15 Hz and at 30 Hz. Upper arm: posture C was associated with a much greater magnitude of vibration than postures A and B at 15 Hz, and postures B and C were associated with a greater magnitude of vibration than posture A at 30 Hz. Posture C was associated with a much greater magnitude of vibration than posture B at 15 and 30 Hz.

Ratio of magnitude of vibration at the thigh, back, and upper arm relative to that at the calf

The magnitudes of vibration at the upper arm at 15 Hz in postures A, B, and C were 2.47, 2.91, and 11.4 m/s^2, respectively. Thus, posture C was associated with vibration conduction to the upper arm that was 4.62 times and 3.92 times greater than that for postures A and B, respectively.

The magnitudes of vibration at the upper arm at 30 Hz in postures A, B, and C were 1.07, 1.56, and 8.81 m/s^2, respectively. Thus, posture B was associated with vibration conduction to the upper arm that was 1.47 times greater than that for posture A, and posture C was associated with vibration conduction to the upper arm that was 8.26 times and 5.65 times greater than that for postures A and B, respectively.

Posture C was associated with a vibration conduction to the calf that was 1.36 times greater than that for posture A at 30 Hz (79.1 vs 58.0 m/s^2). However, the vibration conduction to the back was 0.68 times and 0.66 times smaller for posture C than for posture A at 15 and 30 Hz, respectively (4.24 vs 6.22 m/s^2 at 15 Hz; 4.30 vs 6.56 m/s^2 at 30 Hz).

Adverse effects of WBV

Neither headaches nor injuries (including blisters) occurred in this series.

Discussion

WBV treatment studies have been aimed at improving some aspect of neuromuscular performance, pain, and bone density.[13,14,18] However, little has been studied regarding the optimal posture for training the upper extremities. This study searched for an effective posture to conduct vibration from the lower to the upper extremities while performing WBV exercise by examining three postures (Figure 1). The following results were obtained: 1) posture B was associated with a greater magnitude of vibration to the calf than posture A at 15 Hz, and postures B and C were associated with a greater magnitude than posture A at 30 Hz; 2) posture C was associated with a greater vibration conduction to the upper arm than posture A at 15 and 30 Hz; 3) posture C was associated with a smaller vibration conduction to the back at 15 and 30 Hz; and 4) no adverse effects occurred while performing the WBV exercise using posture C. Although there are some notable limitations, this study revealed that a crouching position on a WBV platform with direct contact between the knees and elbows was effective for conducting vibration from the lower to the upper extremities. The present study raises a question about the possibility of using such a posture to train the upper and lower extremities simultaneously when performing WBV exercise.

Posture B was associated with a greater magnitude of vibration to the calf than posture A at 15 Hz, and postures B and C were associated with a greater magnitude than posture A at 30 Hz. A crouching position with or without contact between the knees and elbows (postures C or B) was associated with a greater vibration conduction to the calf than a standing position with the knees semiflexed (posture A: standard posture), as was recommended in a previous report.[19] This result may be attributable to the fact that a crouching position, compared with a standing position, stabilizes the ankles on the platform more securely and transmits the vibration more effectively. Thus, a crouching position may be useful for conducting vibration to the calf. Avelar et al[20] showed that 90° of knee flexion resulted in a greater isometric muscular contraction to the vastus lateralis than 60° of flexion, suggesting that a crouching position, which can be estimated to require 120° of flexion, may provide more muscle contraction than the standard posture. Nevertheless, conduction to the thigh was smaller in the crouching position at 30 Hz. The vibration might not have been conducted efficiently from the calf to the thigh, when the knees were bent more than 90°, probably because the direction of conduction was reversed at the deeply flexed knees.

Posture C was associated with vibration conduction to the upper arm that was 4.62 times and 8.26 times greater than that for posture A at 15 and 30 Hz, respectively. Since the upper extremities are in contact with the knees in posture C, more vibration is obviously provided to the upper arms. The flexion of the knees and hips should further facilitate vibration conduction to the upper extremities by increasing the contact surface of the soft tissue and decreasing vibration absorption in the joints by limiting the range of motion of the joints, leading to an increase in vibration conduction to the upper extremities.

Posture C was associated with vibration conduction to the back that was 0.68 times and 0.66 times smaller than that for posture A at 15 and 30 Hz, respectively. This result may be explained simply by the position, since the vibration is sufficiently transmitted to the upper extremities when the subject is in a crouching position with direct contact between the knees and elbows.

No adverse effects were observed when performing the WBV exercise using posture C. Such a posture may result in fewer adverse effects, compared with a posture in which the upper arms are placed directly on the platform and the vibration is conducted to the subject's head, possibly resulting in a headache. Amir et al[16] reported a case report of benign paroxysmal positional vertigo after WBV training associated with nausea and vomiting. They mentioned that vibration training could displace the otoconia through vibration to the inner ear or labyrinthine trauma, leading to vertigo. In addition, if the arms are placed directly on the platform for a long period of time, blisters could occur, possibly limiting the duration of training. Bosco et al[21] reported that mechanical vibration applied during arm flexion under isometric conditions increased the mechanical power as an index of the neural efficiency in the arm flexors of elite boxers. In our experience, however, keeping the upper extremities in direct contact with the platform is difficult, unless the frequency is lowered. Although we did not measure the magnitude of vibration at the head, posture C may reduce the risk of headaches and conduct vibration to the upper extremities while enabling a longer duration of WBV exercise.

This study had notable limitations. First, the sample size was relatively small and the power calculation was not done. Second, the training time was short (<20 seconds), so the efficacy of WBV exercise in the examined posture, ie, a crouching position with direct contact between the knees and elbows for improving the physical function of the upper and lower extremities as well as the safety of this posture remains uncertain. In particular, maintaining posture C may be challenging, especially for elderly adults. We need to investigate the training limits in terms of load and time. Ye et al[22] reported that since the effects of WBV appeared to differ depending on the frequency used, the optimal frequency should be determined for each position. While Rittweger et al[23] concluded that oxygen consumption was highest at 26 Hz and Moran et al[24] claimed that muscle destruction was seen at 65 Hz, leading to muscle fatigue, the ideal frequency for WBV remains to be determined. In this study, there were some discrepancies in the magnitude of vibration and the vibration conduction results between 15 and 30 Hz, and the reasons for these discrepancies remain uncertain. Thus, further studies are needed to clarify the effect of WBV exercise, performed in the position described above with various loads and times, on the physical function of the upper and lower extremities, in a sufficient number of subjects. Even though we have mentioned the possibility of an effective posture for training the upper and lower extremities simultaneously, since we did not measure the muscle strength and the training period was very short, further measurements of muscle strength before and after a certain amount of training are needed to confirm its effect.

Conclusion

This study revealed that a crouching position on a WBV platform with direct contact between the knees and elbows was effective for conducting vibration from the lower to the upper extremities. Thus, such a posture could be an option for training the upper and lower extremities simultaneously while performing WBV exercise. However, further studies are needed to confirm the effect of WBV exercise using such a posture on the physical function of the upper and lower extremities.

Disclosure

The authors report no conflicts of interest in this work.

References

1. Wang HH, Chen WH, Liu C, et al. Whole-body vibration combined with extra-load training for enhancing the strength and speed of track and field athletes. *J Strength Cond Res*. 2014;28(9): 2470–2477.
2. Cochrane DJ, Stannard SR. Acute whole body vibration training increases vertical jump and flexibility performance in elite female field hockey players. *Br J Sports Med*. 2005;39(11):860–865.
3. Costantino C, Gimigliano R, Olvirri S, Gimigliano F. Whole body vibration in sport: a critical review. *J Sports Med Phys Fitness*. 2014; 54(6):757–764.
4. Chanou K, Gerodimos V, Karatrantou K, Jamurtas A. Whole-body vibration and rehabilitation of chronic diseases: a review of the literature. *J Sports Sci Med*. 2012;11(2):187–200.
5. Murillo N, Valls-Sole J, Vidal J, Opisso E, Medina J, Kumru H. Focal vibration in neurorehabilitation. *Eur J Phys Rehabil Med*. 2014;50(2):231–242.
6. Sitjà-Rabert M, Rigau D, Fort Vanmeerghaeghe A, Romero-Rodríguez D, Bonastre Subirana M, Bonfill X. Efficacy of whole body vibration exercise in older people: a systematic review. *Disabil Rehabil*. 2012; 34(11):883–893.
7. Lam FM, Lau RW, Chung RC, Pang MY. The effect of whole body vibration on balance, mobility and falls in older adults: a systematic review and meta-analysis. *Maturitas*. 2012;72(3):206–213.
8. Rogan S, Hilfiker R, Herren K, Radlinger L, de Bruin ED. Effects of whole-body vibration on postural control in elderly: a systematic review and meta-analysis. *BMC Geriatr*. 2011;11:72.
9. Goetz CG. Jean-Martin Charcot and his vibratory chair for Parkinson disease. *Neurology*. 2009;73(6):475–478.
10. Cochrane DJ. Vibration exercise: the potential benefits. *Int J Sports Med*. 2011;32(2):75–99.
11. Rittweger J, Just K, Kautzsch K, Reeg P, Felsenberg D. Treatment of chronic lower back pain with lumbar extension and whole-body vibration exercise: a randomized controlled trial. *Spine (Phila Pa 1976)*. 2002;27(17):1829–1834.
12. Iwamoto J, Takeda T, Sato Y, Uzawa M. Effect of whole-body vibration exercise on lumbar bone mineral density, bone turnover, and chronic back pain in post-menopausal osteoporotic women treated with alendronate. *Aging Clin Exp Res*. 2005;17(12):157–163.
13. Zafar H, Alghadir A, Anwer S, Al-Eisa E. Therapeutic effects of whole body vibration training in knee osteoarthritis: a systematic review and meta-analysis. *Arch Phys Med Rehabil*. 2015;96(8):1525–1532.
14. Gómez-Cabello A, Ara I, González-Agüero A, Casajús JA, Vicente-Rodríguez G. Effects of training on bone mass in older adults: a systematic review. *Sports Med*. 2012;42(4):301–325.
15. Cardinale M, Wakeling J. Whole-body vibration exercise: are vibrations good for you? *Br J Sports Med*. 2005;39(9):585–589.
16. Amir I, Young E, Belloso A. Self-limiting benign paroxysmal positional vertigo following use of whole-body vibration training plate. *J Laryngol Otol*. 2010;124(7):796–798.
17. Albasini A, Krause M, Rembitzki I. *Using Whole Body Vibration in Physical Therapy and Sport: Clinical Practice and Treatment Exercises*. 1st ed. London, UK: Churchill Livingstone; 2010.
18. Rauch F, Sievanen H, Boonen S, et al; International Society of Musculoskeletal and Neuronal Interactions. Reporting whole-body vibration intervention studies: recommendations of the International Society of Musculoskeletal and Neuronal Interactions. *J Musculoskelet Neuronal Interact*. 2010;10(3):193–198.
19. Abercromby AF, Amonette WE, Layne CS, McFarlin BK, Hinman MR, Paloski WH. Vibration exposure and biodynamic responses during whole-body vibration training. *Med Sci Sports Exerc*. 2007;39(10): 1794–1800.
20. Avelar NC, Ribeiro VG, Mezêncio B, et al. Influence of the knee flexion on muscle activation and transmissibility during whole body vibration. *J Electromyogr Kinesiol*. 2013;23(4):844–850.
21. Bosco C, Cardinale M, Tsarpela O. Influence of vibration on mechanical power and electromyogram activity in human arm flexor muscles. *Eur J Appl Physiol Occup Physiol*. 1999;79(4):306–311.
22. Ye J, Ng G, Yuen K. Acute effects of whole-body vibration on trunk muscle functioning in young healthy adults. *J Strength Cond Res*. 2014;28(10):2872–2879.
23. Rittweger J, Ehrig J, Just K, Mutschelknauss M, Kirsch KA, Felsenberg D. Oxygen uptake in whole-body vibration exercise: influence of vibration frequency, amplitude and external load. *Int J Sports Med*. 2002;23(6): 428–432.
24. Moran K, McNamara B, Luo J. Effect of vibration training in maximal effort (70% 1RM) dynamic bicep curls. *Med Sci Sports Exerc*. 2007; 39(3):526–533.