Acute Effects of Whole-Body Vibration on Jump Force and Jump Rate of Force Development: A Comparative Study of Different Devices

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Abstract

Bagheri, J, van den Berg-Emons, RJ, Pel, JJ, Horemans, HL, and Stam, HJ. Acute effects of whole-body vibration on jump force and jump rate of force development: A comparative study of different devices. *J Strength Cond Res* 26(3): 691–696, 2012—The goal of this study was to compare the acute effects of whole-body vibration (WBV) delivered by 3 devices with different mechanical behavior on jump force (JF) and jump rate of force development (JRFD). Twelve healthy persons (4 women and 8 men; age 30.5 ± 8.8 years; height 178.6 ± 7.3 cm; body mass 74.8 ± 9.7 kg) were exposed to WBV for 15 and 40 seconds using 2 professional devices (power plate [PP; vertical vibration] and Galileo 2000 [GA; oscillatory motion around the horizontal axis in addition to vertical vibration]) and a home-use device [Power Maxx, PM; horizontal vibration]). The JF and JRFD were evaluated before, immediately after, and 5 minutes after WBV. The JF measured immediately after 40 seconds of vibration by the GA device was reduced (3%, $p = 0.05$), and JRFD measured after 5 minutes of rest after 40 seconds of vibration by the PM device was reduced (12%, $p < 0.05$) compared with the baseline value. The acute effects of WBV (15 or 40 seconds) on JF and JRFD were not significantly different among the 3 devices. In conclusion, our hypothesis that WBV devices with different mechanical behaviors would result in different acute effects on muscle performance was not confirmed.

Key Words countermovement jump, force plate, muscle performance

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Introduction

Whole-body vibration (WBV) is a relatively new approach to train the muscular system of the human body (4,9–11). Whole-body vibration initiates a rapidly and repeating eccentric-concentric action, which brings about muscular work and an elevation in metabolic rate (26). Whole-body vibration is applied through a vibrating surface that supports the person. Whole-body vibration studies are usually performed with the user standing on a motor-driven vibrating plate. The machine mainly affects the muscles that transmit the vibrations to the body via the upright position (24). Based on previous studies, WBV is a safe and tolerable method for improving muscle performance (4,13,19,30–32).

It has been suggested that WBV exercises muscles primarily through the activation of the tonic vibration reflex (TVR) (8,21,27). Applying a vibratory stimulus to the body, all sensory receptors within the epidermis, dermis, joint capsules, and muscles (Ia afferents) will be stimulated, and thereby, the stretch reflex will be activated. The magnitude of muscle activation during vibration is determined by Ia-afferent sensitivity (2,8). Both excitation and inhibition of the stretch reflex during vibration have been reported (8,10,15,21).

However, the effects of WBV on muscle performance are not conclusive (5,10,13,22,31). In athletes, results ranged from no effect to a favorable effect on muscle performance (6,10,12,17,28). In the elderly, improvement in muscle performance was almost always reported (1,3,7,33). Favorable effects on the neuromuscular system were also reported in patients with Parkinson's disease (18), multiple sclerosis (29), stroke (32), and cystic fibrosis (25).

The observed variation in the effects of WBV on muscle performance might partly be explained by differences in the mechanical behavior of WBV devices (23). The GA and PP are professional devices that have been used in many studies. A simpler and less costly device is the Power Maxx (PM), which is designed for home use. Galileo creates an oscillatory motion around the horizontal axis in addition to vertical

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vibration, whereas PP creates only a vertical vibration, and PM vibrates primarily in the horizontal plane (23). We hypothesized that these technical differences between the WBV devices could affect the effects of WBV on muscle performance. Effects of differences in device mechanical behavior on muscle performance would most likely be observable directly after vibration. Hence, the goal of this study was to determine whether there are differences among these vibration devices in terms of acute effects on muscle performance.

Methods

Experimental Approach to the Problem

Within 2 weeks and on separate days, each participant was exposed to 6 different WBV interventions (3 different devices with for each device 2 different durations of intervention, Table 1). At the start of each session, the participants warmed up for 3 minutes by pedaling a stationary cycle. After that, 3 maximum vertical countermovement jumps were performed. Sets of 3 jumps were also performed immediately after and 5 minutes after the vibration intervention. During the 5-minute period after the intervention, the participants rested sitting on a chair (Table 2).

To evaluate the acute effect of the different devices (independent variable) on muscle performance, we measured jump force (JF, dependent variable) and jump rate of force development (JRFD, dependent variable) by force plate measurements.

Subjects

Twelve healthy volunteers were recruited (4 women and 8 men, age 30.5 ± 8.8 years, height 178.6 ± 7.3 cm, and body mass 74.8 ± 9.7 kg). Five of these participants were recreationally trained (participating in a variety of recreational sports and exercise for about 2 h·wk^{-1}), and 7 were athletes (participating in regular sports and exercise for 8 h·wk^{-1}). Each subject read and signed a University Institutional Review Board (Erasmus MC)–approved informed consent form before participation.

Table 1. Whole-body vibration devices and specifications for intervention sessions.*†

Device	Frequency (Hz)	Displacement (mm) (peak to peak)	α_{RMS} (units of g‡)	Duration (s)
GA	24	2.6 ± 0.1	5.5	40
	24	2.6 ± 0.1	5.5	15
PP	30	2.2 ± 0.1	3.3	40
	30	2.2 ± 0.1	3.3	15
PM	28	0.6 ± 0.02	0.4	40
	28	0.6 ± 0.02	0.4	15

*PP = Power Plate; GA = Galileo 2000; PM = Power Maxx.
†Results are expressed as mean ± *SD*.
‡1g = 9.81 m·s^{-2}.

Table 2. Sequence of measurements in each WBV session.*

3-min stationary cycling	First set of 3 jumps	WBV intervention	Second set of 3 jumps	5-min rest on a chair	Third set of 3 jumps

*WBV = whole-body vibration.

Figure 1. Whole-body vibration devices: Power Plate (PP), Galileo 2000 (GA), and Power Maxx (PM).

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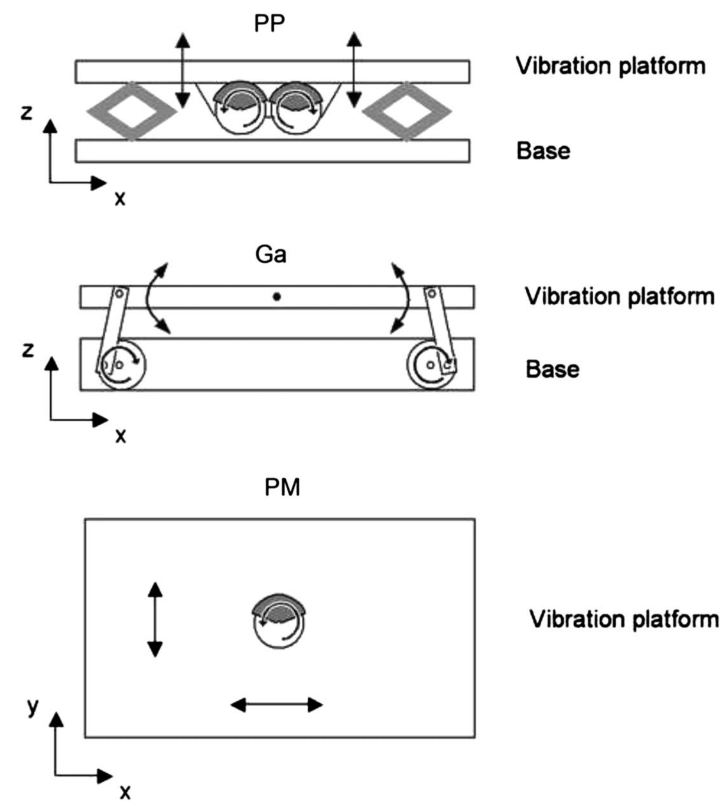

Figure 2. Different directions of vibration in whole-body vibration devices: Power Plate (PP), Galileo 2000 (GA), and Power Maxx (PM).

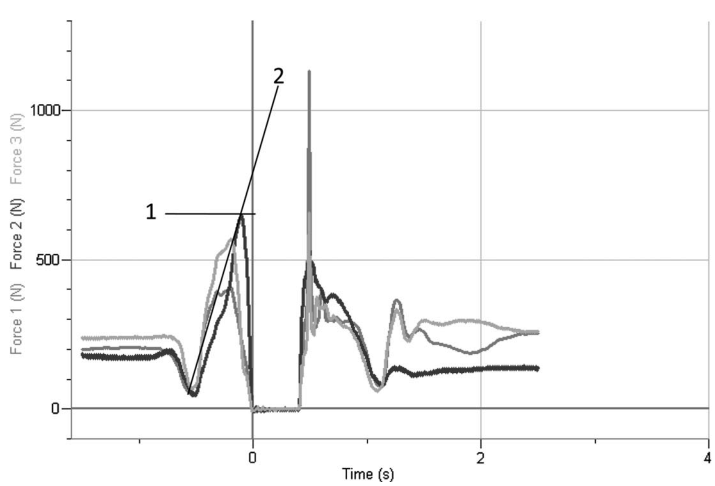

Figure 3. A typical trace for the calculation of the jump parameters based on 3 jumps. 1 = maximum value is peak jump force (JF); 2 = by this line jump rate of force development (JRFD) is calculated.

Candidates were excluded if they had recent or possible thrombosis, severe headache, vestibular disorder, advanced arthritis, lower limb implant, synthetic implant (e.g., pacemaker), lumbar disc disorder, vertebral discopathy, acute systemic infection or inflammation, medication that could interfere with postural control, pregnancy, recent fracture, gall bladder or kidney stone, or malignancy.

Procedures

We used 3 WBV devices with different mechanical behaviors (Figure 1). The PP and GA vibrate in near-perfect vertical sine waves at 25- to 50- and 5- to 40-Hz frequencies (Figure 2). The PP creates only vertical vibrations, and every point on the platform has the same motional property. The GA creates an oscillatory motion around the *x*-axis in addition to vertical vibration. Unlike PP, points on the GA platform have different motional properties; oscillatory effects depend on both the distance between the feet and the position of the axial axis. In a previous study, we showed that, for both devices, platform loading does not influence mechanical behavior (23). The platform of the PM vibrates primarily in the horizontal plane at 22–34 Hz, with minimal vertical acceleration (maximum ~20 $m \cdot s^{-2}$). Loading the PM platform can increase vertical accelerations. Vertical accelerations are highest in the GA (maximally ~130 $m \cdot s^{-2}$) and PP (maximally ~70 $m \cdot s^{-2}$) devices (23).

The interventions consisted of exposure to WBV provided by one of the devices for either 15 or 40 seconds. Because experts from Power Plate and Galileo advised different durations (15 and 40 seconds,

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Table 3. Comparison of jump values measured before and immediately after exposure to WBV for different devices and exposure durations in 12 healthy subjects.*†

Parameters		15 s of WBV			40 s of WBV		
		Before	After	p	Before	After	p
PM	JF	1.92 ± 0.28	1.88 ± 0.32	0.16	1.92 ± 0.28	1.90 ± 0.31	0.24
	JRFD	9.38 ± 4.52	10.70 ± 6.71	0.21	10.57 ± 4.61	11.39 ± 4.61	0.21
PP	JF	1.85 ± 0.26	1.89 ± 0.31	0.68	1.91 ± 0.28	1.83 ± 0.26	0.23
	JRFD	9.68 ± 4.35	11.26 ± 6.21	0.11	10.32 ± 4.91	10.52 ± 5.61	0.83
GA	JF	1.94 ± 0.25	1.91 ± 0.25	0.07	1.95 ± 0.27	1.90 ± 0.32	0.05
	JRFD	10.22 ± 4.61	10.37 ± 4.71	0.82	10.26 ± 4.81	11.02 ± 5.51	0.25

*WBV = whole-body vibration; JF = jump force in kilonewtons; JRFD = jump rate force development in kilonewtons per second; PM = power maxx; PP = power plate; GA = Galileo.

†Results are expressed as the mean of the 3 jump measurements ± *SD*.

respectively) to activate the TVR physiologically, we decided to use both durations. The order of the interventions for each participant was randomly determined. The participants stood on the platform with bare feet, with 90° knee flexion and a straight trunk. They kept their balance by holding the device handle with their hands. During this study, comparable platform frequencies were chosen for all 3 devices. In Table 1, the physical properties are summarized for each platform used, that is, the platform frequencies, average platform displacements (peak-to-peak), average platform accelerations in units of g (= 9.81 m·s^{-2}) and the applied duration of vibration in each subject.

To perform the jump measurements, the participants stood on a force plate (including 2 plates; 30 × 60 cm; Novotec, Pforzheim, Germany) with their bare feet parallel to each other and hands on their waist. They were instructed to jump as quickly and as high as possible. Before the very first jump, the participants did one practice jump to become familiar with the procedure. To reduce the variability of the jump performance, sets of 3 jumps were performed before the WBV intervention, immediately after and 5 minutes after the intervention. The variation of the jump measurement was evaluated by the coefficient of variation (based on jumps before the WBV intervention). Vertical (*Z*-plane) ground reaction force was collected on the force plate sampled at 100 Hz using an external A/D converter and was analyzed offline using customized software. The JF and JRFD were calculated for every jump and were averaged over a set of 3 jumps. The JRFD was defined as the peak slope of the force-time curve generated (Figure 3).

Statistical Analyses

Analysis of variance (ANOVA) was used to compare devices for effects on JF and JRFD. In addition, paired-samples *t* tests were used to compare JF and JRFD measurements from before the WBV intervention with data acquired (a) immediately after

Table 4. Comparison of jump values measured before and 5 minutes after the exposure to WBC for different devices and exposure durations in 12 healthy subjects.*†

Parameters		15 s of WBV			40 s of WBV		
		Before	After	p	Before	After	p
PM	JF	1.92 ± 0.28	1.91 ± 0.25	0.95	1.92 ± 0.28	1.91 ± 0.28	0.88
	JRFD	9.38 ± 4.52	9.93 ± 5.21	0.19	10.57 ± 4.61	9.31 ± 4.42	0.03
PP	JF	1.85 ± 0.26	1.83 ± 0.29	0.48	1.91 ± 0.28	1.90 ± 0.24	0.62
	JRFD	9.68 ± 4.35	9.86 ± 0.44	0.72	10.32 ± 4.91	10.19 ± 4.71	0.81
GA	JF	1.94 ± 0.25	1.88 ± 0.25	0.09	1.95 ± 0.27	1.91 ± 0.25	0.28
	JRFD	10.22 ± 4.61	9.52 ± 4.62	0.06	10.26 ± 4.81	10.13 ± 5.34	0.75

*WBV = whole-body vibration; JF = jump force in kilonewtons; JRFD = jump rate force development in kilonewtons per second; PM = power maxx; PP = power plate; GA = Galileo.

†Results are expressed as the mean of 3 jump measurements ± *SD*.

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WBV and (b) after 5 minutes of rest after WBV. In all statistical analyses, we considered the average of 3 jumps in each set. Two-tailed p values ≤ 0.05 were taken as significant. Data were analyzed with SPSS 16.0.1 for Windows.

Results

All the 12 participants completed the sessions successfully. There were no reports of adverse effects of exposure to WBV, although 3 of the participants declared having a temporary (10 seconds) tingling sensation in their toes after the WBV intervention.

Table 3 compares the JF and JRFD data gathered before and immediately after exposure to WBV, stratified by device and duration of exposure. The ANOVA showed no significant differences among the 3 devices for both JF and JRFD. In general, JF tended to be lower after the intervention, but only the decrease after 40 seconds of vibration (GA) was statistically significant. The JRFD tended to increase immediately after the intervention, but the effects were not statistically significant. Coefficient of variation for JF was 5.93%, and for JRFD it was 21.88%.

Table 4 compares the JF and JRFD data collected before exposure and after 5 minutes of rest after exposure to WBV. No significant differences were found among the devices in terms of effects on JF and JRFD. The JF tended to be lower after exposure to WBV plus 5 minutes' rest, but none of the differences were significant. After 40 seconds of vibration, a significant effect on JRFD after 5 minutes of rest was obtained with the PM device (a reduction of 12%, $p < 0.05$).

Discussion

To our knowledge, this is the first study to compare the acute effects of different WBV devices on muscle performance. We expected that, because the devices generate vibration in different directions (Figure 2), they would exert different effects on muscle performance (23). However, we found that the exposure to WBV produced by these different devices did not have significantly different acute effects on JF and JRFD. Therefore, our hypothesis was not confirmed.

Exposure durations in this study (15 and 40 seconds) were short compared with exposure durations reported in previous studies (4–10 minutes) (6,14,31). Therefore, it is difficult to compare our results with those of the earlier studies. Because it has been reported that short exposures to vibration can activate TVR physiologically (16), we chose relatively short exposures to avoid excessive muscle fatigue.

In our study, compared with pre-WBV values, JF tended to be lower immediately after exposure to WBV, and JRFD tended to be higher. It is interesting to know why short exposure to a single bout of WBV affected JF and JRFD in opposite directions. Reduction of JF might be related to the inhibitory effects of vibration on recruitment of motor units. In this context, electromyography studies of leg muscle have shown increased signals after exposure to WBV of only 10–20% of maximal values, which is not adequate to recruit additional muscle fibers during WBV (26). The JRFD increased likely because of the firing rate of motor units in the initial few seconds of exposure to WBV.

In line with our findings on JF, de Ruiter et al. (14) found a reduced jump height 10 seconds after vibration, which returned to baseline values by 15 minutes. In contrast, Bosco et al. (5) found increased leg-extension power and jump height immediately after a single WBV training session. However, both the subjects and the interventions in their studies were different from ours. Thus, there is no consensus on the effect of WBV on JF, and further research is needed.

There are a number of possible explanations as to why we did not detect a clear favorable effect of WBV on JF and JRFD. First, motor neuron recruitment in response to direct muscle tendon vibration is rather limited, probably because vibration also elicits a certain level of presynaptic Ia inhibition, which brakes the further recruitment of motor neurons (14). Second, during WBV, the vibration is applied to the soles of the feet, and each foot joint will have a dampening effect on the vibration stimulus in the distal to proximal direction of the leg (14). Additionally, WBV causes the reciprocal inhibition of antagonist muscles. During WBV, agonist and antagonist muscles are simultaneously impacted, which may further enhance the inhibitory effects of vibration (14,20).

Our study has 2 potential limitations: First, we could not apply equal amplitudes and frequency settings for the 3 devices because of their different designs. However, we attempted to choose the most comparable device settings. Second, we are aware that the study sample was relatively small. However, the results do not suggest that a larger sample would result in different conclusions.

Practical Applications

In contrast to what we expected, there were no significant differences in acute effects of WBV on JF and JRFD among devices with different mechanical behaviors. Furthermore, there were only minor acute effects. Long-term effects of training programs by using WBV devices have to be evaluated in longitudinal studies. The findings of this study imply that as yet, to improve muscle performance, both professional devices and the home-use device may be used. This is an important finding, because home-use devices have the advantage that they are considerably less costly than professional devices are and that they can be used in the natural surroundings (more time efficient). However, one should realize that loading the PM platform can increase vertical accelerations; this makes the device less suitable for scientific purposes.

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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. Bogaerts, A, Verschueren, S, Delecluse, C, Claessens, AL, and Boonen, S. Effects of whole body vibration training on postural control in older individuals: A 1 year randomized controlled trial. *Gait Posture* 26: 309–316, 2007.
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, 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.
6. Bosco, C, Iacovelli, M, Tsarpela, O, Cardinale, M, Bonifazi, M, Tihanyi, J, Viru, M, Delorenzo, A, and Viru, A. Hormonal responses to whole-body vibration in men. *Eur J Appl Physiol* 81: 449–454, 2000.
7. Bruyere, O, Wuidart, MA, Di Palma, E, Gourlay, M, Ethgen, O, Richy F, and Reginster, JY. Controlled whole body vibration to decrease fall risk and improve health-related quality of life of nursing home residents. *Arch Phys Med Rehabil* 86: 303–307, 2005.
8. Cardinale, M and Bosco, C. The use of vibration as an exercise intervention. *Exerc Sport Sci Rev* 31: 3–7, 2003.
9. Cardinale, M and Rittweger, J. Vibration exercise makes your muscles and bones stronger: Fact or fiction? *J Br Menopause Soc* 12: 12–18, 2006.
10. Cochrane, DJ, Legg, SJ, and Hooker, MJ. The short-term effect of whole-body vibration training on vertical jump, sprint, and agility performance. *J Strength Cond Res* 18: 828–832, 2004.
11. 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.
12. 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.
13. Delecluse, C, Roelants, M, and Verschueren, S. Strength increase after whole-body vibration compared with resistance training. *Med Sci Sports Exerc* 35: 1033–1041, 2003.
14. 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.
15. Desmedt, JE and Godaux, E. Mechanism of the vibration paradox: Excitatory and inhibitory effects of tendon vibration on single soleus muscle motor units in man. *J Physiol* 285: 197–207, 1978.
16. Dolny, DG and Reyes, GF. Whole body vibration exercise: Training and benefits. *Curr Sports Med Rep* 7: 152–157, 2008.
17. Fernandez-Rio, J, Terrados, N, Fernandez-Garcia, B, and Suman, OE. Effects of vibration training on force production in female basketball players. *J Strength Cond Res* 24: 1373–1380, 2010.
18. Haas, CT, Turbanski, S, Kessler, K, and Schmidtbleicher, D. The effects of random whole-body-vibration on motor symptoms in Parkinson's disease. *NeuroRehabilitation* 21: 29–36, 2006.
19. Kawanabe, K, Kawashima, A, Sashimoto, I, Takeda, T, Sato, Y, and Iwamoto, J. Effect of whole-body vibration exercise and muscle strengthening, balance, and walking exercises on walking ability in the elderly. *Keio J Med* 56: 28–33, 2007.
20. Martin, BJ, Roll, JP, and Gauthier, GM. Spinal reflex alterations as a function of intensity and frequency of vibration applied to the feet of seated subjects. *Aviat Space Environ Med* 55: 8–12, 1984.
21. Martin, BJ, Roll, JP, and Gauthier, GM. Inhibitory effects of combined agonist and antagonist muscle vibration on H-reflex in man. *Aviat Space Environ Med* 57: 681–687, 1986.
22. Nordlund, MM and Thorstensson, A. Strength training effects of whole-body vibration? *Scand J Med Sci Sports* 17: 12–17, 2007.
23. Pel, JJ, Bagheri, J, van Dam, LM, van den Berg-Emons, HJ, Horemans, HL, Stam, HJ, and van der Steen, J. Platform accelerations of three different whole-body vibration devices and the transmission of vertical vibrations to the lower limbs. *Med Eng Phys* 31: 937–944, 2009.
24. Rauch, F, Sievanen, H, Boonen, S, Cardinale, M, Degens, H, Felsenberg, D, Roth, J, Schoenau, F, Verschueren, S, Rithweger, J, and International Society of Musculoskeletal and Neural Interactions. Reporting whole-body vibration intervention studies: Recommendations of the International Society of Musculoskeletal and Neuronal Interactions. *J Musculoskelet Neuronal Interact* 10: 193–198, 2010.
25. Rietschel, E, van Koningsbruggen, S, Fricke, O, Semler, O, and Schoenau, E. Whole body vibration: A new therapeutic approach to improve muscle function in cystic fibrosis? *Int J Rehabil Res* 31: 253–256, 2008.
26. Rittweger, J, Beller, G, and Felsenberg, D. Acute physiological effects of exhaustive whole-body vibration exercise in man. *Clin Physiol* 20: 134–142, 2000.
27. Roelants, M, Delecluse, C, Goris, M, and Verschueren, S. Effects of 24 weeks of whole body vibration training on body composition and muscle strength in untrained females. *Int J Sports Med* 25: 1–5, 2004.
28. Rønnestad, 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.
29. Schuhfried, O, Mittermaier, C, Jovanovic, T, Pieber, K, and Paternostro-Sluga, T. Effects of whole-body vibration in patients with multiple sclerosis: A pilot study. *Clin Rehabil* 19: 834–842, 2005.
30. Torvinen, S, Kannus, P, Sievanen, H, Jarvinen, TA, Pasanen, M, Kontulainen, S, Jarvinen, TL, Jarvinen, M, Oja, P, and Vuori, I. Effect of four-month vertical whole body vibration on performance and balance. *Med Sci Sports Exerc* 34: 1523–1528, 2002.
31. Torvinen, S, Sievanen, H, Jarvinen, TA, Pasanen, M, Kontulainen, S, and Kannus, P. Effect of 4-min vertical whole body vibration on muscle performance and body balance: A randomized cross-over study. *Int J Sports Med* 23: 374–379, 2002.
32. van Nes, IJ, Latour, H, Schils, F, Meijer, R, van Kuijk, A, and Geurts, AC. Long-term effects of 6-week whole-body vibration on balance recovery and activities of daily living in the postacute phase of stroke: A randomized, controlled trial. *Stroke* 37: 2331–2335, 2006.
33. Verschueren, SM, Roelants, M, Delecluse, C, Swinnen, S, Vanderschueren, D, and Boonen, S.Effect of 6-month whole body vibration training on hip density, muscle strength, and postural control in postmenopausal women: A randomized controlled pilot study. *J Bone Miner Res* 19: 352–359, 2004.

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