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Original Article

Effects of whole-body vibration after eccentric exercise on muscle soreness and muscle strength recovery

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Abstract. [Purpose] The aim of this study was to investigate whether or not a single whole-body vibration treatment after eccentric exercise can reduce muscle soreness and enhance muscle recovery. [Subjects and Methods] Twenty untrained participants were randomly assigned to two groups: a vibration group (n=10) and control group (n=10). Participants performed eccentric quadriceps training of 4 sets of 5 repetitions at 120% 1RM, with 4 min rest between sets. After that, the vibration group received 3 sets of 1 min whole body vibration (12 Hz, 4 mm) with 30 s of passive recovery between sets. Serum creatine kinase, blood urea nitrogen, muscle soreness (visual analog scale) and muscle strength (peak isometric torque) were assessed. [Results] Creatine kinase was lower in the vibration group than in the control group at 24 h (200.2 ± 8.2 vs. 300.5 ± 26.1 U/L) and at 48 h (175.2 ± 12.5 vs. 285.2 ± 19.7 U/L) post-exercise. Muscle soreness decreased in vibration group compared to control group at 48 h post-exercise (34.1 ± 11.4 vs. 65.2 ± 13.2 mm). [Conclusion] Single whole-body vibration treatment after eccentric exercise reduced delayed onset muscle soreness but it did not affect muscle strength recovery.
Key words: Eccentric exercise, Whole-body vibration, Recovery

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INTRODUCTION

Strength training involving repetitive eccentric exercises can cause muscle damage, resulting in muscle soreness, swelling and eventually reduction of muscle strength, especially when an athlete is unaccustomed to this type of muscle contraction[1–3)]. Previous studies have found significant increases in self-reported pain after performing eccentric exercises involving the elbow flexor[4)]. A reduction in explosive force and increase of muscle soreness have also been reported after 12 sets of 10 eccentric squats in active physical education students[5)]. This muscle damage is usually defined as delayed-onset muscle soreness (DOMS), and it appears between 8 to 20 hours after the exercise reaching its peak between 24 to 48 hours after the damage[6)]. In physiological terms, DOMS is characterized by a sensation of pain felt during movement or palpation of the affected muscle[7)]. Inflammation, increased serum creatine kinase (CK) levels, muscle force loss, and decrease in performance have also been observed during this period[8, 9)].

Recently, whole-body vibration (WBV) has been proposed as a recovery treatment for reducing muscle soreness and muscle force loss after exercise[10, 11)]. Rhea et al.[12)] reported that applying WBV after strenuous resistance training and repeated sprints is effective at reducing the potential pain after a training session. Similar results were found when WBV was applied before 6 sets of 10 maximal isokinetic eccentric contractions of the dominant-limb knee extensors[13)]. Also, the application of vibrations at a frequency of 30 Hz before 70%RM and 90%RM resistance exercises suppressed increases in the stress hormone epinephrine levels immediately after exercise[14)]. Therefore, WBV appears to be effective regardless

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of the exposure time to vibration or moment (i.e. before or after performing the eccentric exercise). Several mechanisms could explain the benefits of WBV as a recovery tool for DOMS. WBV may increase blood flow and oxygen delivery to the muscles[15, 16], and decrease the pain perception responses[17]. Additionally, WBV may avoid the disruption of muscle sarcomeres that occurs during eccentric exercises, and therefore prevent DOMS[18].

However, the evidence regarding the use of WBV to reduce DOMS is controversial and limited. While some authors have found WBV to positively influence DOMS[9, 19], others have concluded that the application of WBV after eccentric exercise does not alleviate the signs of muscle damage (levels of serum CK and muscle soreness) compared to other traditional ways of recovery (i.e. stretching exercise or massage)[8].

The large number of WBV training parameters (vibration type, frequency, amplitude, rest interval between bouts and body position)[20] together with limited existing research on the topic make it difficult to draw definitive conclusions on the effectiveness of WBV and the best recovery treatment to reduce DOMS signs. Furthermore, the aforementioned studies implemented protocols with several vibration sessions after exercise, but to date no research has analyzed if a single session of WBV after eccentric exercise is enough to reduce muscle damage and stimulate the recovery process. Therefore, the aim of this study was to examine whether or not a single whole-body vibration treatment after eccentric strength training can reduce muscle soreness and enhance muscle recovery.

SUBJECTS AND METHODS

The experiment was approved by the Committee of Biomedical Ethics of the University of Extremadura (Spain) on May 6th, 2014, whose chairman was Mr. Fernando Henao (dossier number 31/2014), and it was conducted in accordance with the principles of the Declaration of Helsinki.

Twenty-nine untrained university students signed up voluntarily for the study. Nine participants were excluded from the study because they did not want to provide blood samples (n=4), had some form of musculoskeletal problems (n=2) or participated in a fitness program more than once per week (n=3). As a result, 20 participants were randomly assigned to the vibration group (n=10) or the control group (n=10). The participants were asked to maintain their lifestyle, not to take any medication or nutritional supplements, and not to perform any exercise or sports activity during the period of the intervention. Each volunteer was informed of the experimental procedure. Informed consent was obtained from all the participants in the study.

The participants attended the laboratory on 4 occasions and had to complete all sessions at the same time each day. Five days before their eccentric training, all the participants performed a familiarization session involving the same kind of exercises to be performed in the subsequent training sessions. On the same day, peak quadriceps leg extension strength of 1 repetition maximum (1RM)[21] was set and the workload for the eccentric exercise at 120% 1RM was calculated. During the first experimental visit, before starting the eccentric exercise session, blood samples were collected and stored for subsequent analysis. Moreover, muscle soreness and peak isometric torque (PIT) were evaluated. Later, participants performed the eccentric strength training consisting of a 5-minute warm-up (30% of 1RM) and 4 sets of 5 repetitions at 120% 1RM, with 4 min rest between sets, on a quadriceps leg extension (Selection Med machine, Technogym, Spain). Movement was performed with both limbs in a neutral position and along a range of motion of 90°. Subjects were asked to complete each repetition with maximal effort and a slow controlled movement (2 s) during the eccentric phase. During the concentric phase of the movement, two assistants replaced the lift arm of the weight machine in the initial position using a mechanical jack, so participants did not make any effort during this phase. Five minutes. after performing the eccentric training, the participants received 3 sets of 1 min whole body vibration (12 Hz, 4 mm) with 30 s of passive recovery between each set (vibration group), or an identical protocol with the vibratory platform turned off (control group). No information about the potential effects of the vibration treatment was given to the participants to minimize psychological effects. An oscillating vibratory platform (Galileo Fitness, Novotec Medical, Germany) was used. All the participants were asked to stand on the platform barefoot in a static squat position with their knees bent 30° (full extension=0°), hands on hips, and trunk straight. Joint angle was measured with a goniometer (12-1001HR, Baseline, USA). The vibration protocol was chosen based on previous research that showed that using similar frequencies leads to improvements in muscle recovery[7, 12]. Assessments occurred immediately after the vibration, and at 24 h and 48 h post-exercise.

Body weight and height were measured in the first session using a portable measuring station (Seca 220, Germany).

Blood samples (5 ml) were collected to assess serum CK and blood urea nitrogen (BUN) concentrations. Samples were drawn from the antecubital vein at each measurement time point: pre-exercise, post-exercise, and 24 h and 48 h post-exercise. Before analysis, the serum was separated and frozen at −20°C. Serum concentrations were determined by a dry-chemistry automated multi-analyzer (Spotchem EZ SP-4430, Menarini diagnostics, UK) using standard Menarini test strips. The level of muscle soreness was evaluated using a 100-mm visual analogue scale (VAS), with 0 at the left endpoint representing no pain and 100 at the right endpoint representing extreme pain. All of the participants were asked to point to their level of perceived soreness on the VAS while they maintained a static squat position with their knees flexed at 30° for 5 s. Muscle strength was assessed by recording PIT through dominant-limb knee extensor testing on an isokinetic dynamometer (System 3, Biodex Medical Systems, USA). Participants performed two 5-s maximal isometric contractions at a knee joint angle of 45° (0° was considered as full extension), with a 1 min rest between each maximal effort. They were asked to generate maximal force as fast as possible when the signal was given. Finally, the highest PIT value of both measurements was recorded for analysis. Dynamometer calibration and protocol procedures were performed in accordance with the instructions provided by the manufacturer.

The statistical analysis was carried out with SPSS 19.0 computer software for Windows. The Kolmogorov-Smirnov test was conducted in order to verify the normality of the data distribution, and Levene's test was used to assess the homogeneity of variance. Comparisons between the intervention conditions (vibration vs control) over time for each variable were subjected to two-way repeated-measures ANOVA. Post hoc pairwise comparisons were performed using the Bonferroni test to identify significant differences within groups from pre-exercise values. Significance was accepted for $p \leq 0.05$, a confidence level of 95%. Means and standard deviations (SD) were used as descriptive statistics.

RESULTS

The general characteristics of participants are shown in Table 1. There were no significant differences between the study groups. Table 2 shows the values of muscle damage, muscle soreness and muscle strength at the different measurement times. Eccentric training elicited significant (≤0.05) increases in serum CK at 24 h and 48 h post-exercise in both groups, and VAS scores were also significantly higher at 24 h (both groups) and 48 h (control group only) after the eccentric training. Compared to the vibration group, the control group showed significant (≤0.05) increases in serum CK (at 24 h and 48 h post-exercise) and the VAS score (at 48 h post-exercise). No significant within or between group differences were found for BUN and PIT.

DISCUSSION

The participants' baseline data was in the normal range for healthy people, showing that the subjects were not fatigued and had not done any strenuous physical activity prior to the experiment. Therefore, the changes observed in the experiment resulted from the performance of the eccentric training.

Previous studies have reported that repetitive eccentric contractions can cause broadening or disruption of muscle sarcomeres[18)]. It is known that eccentric contractions may cause greater high-stress damage to recruited muscle fibers than concentric contractions[2)]. This muscle damage leads to inflammation, release of CK and an increased perception of muscle

Table 1. General characteristics of the participants

	Vibration group	Control group
Age (years)	24.2 ± 0.5	23.4 ± 1.4
Height (cm)	177.1 ± 11.5	175.6 ± 5.3
Weight (kg)	75.2 ± 11.5	73.2 ± 5.9
120% 1RM (kg)	123.0 ± 19.2	118.1 ± 18.8

Values are mean ± SD.

Table 2. Markers of muscle damage, muscle soreness and muscle strength

Variables	Pre	Post	24 h	48 h
Serum CK (U/l)				
Control	100.5 ± 4.7	108.0 ± 3.4	300.5 ± 26.1*	285.2 ± 19.7*
Vibration	90.7 ± 5.3	102.5 ± 5.6	200.2 ± 8.2*†	175.2 ± 12.5*†
BUN (mg/dl)				
Control	14.4 ± 3.2	14.9 ± 3.7	16.8 ± 3.7	15.4 ± 2.8
Vibration	16.3 ± 2.8	17.73 ± 2.3	19.6 ± 2.0	16.8 ± 2.8
VAS score (mm)				
Control	6.6 ± 11.5	36.6 ± 20.5	68.3 ± 15.1*	65.2 ± 13.2*
Vibration	6.0 ± 5.5	33.2 ± 16.4	54.4 ± 16.3*	34.1 ± 11.4†
PIT (Nm)				
Control	235.3 ± 53.7	205.7 ± 48.2	187.3 ± 49.0	189.1 ± 60.0
Vibration	225.4 ± 56.9	201.2 ± 62.1	172.6 ± 48.0	177.2 ± 55.6

Values are mean ± SD. BUN: blood urea nitrogen; VAS: Visual analog scale; PIT: peak isometric torque.
*$p \leq 0.05$, significant difference from pre-exercise.
†$p \leq 0.05$, significant difference between groups.

soreness for several days after the exercise[13, 22]. Similar results were evident in our present research, which found there were increased concentrations of serum CK and high pain VAS scores at 24 h and 48 h after eccentric exercise in both groups.

Analysis of the influence of WBV on the values of serum parameters related to muscle damage revealed that serum CK levels at 24 h and 48 h were lower in the vibration group than in the control group. Given that serum CK activity is defined as an index of muscle damage[23], these results indicate that the vibration group sustained less muscle damage after eccentric training than the control group. It was previously demonstrated that muscle blood volume and lymphatic flow increase with vibration treatment and that the magnitude of this increase is positively associated with vibratory load[15]. This rise in muscle perfusion may stimulate muscle recovery by improving oxygen delivery[16] and removing pain substrates[24]. To our knowledge, only two studies[8, 19] have investigated the effects of post-exercise vibration treatment on the reduction of serum CK concentrations after eccentric exercise in knee extensor muscles. Neither study observed variation in serum CK levels. Caution is necessary when making comparisons because the intervention protocols and the type of vibration (device, frequency and amplitude) were different. No significant differences were found within groups or between groups in BUN concentrations. Protein catabolism produces urea, which may be a useful biomarker for monitoring fatigue and overtraining[25]. However, Fallon[26] demonstrated that changes in serum urea are more useful for monitoring training status than for assessing short term fatigue, which may be the reason why there were no changes in BUN after eccentric training in this study.

VAS scores of the vibration group at 48 h were lower than those reported by the control group, indicating less muscle soreness. This result is supported by previous research, which noted that post-exercise vibration alleviated DOMS and provided an analgesic effect. Rhea et al.[12] reported an attenuation of pain ranging from 22–61% when untrained individuals received WBV. Similar results were found by Lau and Nosaka[22] for upper arm muscle soreness, with peak soreness being 18–30% less for the vibration group than for the control group at 2 to 5 days after eccentric exercise. The benefits of vibration treatment on pain have been reported in both clinical and experimental settings for several decades[27]. Muscle vibration activates afferent inputs from sensory units in the muscle[28], and the subsequent afferent activity in myelinated sensory axons may inhibit nociceptive messages, possibly at spinal segmental levels, modifying the pain sensation and elevating the pain threshold[29, 30].

Several studies have reported muscle strength loss following repetitive maximal eccentric contractions[8, 9]. However, no significant decrease in PIT values was observed in our present study. One possible explanation for these conflicting findings could be the type of eccentric training performed. The training performed in the present study consisted of few repetitions of very high intensity, whereas the aforementioned studies used workouts with a high volume (100 and 300 repetitions, respectively), so it is possible that muscle involvement and fatigue were different in these trials. Therefore, post-exercise WBV did not attenuate PIT values. These findings are similar to those obtained by other research that concluded that standing on a vibrating platform[9] or sitting on a vibrating cushion[8] after a session of eccentric exercise did not improve the recovery of the knee extensor's PIT. A limitation of our current study might be the choice of just one angle to evaluate muscle strength because PIT values could vary at different angles. Moreover, other serum markers such as lactate dehydrogenase, myoglobin, troponin or aspartate aminotransferase were not analyzed, and their analysis would have provided more information about muscle damage.

The findings of the present study show that a single post-exercise WBV following eccentric training alleviated muscle damage but did not attenuate muscle strength loss. Therefore, recreational athletes should know that their performance in training or competition could still be decreased at 48 hours after completing an intense eccentric training, regardless of being subjected to a post-exercise vibration treatment that attenuates DOMS. Further studies to establish the appropriate duration, frequency and amplitude of vibration are needed to investigate the effectiveness of a single post-exercise WBV in the improvement of muscle recovery after eccentric training.

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REFERENCES

1) Gatterer H, Peters P, Philippe M, et al.: The effect of pulsating electrostatic field application on the development of delayed onset of muscle soreness (DOMS) symptoms after eccentric exercise. J Phys Ther Sci, 2015, 27: 3105–3107. [Medline] [CrossRef]
2) Proske U, Allen TJ: Damage to skeletal muscle from eccentric exercise. Exerc Sport Sci Rev, 2005, 33: 98–104. [Medline] [CrossRef]
3) Nonaka K, Akiyama J, Tatsuta N, et al.: Cool water immersion after downhill running suppresses exercise-induced muscle damage in the rat soleus muscle. J Phys Ther Sci, 2012, 24: 613–616. [CrossRef]
4) Micklewright D: The effect of soft tissue release on delayed onset muscle soreness: a pilot study. Phys Ther Sport, 2009, 10: 19–24. [Medline] [CrossRef]
5) García-López D, de Paz JA, Jiménez-Jiménez R, et al.: Early explosive force reduction associated with exercise-induced muscle damage. J Physiol Biochem, 2006, 62: 163–169. [Medline] [CrossRef]
6) Yu JY, Jeong JG, Lee BH: Evaluation of muscle damage using ultrasound imaging. J Phys Ther Sci, 2015, 27: 531–534. [Medline] [CrossRef]

7) Lewis PB, Ruby D, Bush-Joseph CA: Muscle soreness and delayed-onset muscle soreness. Clin Sports Med, 2012, 31: 255–262. [Medline] [CrossRef]
8) Fuller JT, Thomson RL, Howe PR, et al.: Vibration therapy is no more effective than the standard practice of massage and stretching for promoting recovery from muscle damage after eccentric exercise. Clin J Sport Med, 2015, 25: 332–337. [Medline] [CrossRef]
9) Barnes MJ, Perry BG, Mündel T, et al.: The effects of vibration therapy on muscle force loss following eccentrically induced muscle damage. Eur J Appl Physiol, 2012, 112: 1189–1194. [Medline] [CrossRef]
10) Koh HW, Cho SH, Kim CY, et al.: Effects of vibratory stimulations on maximal voluntary isometric contraction from delayed onset muscle soreness. J Phys Ther Sci, 2013, 25: 1093–1095. [Medline] [CrossRef]
11) Kosar AC, Candow DG, Putland JT: Potential beneficial effects of whole-body vibration for muscle recovery after exercise. J Strength Cond Res, 2012, 26: 2907–2911. [Medline] [CrossRef]
12) Rhea MR, Bunker D, Marín PJ, et al.: Effect of iTonic whole-body vibration on delayed-onset muscle soreness among untrained individuals. J Strength Cond Res, 2009, 23: 1677–1682. [Medline] [CrossRef]
13) Aminian-Far A, Hadian MR, Olyaei G, et al.: Whole-body vibration and the prevention and treatment of delayed-onset muscle soreness. J Athl Train, 2011, 46: 43–49. [Medline] [CrossRef]
14) Kim SS, Ju SB, Park GD: Changes in stress hormone levels with the application of vibrations before resistance exercises at different intensities. J Phys Ther Sci, 2015, 27: 2845–2847. [Medline] [CrossRef]
15) Fuller JT, Thomson RL, Howe PR, et al.: Effect of vibration on muscle perfusion: a systematic review. Clin Physiol Funct Imaging, 2013, 33: 1–10. [Medline] [CrossRef]
16) Kerschan-Schindl K, Grampp S, Henk C, et al.: Whole-body vibration exercise leads to alterations in muscle blood volume. Clin Physiol, 2001, 21: 377–382. [Medline] [CrossRef]
17) Veqar Z, Imtiyaz S: Vibration Therapy in Management of Delayed Onset Muscle Soreness (DOMS). J Clin Diagn Res, 2014, 8: LE01–LE04. [Medline]
18) Stauber WT, Clarkson PM, Fritz VK, et al.: Extracellular matrix disruption and pain after eccentric muscle action. J Appl Physiol 1985, 1990, 69: 868–874. [Medline]
19) Broadbent S, Rousseau JJ, Thorp RM, et al.: Vibration therapy reduces plasma IL6 and muscle soreness after downhill running. Br J Sports Med, 2010, 44: 888–894. [Medline] [CrossRef]
20) Kim J, Park Y, Seo Y, et al.: The effects of whole-body vibration exercise on isokinetic muscular function of the knee and jump performance depending on squatting position. J Phys Ther Sci, 2016, 28: 159–161. [Medline] [CrossRef]
21) Seo DI, Kim E, Fahs CA, et al.: Reliability of the one-repetition maximum test based on muscle group and gender. J Sports Sci Med, 2012, 11: 221–225. [Medline]
22) Lau WY, Nosaka K: Effect of vibration treatment on symptoms associated with eccentric exercise-induced muscle damage. Am J Phys Med Rehabil, 2011, 90: 648–657. [Medline] [CrossRef]
23) Nosaka K, Clarkson PM: Changes in indicators of inflammation after eccentric exercise of the elbow flexors. Med Sci Sports Exerc, 1996, 28: 953–961. [Medline] [CrossRef]
24) Stewart JM, Karman C, Montgomery LD, et al.: Plantar vibration improves leg fluid flow in perimenopausal women. Am J Physiol Regul Integr Comp Physiol, 2005, 288: R623–R629. [Medline] [CrossRef]
25) Hartmann U, Mester J: Training and overtraining markers in selected sport events. Med Sci Sports Exerc, 2000, 32: 209–215. [Medline] [CrossRef]
26) Fallon KE: Clinical utility of blood tests in elite athletes with short term fatigue. Br J Sports Med, 2006, 40: 541–544, discussion 544. [Medline] [CrossRef]
27) Lundeberg T, Abrahamsson P, Bondesson L, et al.: Effect of vibratory stimulation on experimental and clinical pain. Scand J Rehabil Med, 1988, 20: 149–159. [Medline]
28) Shinohara M: Effects of prolonged vibration on motor unit activity and motor performance. Med Sci Sports Exerc, 2005, 37: 2120–2125. [Medline] [CrossRef]
29) Gay A, Parratte S, Salazard B, et al.: Proprioceptive feedback enhancement induced by vibratory stimulation in complex regional pain syndrome type I: an open comparative pilot study in 11 patients. Joint Bone Spine, 2007, 74: 461–466. [Medline] [CrossRef]
30) Zoppi M, Voegelin MR, Signorini M, et al.: Pain threshold changes by skin vibratory stimulation in healthy subjects. Acta Physiol Scand, 1991, 143: 439–443. [Medline] [CrossRef]