The effect of 8 weeks of whole body vibration training on static balance and explosive strength of lower limbs in physical education students

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Background: It has been shown that whole body vibration training has an effect on strength and balance in athletes of various sports. Objective: The purpose of the study was to examine the effect of 8 weeks of Whole Body Vibration (WBV) training on static balance and explosive strength of the lower limbs, using two different training intensities vibration protocols. Methods: Eighty-three physical education students (age 19.39 ± 2.35 years) volunteered to participate in an 8-week WBV training. They were randomly divided into two groups with 30 sec and 60 sec duration of vibration exposure per exercise, total volume of exercise was the same for both groups. The explosive strength of the lower limbs was assessed by a squat jump and static balance by Balance Error Scoring System at the baseline (pre-test) and after 8 weeks of WBV training at 15 sec, 5, 10, and 15 min after the end of WBV exposure. A two-way ANOVA 2 × 5 (protocol × time) with repeated measures on both factors was used. Univariate analyses with simple contrasts across time were selected as post hoc tests. Results: Results showed a time × protocol interaction effect for static balance (p < .001) but not for the squat jump (p > .05). Furthermore, a time effect was found for the static balance and squat jump test. The 60 sec protocol had a greater percentage improvement compared to the 30 sec protocol in static balance (p = .003), whereas the 30 sec protocol was superior to the 60 sec protocol in explosive strength. However, the differences between the two protocols were not significant. Conclusion: WBV training had positive effects on static balance and explosive strength in physical education students. Balance and jump performance may benefit from WBV training. Therefore, WBV may be an effective training method for the improvement of static balance and lower limb strength.

Keywords: muscle strength, postural stability, vibration exposure

Introduction

Whole Body Vibration (WBV) has been reported as an effective neuromuscular strength training method to improve athletic performance (Chen, Liu, Chuang, Chung, & Shiang, 2014; Preatoni et al., 2012) and is potentially a less demanding method of increasing power output than traditional training (Marin & Rhea, 2010). Previous data support the positive effect of WBV intervention training on explosive strength of the lower limbs (Dallas & Kirialanis, 2013; Dallas, Kirialanis, & Mellos, 2013; Wyon, Guinan, & Hawkey, 2010) and balance (Tsopani et al., 2014). The majority of the above studies referred to the general population, high level athletes and untrained individuals, whereas there is strong to moderate evidence that long-term WBV training has also yielded contradictory results regarding leg muscular performance. Some authors emphasize a positive effect in the explosive strength (Annino et al., 2007; Mahieu et al., 2006), whereas other studies found no significant changes (Delecluse, Roelants, Diels, Koninckx, & Verschueren, 2005; Sands, McNeal, Stone, Russell, & Jemni, 2006). It is mentioned that neuromuscular and neural adaptations determine the long-term effect of the training program (Martin & Park, 1997). Different time protocols were also studied. Carson, Popple, Verschueren, and Riek (2010) compared a 4-week WBV training program on countermovement
jump height to that without vibration supporting that no significant improvements between groups were found, whereas an 8-week WBV training revealed a significant jumping improvement from 6.4 to 11.9% on young adults with an average age of 20.3 years (Chen et al., 2014). Pérez-Turpin et al. (2014) studied 23 volleyball and beach volleyball athletes and concluded that after a 6-week WBV training their lower limb muscle strength and jumping ability is significantly improved compared to traditional strength training. Another 8-week training program was conducted by Preatoni et al. (2012) on female softball and soccer athletes and concluded that combining conventional strength training with WBV doesn’t improve the athletes’ strength. Annino et al. (2007) examined the effect of an 8-weeks WBV training program on 22 ballerinas and found an improvement on knee-extensor muscles although this was only short term. When comparing 14-week training programs of 31 female basketball athletes, both with and without vibration, Fernandez-Rio, Terrados, Fernandez-Garcia, and Suman (2010) concluded that there were no significant improvements between the two programs, even though there was strength increase. Most of the conflicting results are because of the difference in training protocols and training modes used. Studies examining the effect of WBV on balance are limited and refer to trained athletes (Fort, Romero, Bagur, & Guerra, 2012), untrained subjects (Torrinen et al., 2002b) or overweight/obese women. More specifically, Pollock, Provan, Martin, and Newham (2011) who examined the effect of WBV at two amplitudes on balance, joint position sense and cutaneous sensation in eighteen young healthy subjects found that neither amplitude affected joint position sense or static balance, but reduced cutaneous sensation. However, little is known about the effects of vibration training on static balance and explosive strength of physical education students who during their daily courses occupy themselves with sport activities. Furthermore, there are no scientific data comparing different training intensities (repetitions per set) during the same vibration exposure. The purpose of this study was, therefore, to investigate the effect of an 8-week WBV intervention on static balance and explosive strength of lower limbs of physical education students using two different training intensities of vibration protocols.

Methods

Subjects
Eighty-three female physical education students from the department of sport science who had not used WBV training before but who regularly participated in sports activities containing jumping and running (age 19.39 ± 2.35 years, mass 53.83 ± 2.71 kg, and height 165.21 ± 5.26 cm) volunteered to participate in this study. The participants were not involved in any organized physical activity or sports clubs but they were spending most of their time taking classes within the School of Physical Education and Sport Science, in the National and Kapodistrian University of Athens. Participants had no history of injury in the 3 months prior to testing, or pathology to either lower extremity. They were screened for preexisting visual, vestibular or balance disorders through self-reporting. Six subjects’ data were not used for the analysis because they did not complete all the sessions. The study was approved by the local institutional Review Board and all procedures were in alignment with the ethics of the University of Athens. The subjects were informed extensively about the experiment procedures and the possible risks or benefits of the project, and written consent was obtained. Also, subjects were asked to avoid any additional training throughout the period of the study and were randomly assigned to two groups (n1 = 39, age: 19.23 ± 3.18 years, body mass: 53.98 ± 2.87 kg, height: 165.92 ± 5.26 cm; and n2 = 38, age: 19.55 ± 0.55 years, body mass: 53.68 ± 2.55 kg, height: 164.47 ± 5.23 cm) depending on the duration of the vibration exposure (30 or 60 sec). Three days prior to the study, a familiarization session and measurements of anthropometric characteristics were performed. Both groups exercised for 8 weeks on a vibration platform, following different sets and duration of exercises (Table 1).

Experimental procedure
All participants were exposed to vertical sinusoidal mechanical WBV while standing on the commercially available Power Plate Next Generation WVB platform (Performance Health Systems, Northbrook, IL, USA). The vibration was set at 30 Hz, which produced a peak-to-peak amplitude of 2.5 mm and an acceleration of 2.28 g. During all of the vibration-training session, the participants wore the same gymnastic shoes to standardize the damping of the vibration due to the footwear (Marin, Bunker, Phea, & Ayllon, 2009). All subjects were trained three days per week for 8 weeks on a vibration platform using the same volume of the semi-squat isometric exercise, but the number of sets and the duration of vibration exposure were modified. The duration of 30 sec was used in hope of improving the performance enhancement found by Cormie, Deane, Triplett, and McBride (2006). It was hypothesized that 60 sec WBV exposure would be equally effective as 30 sec WBV exposure. The training volume was increased systematically over the 8-week training period by increasing the number of sets of the exercises.
used. The number of sets increased after the end of 3rd and 6th week (Table 1). Each WBV training session was preceded by a 4 min warm up that included light aerobic exercises and stretching of knee extensor muscles. To provide a proper time for relaxation, the rest between the sets and exercises were 30 sec and 60 sec respectively. Both protocols were executed with subjects standing motionless in a semi squat position. In isometric exercise all participants were instructed to maintain a static semi squat position bending their knees at an angle of 120 degrees, which was standardized using a goniometer. The order of the trials was not randomized to avoid cross-contamination of the results.

Power analysis was conducted according to the findings of Wyon et al. (2010). Specifically, for an effect size of 1.13 repeated assessments, power of .80 and alpha level of .05, at total sample of eight participants was required to detect significant differences (Grimm, 1993).

### Measurements
All subjects were tested on two occasions, at the start baseline (pre-test), and after the end of 8-weeks of WBV training (post-test): within 15 sec (Post 1), 5 (Post 5), 10 (Post 10), and 15 minutes (Post 15) after the end of WBV exposure. The participants were informed about the test procedures and were asked to perform all these tests at maximum intensity. The order of the performances tests was counterbalanced. A familiarization session on Power Plate Next Generation WVb platform, on Balance Error Scoring System and measurements of anthropometric characteristics were performed one day before testing. All tests were performed randomly.

### Static balance
Postural stability was measured using Balance Error Scoring System (BESS) which assesses static balance with good validity (Riemann, Guskiewicz, & Shields, 1999) and good reliability (Bell, Guskiewicz, Clark, & Padua, 2011). The BESS comprises of 6 conditions: double-leg stance (hands on the hips and feet together), single-leg stance (standing on the non-dominant leg with hands on hips), and tandem stance (non-dominant leg behind the dominant foot) in a heel-to-toe fashion. The stances are performed, with eyes closed, on a firm surface and on a foam surface with errors counted during each 20 sec trial. The firm surface was a wooden floor and the foam surface was a 25 × 25 × 6.25 cm balance pad (Airex AG, Sins, Switzerland). Each of the 20 sec trials were scored by counting the errors, or the deviations from the proper stance. An error was credited to the participant when any of the following occurred: a) moving the hand off the iliac crests; b) opening the eyes; c) stepping, stumbling, or falling; d) abduction or flexion of the hip beyond 30°; e) lifting of the forefoot or heel off the testing surface; or f) remaining out of the test position for more than 5 sec (Riemann et al., 1999). Participants who were unable to follow the testing procedure for a minimum of 5 sec were assigned the highest score, ten, for that testing condition. The maximum total number of errors for any single condition was ten. Error scores were calculated for each of the 6 conditions and summed up to obtain the total BESS score. A full description of BESS and information regarding the test can be found in Riemann et al. (1999). Each participant was instructed to remain as still as possible; if they moved from the test position, participants had to return to it as soon as possible. The order of BESS testing was counterbalanced across the 6 conditions for each participant.

### Squat jump test
Explosive strength of the lower limbs was assessed using the squat jump (SJ) that was performed on a switch mat (Bosco, Luhtanen, & Komi, 1983) connected to a digital timer (accuracy ± 0.001 sec, Ergojump, Psion XP, MA.Gi.CA., Rome, Italy), which recorded the flight time of each single jump. The height of the jump was calculated from flight time (Bosco et al., 1998). Prior to testing, the participants underwent one familiarization trial to ensure the proper performance technique for this jump. For the squat jump test, the participants
were asked to reach and hold a semi-squat position (at 120 degrees) and maintain it for 2 sec until an acoustic signal was heard. We decided to select the semi-squat position due to the fact that the same position was applied during the 8-week vibration protocols. Participants then had to jump once, as high as possible, without performing any countermovement before jumping. The subjects jumped only when they had established the initial position measured by the goniometer. During SJ, the participants kept their trunk in an upright position and their hands on their hips. The participants were instructed to perform two maximal trials with a rest period of 30 sec and the best jump was considered for further statistical analysis.

Statistical analysis
A two-way ANOVA 2 × 5 (protocol × time) with repeated measures on both factors was used. The level of significance was set at $\alpha = .05$. Effect size is also reported through partial eta-squared ($\eta^2_p$). Values above .80 were considered large, .20 to .50 was medium and below .20 was small. Univariate analyses with simple contrasts across time were selected as post-hoc tests. The intraclass coefficients assess the reliability across time (Pre, Post 1, Post 5, Post 10, Post 15) for each protocol and dependent variable. Percent changes in all examined variables after the vibration protocols from baseline (pre) tests were calculated. Interclass reliability coefficients among measurements were .978–.985 for various protocols. All analyses were executed using the SPSS Statistics (Version 20; IBM, Armonk, NY, USA) statistical package.

Results
A time × protocol interaction effect was found for BESS ($F(4) = 2.845, p = .001, \eta^2_p = .136$). No significant interaction between protocol × time was found with respect to SJ ($F(4) = 2.391, p = .059, \eta^2_p = .117$).

A time effect was found for BESS test ($F(4) = 36.039, p = .001, \eta^2_p = .667$) (Figure 1) and SJ ($F(4) = 112.293, p = .001, \eta^2_p = .862$) (Figure 2).

The $r$-parameter estimates showed significant differences for BESS measurements (Table 2): Pre vs Post 1 ($F(4) = 14.034, p = .001, \eta^2_p = .158$), Post 1 vs Post 5 ($F(4) = 18.418, p = .001, \eta^2_p = .197$), Post 5 vs Post 10 ($F(4) = 13.161, p = .001, \eta^2_p = .667$), and Post 10 vs Post 15 ($F(4) = 136.347, p = .001, \eta^2_p = .645$), and for SJ measurements: Pre vs Post 1 ($F(4) = 225.606, p = .001, \eta^2_p = .751$), Post 1 vs Post 5 ($F(4) = 65.836, p = .001, \eta^2_p = .467$), and Post 10 vs Post 15 ($F(4) = 160.79, p = .001, \eta^2_p = .682$). Furthermore, significant differences were found on both protocols in post-test measurements with respect to baseline values for SJ ($p = .001$) and for BESS except for the Post 15 in 30 sec protocol (Table 2).

Discussion
The selection of these protocols was based on the desire to investigate whether 8 weeks of WBV training with two different WBV protocols could enhance static balance and explosive strength of the lower limbs of physical education students who incorporated these
Effect of vibration training on balance and strength

It is emphasized that our WBV protocols used static isometric exercises focusing on balance and neuromuscular control as subjects need to remain stable during the vibration exposure. The results showed significant improvement in static balance and explosive strength of lower limbs after carrying out an 8-week WBV training program. However, the improvement was not statistically significant between the two different training intensity protocols.

BESS

Our results showed that practicing for 8 weeks on a WBV platform for 30 sec at a time in a variety of series induced a 3.29% up to 48.17% increment after the vibration exposure, whereas the 60 sec group showed an increment 6.83% up to 53.46%. However, the differences between protocols were not statistically significant. Percentage improvement immediately after the end of vibration protocol was 12.38% and 23.15% for the 30 sec and 60 sec, respectively. Furthermore, the 60 sec protocol showed greater improvements in all post measurements (47.82%, 53.30% and 6.72% for the 5, 10 and 15 min, respectively) compared to 30 sec protocol (34.30%, 48.01%, and 3.18% for the 5, 10 and 15 min, respectively). The positive effect of WBV training found on the static balance of physical education students is in agreement with those of Fort et al. (2012) who examined elite female adolescent basketball players training for 15 weeks with improvements already observed after the first 8 weeks of WBV training, and those of other studies that examined untrained people (Bogaerts et al., 2007; Cheung et al., 2007). The improvement in static balance may be attributed to the fact that the central nervous system receives information from different neural receptors (proprioceptors, visual system, and vestibular system) to control neuromuscular responses. Whole-body vibration training focuses especially on the neuromuscular spindle that is activated by the tonic vibration reflex (Cardinale, Leiper, Erskine, Milroy, & Bell, 2006; Luo, McNamara, & Moran, 2005). Furthermore, the author suggests that WBV could be a useful tool to improve the proprioceptive system after anterior cruciate ligament reconstruction as there is strong evidence that following WBV training, knee proprioception and postural stability improve significantly. Furthermore, the chronic effect of training, as Martin and Park (1997) stated, is probably achieved by neuromuscular and neural adaptations.

Squat jump

The results of our study showed that practicing for 8 weeks on a WBV platform and for the 30 sec at a time in a variety of sets induced a 6.97% up to 9.84% increment after the vibration exposure, whereas for the

| Table 2 |
|--------------------|----------------|----------------|----------------|----------------|----------------|
|                  | Pre            | Post 1         | Post 5         | Post 10        | Post 15        |
| Squat jump (cm)   |                |                |                |                |                |
| 30 sec            | 26.11 ± 3.06   | 27.93 ± 3.43*  | 28.68 ± 2.72*  | 28.63 ± 2.55*  | 26.50 ± 2.59*  |
| 60 sec            | 26.44 ± 3.55   | 28.00 ± 2.88*  | 28.48 ± 2.52*  | 28.49 ± 2.28*  | 26.78 ± 3.13*  |
| BESS (number of errors) |            |                |                |                |                |
| 30 sec            | 9.71 ± 4.70    | 8.64 ± 3.49*   | 7.23 ± 2.89*   | 6.56 ± 2.16*   | 9.41 ± 3.97    |
| 60 sec            | 9.52 ± 5.08    | 7.73 ± 4.29*   | 6.44 ± 3.35*   | 6.21 ± 3.07*   | 8.92 ± 4.32*   |

*significant difference with respect to baseline values (pre-test)
same volume, the 60 sec group showed an increment of 5.90% up to 7.75%. Percentage improvement immediately after the end of vibration protocol was 6.97% and 5.90% for the 30 sec and 60 sec, respectively. Furthermore, the 30 sec protocol showed greater improvements in all post measurements (9.84%, 9.65% and 1.49% for the 5, 10, and 15 min, respectively) compared to the 60 sec protocol (7.71%, 7.75%, and 1.28% for the 5, 10, and 15 min, respectively). Our results are in line with those of Annino et al. (2007) who revealed significant improvement in explosive strength after 8 weeks of vibration training in young female athletes and of those of Mahieu et al. (2006) and Fort et al. (2012) who examined trained populations after completing vibration training programs of 6 and 8 weeks, respectively. Furthermore, our results verify previous findings which showed that WBV improves explosive strength of lower limbs (Dabbs, Lundahl, & Garner, 2015; Roelants, Delecluse, Coris, & Verschueren, 2004; Torvinen et al., 2002a, 2002b) supporting the importance of muscular strength on balance ability (Altug, Alkman, Büker, & Cavlak, 2015).

Percentage improvements that were found in our study are comparable with the study by Cole and Mahoney (2010) who found an improvement of 6.7% in jump height. Moreover, our findings are similar to those of other authors (Delecluse, Roelants, & Verschueren, 2003; Russo et al., 2003; Torvinen et al., 2002b) who reported a gain in jump height of 4.7% up to 9% after 5 and up to 24 weeks WBV training. In contrast, our findings opposed those of Cochrane, Legg, and Hooker (2004) who revealed no significant improvement in jump height. Few theories exist on the effects of vibration on muscular performance (Cardinale & Bosco, 2003; Roelants et al., 2004). According to Bosco, Cardinale, and Tsarpela (1999) improvements in muscular performance due to WBV training resembles that following several weeks of resistance training. During a WBV loading, skeletal muscles undergo small changes in muscle length, most likely since mechanical vibration is able to induce a tonic excitatory influence on the muscles exposed to it (Seidel, 1988). This excitatory influence named “tonic vibration reflex” excite the primary sensory endings of the muscle spindles, resulting in an increased firing rate of primary motor neuron pool afferent fibers 1a and activation of α-motor neurons (Bosco et al., 1999; de Ruiter, van Raak, Schilperoort, Hollande, & de Haan, 2003). The tonic vibration reflex induced by the vibration may cause an increased recruitment of motor units via activation of muscle spindles and polysynaptic pathways (de Gail, Lance, & Neilson, 1966), which is seen as a temporary increase in the muscle activity. Furthermore, the increase in strength following WBV training may be due to elevated essential hormones, i.e. testosterone, growth hormone, and insulin-like growth factor.

These findings suggest that it could be useful to achieve neuromuscular adaptations to improve physical performance in various sports and to encourage the use of this kind of training as athletes do not burden their musculoskeletal system as with the traditional method of external resistance training. Moreover, this training method is useful not only for coaches designing training programs for trainers or athletes but also for the prevention of injuries. Thus, sports with high injury rates, as balancing and jumping, may benefit from WBV training.

Certain limitations do not allow the generalization of the present findings without considerable caution. First, no control group was involved in order to reveal the differences between vibration and no vibration protocols. However, it is mentioned that our main purpose was to examine the effectiveness of the two vibration protocols that were applied in our study.

Conclusions

Results of the study showed that irrespectively of the duration of exercise during WBV exposure, there are positive effects on static balance and explosive strength in physical education students. Eight weeks WBV training in physical education students with different duration intensity training in each trial are equally effective on explosive strength of lower limbs and static balance. However, since a placebo protocol was not used, the results of our study should be applied with caution.

Conflict of interest

There were no conflicts of interest.

References


