The Swedish Journal of Scientific Research

Original Article

The Acute Effect of Whole-Body Vibration Training on Postural Control on Female Rhythmic Gymnasts

George Dallas[1], Despina Tsopani[1], Sotiris Papouliakos[2], Maria Riga[3], George Korres[4]

[1]Department of Physical Education and Sport Science, University of Athens, Greece, [2]University of Athens, G. Gennimatas, Hospital, Greece, [3]Democritus University of Thrace, University Hospital of Alexandroupolis, Greece, [4]University of Athens, Hippokratio Hospital, Greece

ABSTRACT

The purpose of the present study was to examine the acute effect of Whole-Body-Vibration (WBV) on rhythmic gymnasts' static and dynamic balance. It was hypothesized that vibration exposure induces positive short-term effect on postural control, enhancing the ankle strategy. This hypothesis was tested on eleven elite rhythmic gymnasts, who were examined twice, once with WBV and once without WBV (NWBV). Balance was assessed under six different conditions with the Sensory Organization Test (SOT) based on the EquiTest Dynamic Posturography system. All tests were performed at baseline, immediately after and 15 minutes after the end of the intervention. The results showed that the improvement of the gymnasts' postural control was significantly greater after the WBV as compared to the NWBV protocol in all examined parameters. Therefore, WBV may be an effective warm-up method for the enhancement of the ankle strategy during performance.

Keywords: Vibration exposure, static balance, dynamic balance, gymnastics, proprioception

INTRODUCTION

In rhythmic gymnastics the gymnast's ability to perform successfully various skills as turns, walkovers and rolls requires balance control. Balance, referred to as a coordination ability during which the center gravity of the body (CoG) is sustained within its base of support (BoS) (Blackburn, Guskiewicz, Petschauer, & Prentice, 2000), is maintained by three sensory processes working together; the visual, vestibular, and somatosensory (Horak, Nashner, & Diener, 1990). A decrease of postural stability adversely affects performance (Vuillerme, Danion, Marin, Boyadjian, Prieur, & Weise, 2001). According to Shaffer and Harrison (2007) and Carr and Shepherd (2000), postural control represents a complex interplay between the sensory and motor systems and involves perceiving environmental stimuli, responding to alterations in the body orientation within the environment and maintaining CoG within the base of support. With regards to dynamic stability, Hof, Gazendam, & Sinke (2005) propose an extended rule, defining as the margin of stability (*b*) the minimum distance from the extrapolated centre of Mass position (XcoM) to the boundaries of the BoS. Both static and dynamic balance is needed in rhythmic gymnastics performance. Static balance refers to the ability to stay upright within the base of support and dynamic balance refers to the ability to recover the equilibrium after external dynamic perturbations. Another balance requirement in rhythmic gymnastics is postural steadiness, which refers to standing as still as possible (Juras, Stomka, Fredyk, Sobota, & Bacik, 2008). Balance is usually measured using static and dynamic validated balance tests (Davlin, 2004) and force plate devices (Holviala, Sallinen, Kraemer, Alen, & Hakkinen, 2006; Rankin, Woollacott, Shumway-Cook, & Brown, 2000).

Access this article online

Website: http://sjsr.se/

ISSN: 2001-9211

Address for correspondence:
George Dallas, Assistant Professor in Artistic Gymnastics, Department of Physical Education and Sport Science, University of Athens, Greece. E-mails: gdallas@phed.uoa.gr

Whole Body Vibration (WBV) mechanically activates muscles by eliciting neuromuscular activity (Rittweger, Beller, & Felsenberg, 2000). WBV training requires standing on a vibration platform that generates side to side alternating vertical sinusoidal mechanical vibration. The transmission of mechanical oscillations from the vibrating platform may lead to physiological changes in muscle spindles, joint mechanoreceptors, higher brain activity and strength and power properties (Moezy, Olyaei, Hadian, Razi, Mohammad, & Faghihzadeh, 2008).) To that extent, researchers have reported the significant effect of WBV training upon balance (Cheung, Mok, Qin, Sze, Lee, & Leung, 2007; Torvinen, Kannu, Sievanen, Jarvinen, Pasanen, Kontulainen, et al. (2002a;b; van Nes, Geurts, Hendricks, & Duysens, 2004), functional mobility (Merriman, & Jackson, 2009; Vissersa, Verrijkenb, Mertensc, Van Gilsc, Van de Sompelc, Truijena, et al., 2010), body composition (Roelants, Delecluse, Goris, & Verschueren, 2004), decrease fall risk (Bogaerts, Verschueren, Delecluse, Claessens, & Boonen, 2007; Bruyere, Wuidart, Di Palma, Gourlay, Ethgen, Richy, & Reginster, 2005; Rees, Murphy, & Watsfort, 2009), overall quality of life (Bogaerts, Verschueren, Delecluse, Claessens, & Boonen, 2007; Bruyere, Wuidart, Di Palma, Gourlay, Ethgen, Richy, & Reginster, 2005; Rees, Murphy, & Watsfort, 2009; Trans, Aaboe, Henriksen Christensen, Bliddal, & Lund, 2009) etc, of individuals from 20 to 80 years old. WBV has been examined in several sports (Bosco, Cardinale, & Tsarpela, 1999a; Bosco, Colli, Introini, Cardinale, Tsarpela, Madella, et al. 1999b; Rehn, Lidstrom, Skoglund, & Lindstrom, 2007) and confirmed the improvement of muscle strength and power (Bautmans, Van Hees, Lemper, & Mets, 2005; Cochrane, & Stannard, 2005; Dallas & Kirialanis, 2013; Dallas, Kirialanis, Mellos, 2014; Delecluse, Roelants, & Verschueren, 2003; Kinser, Ramsey, O'Bryant, Ayres, Sands, Stone, 2008), flexibility (Cochrane, & Stannard, 2005; Dallas & Kirialanis, 2013; Dallas, Kirialanis, Mellos, 2014; Kinser, Ramsey, O'Bryant, Ayres, Sands, Stone, 2008; Sands, McNeal, Stone, Russell, & Jemni, 2006), speed (Cochrane, Legg, & Hooker, 2004; Paradisis, Zacharogiannis, 2007), balance (Torvinen, Kannus, Sievanen, Jarvinen, Pasanen, Kontulainen, S., et al. 2002b; 2003; Tsopani, Dallas, Tsiganos, Papouliakos, Di Cagno, Korres, et al. 2014) etc. Recent studies about WBV training as an effective method to enhance sport performance showed conflicting results. Ebersbach, Edler, Kaufhold, & Wissel, (2008) and Cheung, Mok, Qin, Sze, Lee, & Leung (2007), who investigated the effect of WBV on balance, revealed no significant differences either between or within groups regarding postural sway. However, postural control improvement was reported in directional control and sway, during arm abduction or anter flexion, after 6-month WBV training (Verschueren, Roelants, Delecluse, Swinnen, Vanderschueren, & Boonen, 2004). In addition, Moezy, Olyaei, Hadian, Razi, Mohammad, & Faghihzadeh (2008) showed that postural stability, measured by the deviation of centre of pressure (CoP) test, in anterior cruciate ligament reconstruction athletes, was significantly greater in the WBV group, compared with the NWBV group. Furthermore, the lateral sway of the center of pressure was smaller in dancers than in untrained subjects during unilateral leg movements performed while standing (Mouchnino, Aurenty, Massion, & Pedotti, 1992). However, two studies of Torvinen and colleagues reported that 4-8-month WBV intervention had no effect on the dynamic and static balance (2002b; 2003). It has also been demonstrated that the efficacy of WBV on balancing ability may be dependent on age (Ferber-Viart, Ionescu, Morlet, Froehlich, & Dubreuil, 2006) and physical conditions (Schuhfried, Mittermaier, Jovanovic, Pieber, & Paternostro-Sluga, 2005; van Nes, Geurts, Hendricks, & Duysens, 2004). Several mechanistic findings indicate that WBV induces several neural and muscular changes, such as stimulation of human ankles (Burke, Rymer, & Walsh, 1976), which might improve the balancing ability. The positive effects of WBV on muscular performance (Bautmans, Van Hees, Lemper, & Mets, 2005;Schuhfried, Mittermaier, Jovanovic, Pieber, & Paternostro-Sluga, 2005;van Nes, Geurts, Hendricks, & Duysens, 2004) should help to enhance the balancing ability (Okada, Hirakawa, Takada, & Kinoshita, 2001). With respect to rhythmic gymnastics, Tsopani, Dallas, Tsiganos, Papouliakos, Di Cagno, Korres, et al. (2014), examined the effect of WBV and found significant improvement on 'Limits of Stability' (LOS), and 'Rhythmic Weight Shift' (RWS) balances tests. These two tests (LOS & RWS) require participants to remain stable on the platform and synchronize their weight shift according to external visual stimuli (Tsopani, Dallas, Tsiganos, Papouliakos, Di Cagno, Korres, et al. 2014). However, high level rhythmic gymnasts are required often to execute balanced exercises rapidly. The success of these exercises is based not only upon the visual feedback, but on the vestibular system and proprioception as well, since the role of visual stimulus is either limited or absent. Based on the fact that WBV enhances balance performance (Cheung, Mok, Qin, Sze, Lee, & Leung, 2007; Torvinen, Kannu, Sievanen, Jarvinen, Pasanen, Kontulainen, et al. 2002a;b; Tsopani, Dallas, Tsiganos, Papouliakos, Di Cagno, Korres, et al. 2014; van Nes, Geurts, Hendricks, & Duysens, 2004), and muscle strength (Bautmans, van Hees, Lemper, & Mets, 2005; Cochrane, & Stannard, 2005; Dallas, &Kirialanis, 2013; Dallas, Kirialanis & Mellos 2014; Delecluse, Roelants, & Verschueren, 2003; Kinser, Ramsey, O'Bryant, Ayres, Sands, & Stone, 2008), it remains unknown if WBV has an effect on postural stability of elite rhythmic gymnasts who are characterized by high level athletic performance. Thus, the present study was designed to examine the acute effect of WBV training on Sensory Organization Test (SOT) recruiting mainly the vestibular and somatosensory systems. The working hypothesis is that a single bout of WBV, compared to an equivalent exercise program performed without vibration, results in acute improvement of postural control.

METHOD

Experimental Approach to the Problem

This is a repetition measure design to assess the acute effects of a single bout of WBV on elite rhythmic gymnast static and dynamic balance, evaluated by Sensory Organization Test (SOT).

Subjects

Eleven national rhythmic gymnasts, mean age 17.54±0.52 years, body mass 51.27±2.24 kg, height 170.54±3.48 cm, and percent body fat 15.29±1.22, volunteered to participate in the present study. All participants had more than 10-12 years of training (6 days per week for 4 hours per day) and competition experience with no previous experience in WBV. The exclusion criteria from the study were neurological, musculoskeletal, or other chronic diseases and no injuries, as reported by the medical history questionnaire. Participants were informed of the rationale of the study, the use of the resultant data, and the issues and goals being pursued. The study was designed to conform to the Declaration of Helsinki and was approved by the local Ethics Committee. Participants and the parents of the underage gymnasts gave their written consent prior to participating in the study.

Design

All participants performed two trials under two different protocols on two separate days, once without WBV (NWBV), and once with WBV. In order to compensate for any habituation due to intervention six subjects were measured in the order WBV-NWBV and the other five in the reverse order. The vibration protocol consisted of a single bout WBV training. One hour prior to the first trial, a familiarization session and anthropometric measurements were performed. The familiarization session included instructions on how to perform the exercises on the whole body vibration platform. The order of the trials was not randomized to avoid cross-contamination of the results.

The WBV was performed by using the Galileo 900 (Galileo Fitness, Novotec, Germany), which is a side-alternating vibration device, working as a teeterboard with amplitude of 0 to 5.3 mm (medial to distal) and a variable frequency of 5 to 30Hz. The amplitude was controlled by adjusting the foot position from 1 to 3, the larger the position and the greater the amplitude. Before treatment, instructions on using the Galileo 900 were given by the researcher and its safety issues were explained. The frequency of the vibration was set at 30 Hz and 2mm amplitude, for a total time of 75 seconds. According to other studies (Bosco, Iacovelli, & Tsarpela, 2000; Cochrane, & Stannard, 2005; Fagnani, Giombini, Di Cesare, Pigozzi, & Di Salvo, 2006; Jacobs, & Burns, 2009; Mahiu, Witvrouw, van de Voorte, Michilsesns, Arbyn, & van den Broecke, 2006; Torvinen, Kannu, Sievanen, Jarvinen, Pasanen, Kontulainen, et al. (2002a;b) low frequencies and amplitudes are most effective in improving balance and muscular performance. The participants were exposed to a single bout WBV training at moderate intensity using different execution forms of five exercises, each one lasting 15 seconds (static and isotonic squat; single leg stance for right and left leg; stretching hamstring muscles). The duration of 15 seconds was used to obtain the performance enhancement found by Cormie, Deane, Triplett, & McBride (2006). During all the vibration-training sessions, the participants wore their usual gymnastics shoes to avoid bruises and to standardize the damping of the vibration caused by the footwear. As there are no scientific-based WBV programs, the training program in the present study was based on similar protocols that resulted in significant changes in muscle performance (Delecluse, Roelants, & Verschueren, 2003; Torvinen, Kannu, Sievanen, Jarvinen, Pasanen, Kontulainen, S, et al. 2002a). In order to achieve the purpose of this investigation, the NWBV treatment was composed of the same exercises as the WBV on the Galileo platform but with the device switched off. Gymnasts in both programs wore sport shoes during the training sessions.

Measurements

A battery of tests was performed at baseline (pre), immediately after the end of the trial (post 1) and 15 minutes after the end of WBV trial (post 15). The participants were informed about the test procedures and were asked to perform all tests at maximum intensity. The participants had one familiarization session before each test. The maximum duration of the test battery was four minutes.

Postural Control (Stability)

Postural Control was examined by means of the EquiTest of Computerized Dynamic Posturography (CDP) (2001). NeuroCom's EquiTest system is equipped with a moving visual surround (wall), the most sophisticated technology available for isolating and assessing sensory modality interaction. The test performed in the present study was the Sensory Organization Test (SOT). The SOT based on the EquiTest Posturography system is used for the laboratory assessment of postural stability.

The SOT can objectively identify any abnormalities in the three systems (visual, vestibular, and somatosensory). The SOT evaluates the integrity of these three sensory modalities by selectively disrupting somatosensory and/or visual information regarding body CoG orientation in relation to display from the vertical and then measuring the subject's ability to maintain and recover balance (Nashner, 1993). According to Wrisley, Stephens, Mosley, Wojnowski, Duffy, & Burkard, (2007) the test isolates various sensory contributions by either removing or distorting the visual and/or somatosensory inputs to postural control. It is mentioned that normal participants move primarily about the ankle joints when the surface is stable and shift to hip movement as they become less stable. The EquiTest CDP system is able to quantify the relative amount of ankle and hip strategy to compensate for forces in the anterior-posterior direction through Strategy Analysis, with ankle strategy scores being close to 100, while hip strategy scores being close to zero.

Gymnasts were allowed to become familiar with the system and performed one trial before proceeding to the tests. All participants were examined on six different sensory conditions: 1) normal vision with fixed support; 2) absent vision with fixed support; 3) swayed-reference vision with fixed support; 4) normal vision swayed-referenced support; 5) swayed-reference support with absent vision; and 6) swayed-referenced vision with swayed-reference support (Figure 1). The duration of each sensory condition was 20 seconds.

The purpose of the 6 conditions was to isolate the different sensory systems used for balance control. Conditions 1 and 2 measured the subjects' baseline stability, whereas condition 3 the visual surround was conflict. Condition 4 the somatosensory input was conflict whereas, in condition 5 and condition 6 the visual surround and somatosensory inputs were conflicted; this test isolates the vestibular system. After the instructions were received, each gymnast was placed on the balance machine (NeuroCom) and tested 3 times on all 6 conditions.

Statistical Analysis

Throughout the six experimental conditions of the SOT, the dependent variable measured was the postural stability expressed in percentage form and averaged in each case over three trials. Each of the six experimental conditions of the SOT was subjected to a two-way (2 X 3) ANOVA (protocol X time) analysis with repeated measures. The first within subjects factor was protocol (WBV-NWBV) with time (pre, post 1 and post 15) being the second nested within subjects factor. The interaction between the two factors (protocol X time) was also considered in the model. Significant effects of the factors or their interactions were tested through their F-values with the appropriate degrees of freedom that yield the corresponding p-values. The estimates of

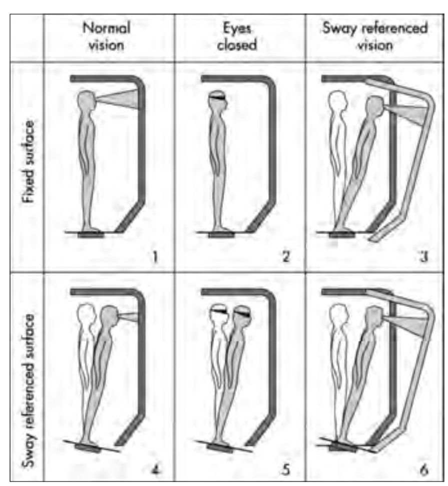

Figure 1: The 6 conditions of the NeuroCom Sensory Organization Test (SOT)

effect size are also reported through the corresponding η^2 values. This is an approximate measure of the proportion of the overall parameter variability attributable to the effect of the factor. Post hoc pairwise comparisons with Bonferroni adjustments of the means of time within each protocol and protocol within each time were also conducted. All values are presented as means ± SD. The level of significance was set at 0.05.

RESULTS

Table 1 describes the results of the two-way ANOVA (protocol X time) analysis with repeated measures on each of the six conditions of the SOT.

The six mean values (± SD) for each of the three time measurements in each of the two protocols are shown in table 2 and are also depicted in figure 2.

In table 2 asterisks denote statistically significant differences of the post 15 from the previous two measurements (pre and post 1), whereas in figure 2 asterisks denote statistically significant difference between the two protocols for the specific time measurement.

With regards to condition 1 there was a significant protocol effect, which is attributed to the fact that in the post 1 measurement the athletes scored better in the WBV protocol than in the NWBV protocol. However, this effect is overshadowed by the very significant time effect, which is totally attributed to the fact that, irrespective of the protocol, the athletes exhibited a very sharp performance reduction at the post 15 measurement.

With regards to condition 2 beyond the significance of the protocol and time effects, there was also a significant protocol X time interaction effect. This is explained by the observation that the significant increase in performance at the post 15 measurement is more striking in the WBV condition than in the NWBV condition. As a result in both the post 1 and post 15 measurements the athletes performed significantly better in the WBV condition. Exactly the same apply to condition 4.

In condition 3, the effect of protocol remains significant but the effect of time disappears although it qualifies through the second order interaction of protocol X time. This is a result of the fact that, while in the WBV protocol the athletes performed equally in all three time measurements, in the NWBV protocol the athletes gradually performed worse, though not in a significant manner. However, these resulted in significantly better performances in the WBV protocol at the post 1 and post 15 time measurements.

In condition 5, the effect of time remains significant but the effect of protocol disappears although it

Table 1: Results of the 2-way ANOVA with repeated measures reporting the significance (p-value) and the effect size (η^2) of protocol, time and their interaction on postural stability in each of the six SOT experimental conditions

	protocol		time		protocol X time	
	p-value	η^2	p-value	η^2	p-value	η^2
Condition 1	0.005	0.560	0.000	0.910	0.256	0.128
Condition 2	0.002	0.640	0.000	0.615	0.039	0.276
Condition 3	0.000	0.882	0.138	0.180	0.011	0.360
Condition 4	0.014	0.471	0.000	0.884	0.009	0.377
Condition 5	0.647	0.022	0.000	0.749	0.046	0.224
Condition 6	0.941	0.001	0.486	0.070	0.628	0.045

Table 2: Means (±SD) of postural stability (expressed in percentage form) at each of the three time measurements (pre, post 1 and post 15) in each of the two protocols (WBV, NWBV) for each of the six SOT experimental conditions. Asterisks denote statistically significant differences ($p<0.05$) of the post 15 measurements in comparison to the previous measurements

	WBV			NWBV		
	Pre	Post 1	Post 15	Pre	Post 1	Post 15
Condition 1	96.0±1.1	96.2±1.2	92.3±1.3*	95.6±1.1	94.8±1.2	91.1±1.4*
Condition 2	93.0±2.6	93.6±1.8	96.1±1.1*	92.5±2.9	91.3±1.9	94.5±1.7*
Condition 3	93.5±2.2	93.7±2.0	93.9±1.3	92.8±2.1	91.9±2.2	90.8±1.7
Condition 4	87.4±2.6	87.9±2.2	93.9±2.3*	87.3±2.4	86.4±1.6	91.8±1.4*
Condition 5	69.2±8.9	70.2±8.4	88.4±1.9*	72.6±11.5	71.4±10.5	86.2±1.7*
Condition 6	68.7±3.9	69.3±3.2	70.6±7.8	68.9±4.0	68.2±3.3	71.3±10.3

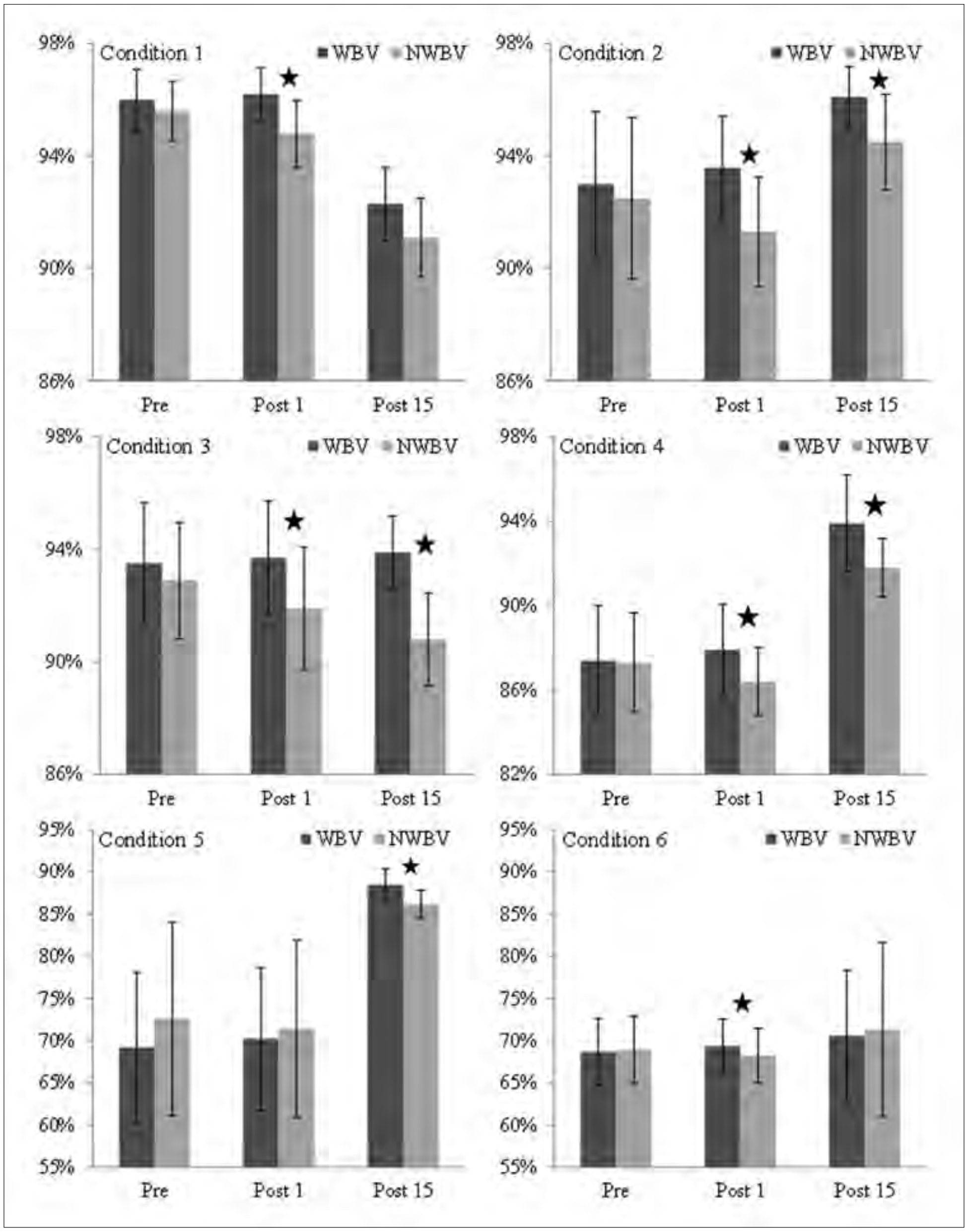

Figure 2: Means (±SD) at each of the three time measurements (pre, post 1 and post 15) in each of the two protocols (WBV, NWBV) for each of the six SOT experimental conditions. Asterisks denote statistically significant differences ($p<0.05$) between the WBV and NWBV protocols for the specific time measurement

qualifies through the second order interaction of protocol X time. This is a result of the fact that the athletes performed significantly better at the post 15 measurement in both protocols, yielding in the end an advantage of the WBV protocol.

With regards to condition 6 there were no significant effects of the two factors or their interaction, with the only observable difference in favor of the WBV protocol being at the post 1 measurement.

DISCUSSION

The purpose of this study was to verify the acute effects of WBV on postural control as assessed by the Sensory Organization Test (SOT) in elite rhythmic gymnasts. The primary finding of the study was that a single short-bout WBV induced a significant, transient increase on elite rhythmic gymnasts' postural control immediately after the end of the vibration loading. More specifically, it is evident in all conditions that immediately after the end of WBV program gymnasts improved their postural control as they were more stable than with the NWBV protocol that revealed a reduction in post measurements in comparison to baseline values. Moreover, it is evident that the effect of WBV protocol extends up to 15 min after the end of vibration loading.

The fact that in three conditions there was also an improvement in the post 15 measurement in the NWBV protocol indicates the presence of practice/learning order effects. However, in all three conditions these measurements of postural control remained higher in the WBV protocol, indicating that the protocol effect was above and independent of the learning effect. Based on the fact that the improvements in these balance parameters were greater after the WBV protocol, it is clear that the immediate effect of a short-bout vibration protocol was beneficial for the gymnasts' postural control. However, in both protocols the athletes failed to retain balance scores 15 min later in condition 1 in contrast to previous studies that demonstrated an immediate suppression of reflex activity in healthy subjects and the need of a recovery period in order to realize the WBV effect (Kipp, Johnson, Doeringer, & Hoffman, 2011). Different findings on the WBV efficacy on balance ability should depend on sample age (Ferber-Viart, Ionescu, Morlet, Froehlich, & Dubreuil, 2006) and physical conditions (Schuhfried, Mittermaier, Jovanovic, Pieber, & Paternostro-Sluga, 2005; van Nes, Geurts, Hendricks, & Duysens,2004). WBV increased the activity level of the muscle spindles and altered the neuromuscular system. One possible explanation is that the vibration generally increases the neural activation in submaximal intensities in a short time and without applying a large load (Rittweger et al, 2000). Possible mechanisms that play a role in these contractions is the Golgi tendon organ and the amount of force applied (Hagbarth et al, 1986).

Consequently athletes may be able to activate muscles more effectively, with immediate effect in future contractions. This improvement may result in faster and more vigorous activation of the somatosensory system in response to postural sway or perturbations (Cardinale, & Bosco, 2003). It has been shown that WBV elicit a response named "tonic vibration reflex" (TVR) (Eklund, & Hagbarth, 1966). The vibration-induced TVR involves activation of muscle spindles, mediation of the neural signal by 1a afferents (Hagbarth, 1973), and activation of the muscle fibers via large α-motor neurons. The TVR induced by the vibration is also capable of causing an increasing 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. The improved postural control after the vibration protocol suggests that neurogenic adaptation may occur in the muscles of lower limbs. By increasing postural complexity (altered somatosensory and visual information), as in the sixth condition of SOT test, the improvements in postural control where delayed (post 15), as was demonstrated in a previous study (Armstrong, Nestle, Grinnell, Cole, van Gilder, Warren, et al. 2008). Furthermore, the present results confirm findings by Riley & Clark (2003), reporting that an increase in amount and variability appeared in postural sway as the SOT condition became increasingly difficult (as at the SOT condition moved from eyes open to eyes closed, to sway-referenced visual surround or support surface, and to sway-reference surface and visual surround). Elite gymnasts have well-developed muscle strength, reflex sensitivity, and fast twitch fiber recruitment. It is plausible that only a bout of WBV treatment may not be adequate to improve the postural control in gymnastics with long term effects. The gymnast training includes every day exercises to minimize changes in muscle length due to balance impairment, and to guarantee an efficient performance. Moreover, it is well known that the lateral sway of the center of pressure was smaller in athletes and dancers than in untrained subjects during unilateral leg movements performed while standing (Mouchnino, Aurenty, Massion, & Pedotti, 1992). Few studies have been conducted using athletes competing in national and international level competitions and in particular young competitive gymnasts (Dallas, & Kirialanis, 2013; Dallas, Kirialanis & Mellos 2014; Kinser, Ramsey, O'Bryant, Ayres, Sands, & Stone, 2008).

WBV is proposed as a suitable warm-up method in a number of studies (Kinser, Ramsey, O'Bryant, Ayres, Sands, & Stone, 2008; Sands, McNeal, Stone, Russell, & Jemni, 2006; Torvinen, Kannu, Sievanen, Jarvinen, Pasanen, Kontulainen, et al. 2002a). In particular it is suggested that vibration may be a beneficial warm-up/training method for gymnasts to improve flexibility (Dallas, & Kirialanis, 2013; Dallas, Kirialanis & Mellos 2014; Kinser, Ramsey, O'Bryant, Ayres, Sands, & Stone, 2008) while maintaining or/and increasing jumping ability (Dallas, & Kirialanis, 2013; Dallas, Kirialanis

& Mellos 2014; Torvinen, Kannu, Sievanen, Jarvinen, Pasanen, Kontulainen, et al. 2002a). In conclusion, the positive short-term effect induced by WBV on postural control is confirmed in this study in a sample of elite rhythmic gymnasts. Therefore WBV may be an effective warm-up method for the enhancement of ankle strategy during performance.

A limitation of the study is its small sample size. Nonetheless the eleven athletes included encompass all the elite Greek gymnasts – members of the National Team participating in the Olympics and World Championships, ipso facto the sample is self-contained and therefore in the current context any a priori sample size estimation would be inappropriate.

ACKNOWLEDGEMENTS

The authors would like to thanks all the participants for taking part in this study. We also thank Greek Gymnastics Federation for her help in recruiting the subjects and the Medical Laboratory for providing the Equi Test Computerized Dynamic Posturography system. However, the authors have no conflict of interest to report.

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