THE EFFECT OF 6-WEEKS WHOLE BODY VIBRATION ON MUSCULAR PERFORMANCE ON YOUNG NON-COMPETITIVE FEMALE ARTISTIC GYMNASTS

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Abstract

The purpose of this study was to investigate the effects of a 6-week whole body vibration-intervention on muscle performance and flexibility on gymnasts. Twenty-two young non-competitive-moderate trained gymnasts that volunteered to participate in the study separated into either the vibration group or the no vibration group according to their training regime. The vibration intervention consisted of a 6-week whole-body vibration, 3 times per week and involved eccentric and concentric squatting movements on a vibration platform with the participants performing three exercises on the vibration device whereas for the no vibration group vibration platform was turned off. Five performance tests (20m running speed, sit & reach test, squat jump, counter movement jump and single leg squat (right leg and left leg) were performed at the beginning of the intervention, and after the end of 6-week intervention program. According to the results significant interaction effect between group and time was found for the running speed and Squat Jump test. On the contrary, significant main effect were found were found for time on the running speed, Squat Jump, Counter movement jump and single leg squat. Conclusively, it has been reported that Whole body vibration is an effective method to improve Squat Jump performance in young non-competitive female artistic gymnasts.

Keywords: *explosive strength, intervention, gymnastics.*

INTRODUCTION

Whole Body Vibration (WBV) exercise or vibration training is a new type of exercise that has been reported to be an effective method to improve athletic performance (Cole & Mahoney, 2010). It is considered an ergogenic aid for training and competition (Bazett-Jones, Finch, & Dugan, 2008) and is potentially a less-consuming method for increasing power output than traditional training (Marin & Rhea, 2010). The main argument for using vibration for muscle training has been based on the assumption that strength improvements can be easily achieved during a short time (Dallas et al., 2015; Tsopani et al., 2014). When a person stands on a vibration platform it generates vertical sinusoidal vibration which are transmitted directly to the tendon, which in turn leads to activation of the alpha-motoneurons and initiates muscle contractions comparable to the “tonic vibration reflex (TVR)" (Nortlund & Thorstensson, 2007). 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). TVR is the sustained contraction of a muscle due to the effect of vibration that activates muscle spindles, which are muscle receptors sensitive to stretch in the muscle. Afferent fibers send a signal to the spinal cord from the muscles spindles activating a reflex which causes the muscle to contract. TVR also causes an increase in recruitment and synchronization of motor units within the muscle 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. According to Rothmuller and Cafarelli (1995) vibration enhances the stretch reflex loop through the activation of the primary endings of the muscle spindle, which influences agonist muscle contraction while antagonists are simultaneously inhibited. Further, according to Cardinale & Bosco (2003), the acute enhancement of neuromuscular performance after vibration is probably related to an increase in the sensitivity of the stretch reflex. Furthermore, vibration appears to inhibit activation of antagonist muscles through Ia-inhibitory neurons, thus altering the intramuscular coordination patterns leading to a decreased braking force around the joints stimulated by vibration. Vibration might raise the muscle temperature due to the friction between the vibrating tissues, increase the blood flow, which could in turn enhance the extensibility of the muscle and ROM and change the pain threshold (Sands et al, 2008).

Several studies showed that WBV training resulted in improved muscle strength or muscle performance. Specifically, it has been shown that exposure to WBV increases the explosive strength of the lower limbs, flexibility with or without stretching (Dallas & Kirialanis, 2013; Dallas, Kirialanis, & Mellos, 2014a; b; Dallas et al., 2015; Tsopani et al, 2014) and sprint running (Paradisis & Zacharogiannis, 2007). The majority of these studies are referred to female and male participants aged between 22-43 years (Carson, Popple, Verschueren, & Riek, 2010) or young adults (Chen, Liu, Chuang, Chung, & Shiang, 2014) or trained individuals; volleyball and beach volley athletes (Pérez-Turpin et al., 2014) or female basketball athletes (Fernadez-Rio, Terrados, & Suman, 2012), whereas there is a strong to moderate evidence that long-term whole body vibration exercise can have positive effects regarding leg muscular performance (Annino et al., 2007; Chen et al., 2014; Fernandez-Rio et al., 2012; Dallas et al, 2017; Pérez-Turpin et al., 2014; Preatoni et al., 2012). However, there are controversial results with regards to the effect WBV on explosive strength of lower limbs with some of these studies to indicate positive effect (Fernadez-Rio et al., 2012; Pérez-Turpin et al., 2014; Preatoni et al, 2012), whereas other studies found no positive effect (Carson et al., 2010).

In addition, a number of these studies have been applied a single bout of vibration to examine acute effect of vibration (Dallas & Kirialanis, 2013; Dallas, Kirialanis, & Mellos, 2014a; b; Tsopani et al, 2014), whereas other studies examine the effect of intervention program on muscle performance (Fernandez-Rio et al, 2012; Perez-Turpin et al, 2014; Preatoni et al, 2012; Sands et al, 2006). In addition, studies that are referred to gymnastics sports have examined mainly the vibration effect on flexibility in competitive gymnasts (Dallas & Kirialanis, 2013), on young gymnasts (Dallas et al., 2014a) or high level gymnasts (Sands et al, 2006; Tsopani et al., 2014).

Studies on long-term effects of vibration training have also yielded contradictory outcomes. Significant enhancement was found in the parameters evaluated by Annino et al. (2007), whereas other studies found no significant changes (Hand, Verschuere, & Osternig, 2009).

More specifically, Paradisis and Zacharogiannis (2007) and Wyon, Guinan, and Hawkey (2010) concluded that the 6 weeks program improves sprint running and explosive power of lower limbs of healthy subjects. Perez-Turpin et al. (2014) studied 23 beach volleyball and volleyball athletes reported that implementation of 6-week WBV training increases leg strength more and leads to greater improvement in jump performance than traditional strength training. Different time protocols were also studied. Carson et al. (2010) compared a 4-week WBV training program to that without vibration. The subjects were aged 22-43 years and concluded that the non-vibration group increased the CMJ height; however, there were no significant improvements between groups. An 8 week WBV program by Chen et al. (2014) on injury-free young adults with average age of 20.3 years revealed a significant jumping improvement from 6.4 to 11.9%. Another 8 week training program (periodized) was carried out 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. The 8-week WBV training program of 22 ballerinas by Annino et al. (2007) concluded that it improves explosive strength on knee-extensor muscles although this is only short term. When comparing with and without vibration 14-week training programs of 31 female basketball athletes Fernandez-Rio et al. (2012) concluded that there were no significant improvements between the two programs even though there was strength increase. Further, a meta-analysis found that WBV has small and inconsistent acute and chronic effects on athletic performance in competitive and /or elite athletes (Hortobagyi, Lesisnski, Fernandez-del-Olmo, & Granacher, 2015).

Although, there is a lack of data concerning the improvement of muscular strength in young gymnasts, previous data by Ronnestad (2004) support that vibration may enhance measures of explosiveness. Furthermore, as Kinser and colleagues (2008) stated the combination of vibration and stretching can enhance flexibility while maintaining explosive strength in young gymnasts aged 11.3 ± 2.6 years. In addition, Rohmert et al. (1989) showed that muscles with increased muscle length or tension are most affected by vibration. Therefore, it may be advantageous to use a combination of vibration and stretching as part of the warm-up for gymnasts, thus enhancing flexibility and maintaining or improving explosive performance (Stone et al, 2006). However, despite the above noted effect of vibration devises among subjects, scientific evidence on the efficacy of long term intervention vibration program on young gymnasts is lacking. Further, to our best knowledge, there are not scientific data related to the effect of long term intervention program on gymnasts. Therefore, the purpose of this study was to investigate the effect of a 6-week whole body vibration intervention on explosive strength of lower limbs, flexibility and running speed (RS) of young moderately trained artistic gymnasts. It was hypothesized that 8-week vibration intervention program will be more effective in improving muscular performance compared to the same program without vibration.

METHODS

Twenty-two young, healthy volunteers participated in this study (age 9.70 ± 0.95 years, body mass 34.47 ± 6.94 kg, and body height 137.67 ± 8.14 cm). All individuals, the last 2 years, were participated in a scheduled training program for 3 times per week in clubs of artistic gymnastics and had no previous experience in WBV. They were randomly assigned to two groups, which included a WBV group (VG: n = 12) and a non-vibration group (NVG: n = 10). During the six-week intervention period, both groups were advised to continue with their regular habitual gymnastics training. Furthermore, participants incorporated an additional conditioning program at the end of each training session performing three exercises according to their protocol. Subjects were informed extensively about the experiment procedures and the possible risks or benefits of the project. They had no musculoskeletal injuries in the previous 6 months, and all parents provided written informed consent before participation of their children in the experimental design. The study was approved by the local institutional Review Board and all procedures were in accordance with the Helsinki declaration of 1975 as revised in 1996.Three days prior to the study, the anthropometric characteristics of subjects (age, body mass, body height) were measured and a familiarization session to get acquainted with the proper technique for the execution of the examined exercises (running speed, flexibility test, jumping tests) were performed. The vibration protocol consisted of a 6-week WBV training, which will be discussed in detailed herein. The intervention program was implemented at the end of each training session, as the technical skills training module is usually preceded. The total duration of training lasts about 60 minutes, with the most time, other than that of warm-up, devoted to the learning of simple technical exercises. Therefore, the degree of fatigue may be reduced to a minimum.

On each session, each subject performed a 3-min standardized warm-up that include running at low intensity and light callisthenic exercises. Participants in the VG were exposed to vertical sinusoidal mechanical WBV while standing on the commercially available Power Plate® Next Generation WVB platform (Power Plate North America, Northbrook, Illinois), whereas participants in NVG performed the same exercises but the WBV platform was turned off. 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. The participants were exposed for 6 weeks using different execution forms of three exercises. Every training session was supervised by the researchers. In first exercise, participants were instructed to move through the eccentric portion of the movement for two sec and the concentric portion for two sec synchronized by a metronome operating with 20 bpm to a depth of approximately 90° of knee flexion. In exercise two and three, the participants standing on one leg, flexed their knee to a depth of approximately 90° of knee flexion and instructed to move as in the first exercise. The duration of 30 sec was used in hopes to improving the performance enhancement found by Cormie et al. (2006). During all the vibration-training session, the participants wore the same gymnastics shoes to avoid bruises and to standardize the damping of the vibration caused by the footwear. The training load on the vibration platform for the two groups, for each one exercise was as follows:

Table 1
Training load for intervention protocol

Week	Series	Duration (sec)
1 - 3	1	30
4 - 6	2	30

The rest between the sets and exercises was 30 sec to provide a proper time for relaxation. 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 (Torvinen et al, 2002a).

A battery of tests (Running speed 20 m: RS; Flexibility test: S & R test;

Jumping tests) was performed at the start baseline (pre-test), one day after the end of sixth week (Post 1) and 5-min (Post 5) and 10-min (Post 10) after the end of the intervention protocol to measure the effects of training. The participants were informed about the test procedures and were asked to perform all these tests at maximum intensity. Before each test, the participants had one uninventive familiarization trial. Testing for each subject was completed in the same order during each testing period. All subjects participated in supervised training three days per week during the six-week training sessions. For all test items the Interclass reliability coefficients was estimated to be 0.91 – 0.96.

In the first day of performance testing, the participants, after completion of the standardized 3-min warm-up, performed two maximal 20 m RS with subjects started from a crouched position. The sprint was performed in a gymnastic hall at a constant temperature of 22° C. The time was obtained using the Brower timing systems (Brower, USA). A rest period of 5 minutes was given between each trial.

Flexibility was measured using the sit and reach test using a Flex-Tester box (Cranlea, UK). Participant, sitting barefoot on the floor with legs out straight ahead, were instructed to lean forward slowly as far as possible, toward a graduated ruler held on the box from -25 to +25, without bending their knees and held at the greatest stretch for 2 sec. The investigator has to be sure that there are no jerky movement on the part of the participant and that their fingertips remain at the same level and the legs flat. The score is recorded as the distance before or beyond the toes. The test was repeated twice with a rest period of 10 sec (15), and the best score was recorded.

Jumping performance was measured using the squat jump (SJ), the counter movement jump (CMJ) and single leg squat (right leg (RL) and left leg (LL). Vertical jump tests were conducted on a switch mat connected to a digital timer (accuracy±0.001s, Ergojump, Psion XP, MA.GI.CA. Rome, Italy), which recorded the flight time (t_f) of each single jump. The height of rise of the centre of mass in all jump tests was determined by the flight time and used in order to analyze the explosive strength characteristics of the leg muscles as reported elsewhere (Bosco et al., 1998). Prior to testing, the participants underwent one or two familiarization trials to ensure the proper performance technique for these three different jumps.

The squat jump (SJ) started from a semi-squatting position with the knee flexed approximately at 90° that was maintained for 2 sec before jumping vertically. During SJ, the participants kept their trunk in an upright position and their hands on 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. For the counter movement jump (CMJ) the participants were instructed to perform a maximal vertical jump starting from upright position, with hands positioned at the hips to assess the lower-limb explosive performance capacity. The same regime as previous for SJ was followed. During CMJ, the participants kept their trunk in an upright position and their hands on 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. SJ involved the participants assuming a 90° knee bend position holding for two seconds, and jumping. The CMJ began in an upright position, had no pause, and was one, fluid, jumping movement. Depth for the eccentric portion of the CMJ was self-selected. The single leg squat (right and left), was performing under instructions that were given for the SJ test.

The SPSS version 24 was used for the statistical analysis. The arithmetic mean, standard deviation, and range were calculated for each variable and trial. To explore the impact of time (pre, post1, post5, post10) and group (VG, NVG) on the dependent variables, a two-way (group x time) ANOVA with repeated measures on the second factor was used for the statistical analysis. Sphericity was checked using Mauchly's test, and the Greenhouse-Geisser's correction on degrees of freedom was applied when necessary. Levene's test of equality of error variances was used to check the assumption of homogeneity of variances. In cases where interaction between time and group was detected, the simple effects were investigated, and Bonferonni's correction was used. In the absence of interaction, the main effects of the two factors (time and group) on the dependent variables were investigated. All statistical significances were tested at $\alpha = 0.05$.

RESULTS

The statistical analyses revealed that the interaction effect between time and group was statistically insignificant for RS ($F_{(3, 60)} = 0.947$, $p > 0.05$). On the contrary, significant main effect was found for time ($F_{(3, 60)} = 3.558$, $p < 0.019$, $\eta^2 = 0,151$), but the post hoc analysis revealed no significant differences among the factor's levels. Furthermore, no significant main effect was found for group ($F_{(1, 20)} = 4.222$, $p > 0.05$). The mean values of the examined parameters are presented in table 1. Regarding S & R, the statistical analysis demonstrated no significant interaction effect between the two factors ($F_{(3, 60)} = 0.070$, $p > 0.05$) and also no significant main effect for time ($F_{(3, 60)} = 0.777$, $p > 0.05$) and group ($F_{(1, 20)} = 0.112$, $p > 0.05$). The SJ results indicated a significant interaction effect between the two factors ($F_{(3, 60)} = 3.911$, $p < 0.042$, $\eta^2 = 0.164$). The post hoc analysis showed that squat jump significantly increased after 6 weeks vibration training, either it was measured immediately after the vibration (Mean difference = 3.417 cm, $p < 0.05$, 95% CI = 1.430–5.403 cm), or 5 (Mean difference = 3.417 cm, $p < 0.05$, 95% CI = 1.292–5.540 cm) and 10 min later (Mean difference = 3.000 cm, $p < 0.05$, 95% CI = - 1.103–4.896 cm). There was no significant interaction effect between time and group for CMJ ($F_{(3, 60)} = 1.477$, $p > 0.05$). While the analysis revealed a statistically significant main effect for time ($F_{(3, 60)} = 4.163$, $p < 0.024$, $\eta^2 = 0.172$), the post hoc analysis did not indicate any significant difference among the four levels. The main effect for group was not significant ($F_{(1, 20)} = 0.536$, $p > 0.05$). Regarding the RL there was not found significant interaction ($F_{(3, 60)} = 0.471$, $p > 0.05$) or main effect for group ($F_{(1, 20)} = 0.972$, $p > 0.05$). On the contrary, it was found significant main effect for time ($F_{(3, 60)} = 4.918$, $p < 0.004$, $\eta^2 = 0,197$). The post hoc analysis did not indicate significant difference in the RL high among the four levels. As concerns the LL, the interaction effect between the two factors was found no significant ($F_{(3, 60)} = 1.143$, $p > 0.05$). The main effect for group was also insignificant ($F_{(1, 20)} = 0.537$, $p > 0.05$), but the main effect for time was found statistically significant ($F_{(3, 60)} = 5.334$, $p < 0.008$). It was indicated by the post hoc analysis that the LL height was greater after 5 min of the vibration intervention, compared with the LL height measured before the 6 weeks vibration training.

DISCUSION

The primary findings of this study was that 6-week strength training produced significant improvement on VG in RS, and SJ performance of non-competitive young female artistic gymnasts, whereas non-significant improvement was found at all examined parameters on NVG. To date, quantity in WBV protocol and quantity to outcome relationship has not been established (Rehn, Lidstrom, Skoglund, & Lindstrom, 2007). Studies, with or without a successful outcome, use a number of different frequencies, durations and amplitudes using a progressive protocol thus increasing the intensity of the frequency and/or duration and/or amplitude of the WBV protocol (Cole & Mahoney, 2010).

Although non-significant main effect was found for group, VG showed greater improvement (4.41%) on running speed (RS) compared to NVG (1.64%) after the end of the vibration protocol. These results are in accordance with data of Paradisis and Zacharogiannis (2007) who concluded that there is a 2.10% improvement in the time of 60m sprinting. The non-significant differences between two groups in our study verify previous results of Roberts, Hunter, Hopkins, & Feland (2009) who state that there were no observed differences in the 30 m sprint times in collegiate athletes. Conversely, our results opposed to those of Cole and Mahoney (2010) who found that WBV training may have had a small detrimental effect on speed during a 40m-dash test. However, other data failed to provide evidence that acute WBV stimulus positively affects sprint performance (Cochrane, 2013; Roberts et al, 2009). It has been observed that WBV training induces tonic vibration reflection; a higher activation of the muscular spindles and motor neurons which decreases the Electromagnetic delay (EMD) and increases the motor units. The neurological theory of muscular coordination could be a reason for this fast improvement in performance; motor neurons in one practical group of muscles and joints are prepared and there are improvements: in motor units coordination and integration, in synergist muscles co-contraction, and in antagonist muscles inhibition (Cardinale & Wakeling, 2005).

Table 2
Mean values and standard deviations on various measurements.

	Pre		Post 0	
	VG	NVG	VG	NVG
RS (sec)	4.26 ± 0.17	4.32 ± 0.32	4.08 ± 0.26↑	4.25 ± 0.22
S & R (cm)	28.00 ± 4.99	27.20 ± 4.73	27.67 ± 5.10	27.20 ± 4.80
SJ (cm)	18.75 ± 2.73	20.20 ± 3.01	22.17 ± 3.32↑	21.00 ± 2.71
CMJ (cm)	21.69 ± 2.00	21.94 ± 2.73	23.74 ± 3.60↑	22.66 ± 2.83
RL (cm)	10.41 ± 1.50	9.70 ± 3.16	12.17 ± 2.65↑	10.80 ± 2.61
LL (cm)	9.41 ± 1.97	9.50 ± 2.27	11.16 ± 2.82↑	10.10 ± 2.28
	Post 5		Post 10	
	VG	NVG	VG	NVG
RS (sec)	3.97 ± 0.26↑	4.22 ± 0.22	4.07 ± 0.27	4.26 ± 0.27
S & R (cm)	28.17 ± 5.00	27.70 ± 4.44	28.67 ± 4.83	27.80 ± 4.42
SJ (cm)	22.17 ± 3.40↑	21.10 ± 3.14	21.75 ± 3.52↑	21.20 ± 3.08
CMJ (cm)	23.81 ± 3.54↑	22.42 ± 3.03	23.37 ± 3.22	22.11 ± 2.99
RL (cm)	12.25 ± 2.89↑	10.90 ± 2.88	11.33 ± 2.46	10.80 ± 3.01
LL (cm)	11.33 ± 2.42↑	10.20 ± 2.25	10.91 ± 2.64	10.20 ± 3.08

↑ denote significant difference compared to baseline (pre) values ($p < .05$)

In Sit & Reach test (S & R), VG showed a slight mean decrease by -0.33 cm (1.21%) immediately after the end of 6-weeks vibration, whereas NVG remain unchangeable, that means WBV training may not be reflected in improvements in flexibility. This finding is in accordance with data of Cole and Mahoney (2010), which revealed no significant effect of WBV on flexibility of the hamstrings and lower back after 5-weeks of WBV training. However, our results opposed to those of Marshall and Wyon (2012) who found a significant large increase by 30% in ROM in young trained dancers without increasing thigh and calf circumferences after a 4-week vibration protocol and those of Sands et al. (2006) who a significant improvement, after 4-week vibration training on young high trained male gymnasts, on one split side performance. However, the improvement by 4.17% that appeared in our study 10 min after the end of the vibration protocol in VG was greater compared to that of NVG (2.80%), which suggest that the vibration exposure may have activated the Ia inhibitory interneurones of the antagonist muscle. It is mentioned that these discrepancies on the aforementioned results may be attributed to the different vibration protocols that were applied, the status and the chronological age of the subjects.

Results showed that a 6-week Whole Body Vibration induced, immediately after of the end of vibration protocol, a significant percentage improvement by 18.81% on squat jump (SJ) on VG which is significant greater from those of NVG (3.96%). The improvement that showed VG support previous findings which revealed that WBV increases explosive strength of lower limbs (Fernadez-Rio et al., 2012). Furthermore, the percentage improvements of VG 5 and 10 min after the end of vibration protocol (18.81% and 16.00%, respectively) are much greater from those of NVG (4.45% and 4.95%, respectively). In the present study the applied protocol of 6-weeks had a positive effect on counter movement jump (CMJ) performance. It was found that VG showed greater improvements (9.45%) than NVG (0.96%). This improvement by 9.45% support previous findings of Wyon et al. (2010) that found a beneficial effect of vertical jump height after 6-week vibration intervention in moderately trained undergraduate female dance students. Furthermore, results of our study are in congruence with those of other authors that founded an increase by 1.49% - 9.0% after several weeks of WBV training (Annino et al., 2007; Armstrong, Grinnell, & Warren, 2010; Bazett-Jones et al, 2008; Cole & Mahoney, 2010; Hand et al, 2009). Furthermore, the percentage improvements of VG 5 and 10 min after the end of vibration protocol (9.77% and 7.70%, respectively) are much greater from those of NVG (3.36% and 0.77%, respectively). Suggested neuromuscular improvement mechanisms are: increased corticomotor excitability and decreased short-interval intracortical inhibition, increased muscle activity due to dampening of the vibrational oscillations (Boyer & Nigg, 2007), increased motor unit activity (Pollock, Woledge, Martin, & Newham, 2012).

Significant greater improvements were found in right leg (RL) and left leg (LL) on VG immediately after the end of vibration protocol (16.91% and 18.57%, respectively) compared to NVG (11.34% and 6.31%, respectively). These results confirm findings of Shin, Lee, & Song. (2015) who found a considerably larger increase on SLJ in unilateral vibratory stimulation group (UVSG: 21% for the weak leg [WL]) and 12% for the strong leg [SL]) in comparison to the NVG (1.86% and 1.98% for the WL and SL, respectively). Further, the bilateral deficit (BLD) of 4.41% found in our study, support data of Costa, Moreira, Cavalcanti, Krinski, and Aoki (2015) who reported a strength reduction of 11%, meaning a BLD, after a resistance training protocol that consisted of 3 sets of leg extensions using a load of 50% 1RM. The bilateral deficit is α phenomenon where the sum of force produced by each leg individually is greater than the force produced by both legs combined in bilateral movement and is due to neural inhibition during bilateral tasks. WBV induces a non-voluntary muscle contraction i.e. TVR, activating α-motor neurons and increasing the sensitivity of primary ending of the muscle spindles thus stimulating the Ia afferent fiber of the muscle spindle. Moreover, more muscles are recruited via the muscle spindles and neuron bundles. According to Henneman’s size principle, as contraction strength increases, motor units are recruited from smallest to largest. According to Swearingen et al. (2011), small type I muscles are recruited before large type II, and with more large type II muscles, muscle strength and movement improve. According to the above, even slight WBV training can significantly affected muscle recruitment required for the single leg jump. Although knowledge the neurological and physiological mechanism of WBV training is limited there has been numerous research into the mechanisms through which WBV training affects performance. Our study sample was fairly small and thus the results of the WBV should be interpreted with caution. Furthermore, although there were no reported injuries during the period of our study, care should be taken vibration training is believed to be stressful for this particular age group. Additional studies are required with longer interventions in order to verify whether WBV training as a complement to resistance training produces specific benefits. The results of our study, however, may encourage trainers to include WBV sessions in their training programs so as to increase leg strength and jump height.

Certain limitations do not allow the generalization of this study. The results refer to a specific category of athletes and a specific level of technical training. The intervention protocol was applied after the end of each workout, with the potential for the resulting fatigue to affect the end result. To carry out a study by applying the intervention protocol at the beginning of the training sessions and at athletes of competitive level would give different results.

CONCLUSIONS

The findings of this study demonstrate that the implementation of 6-week WBV training in non-competitive young female artistic gymnasts improve leg strength more and leads to greater improvement in jump performance than traditional strength training (NVG).

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