

THE ACUTE EFFECT OF WHOLE BODY VIBRATION TRAINING ON FLEXIBILITY AND EXPLOSIVE STRENGTH OF YOUNG GYMNASTS

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ABSTRACT: The purpose of this study was to examine the acute effect of a single bout of whole body vibration (WBV) on flexibility and explosive strength of lower limbs in young artistic gymnasts. Thirty-two young competitive gymnasts volunteered to participate in this study, and were allocated to either the vibration group or traditional body weight training according to the vibration protocol. The vibration intervention consisted of a single bout of eccentric and concentric squatting movements on a vibration platform that was turned on (vibration group: VG n=15), whereas the traditional body weight (no vibration) group performed the same training protocol with the WBV device turned off (NVG: n= 17). Flexibility (sit and reach test) and explosive strength tests [squat jump (SJ), counter movement jump (CMJ), and single leg squat (right leg (RL) and left leg (LL))] were performed initially (pre-test), immediately after the intervention (post-test 1), and 15 minutes after the end of the intervention programme (post-test 15). Four 2x3 ANOVAs were used to examine the interaction between group (VG vs NVG) and time (pre, post 1, and post 15) with respect to examined variables. The results revealed that a significant interaction between group and time was found with respect to SJ ($p < 0.05$). However, no significant interaction between group and time was found with respect to flexibility, CMJ, RL and LL after the end of the intervention programme ($p > 0.05$). Further, the percentage improvement of the VG was significantly greater in all examined variables compared to the NVG. This study concluded that WBV training improves flexibility and explosive strength of lower limbs in young trained artistic gymnasts and maintains the initial level of performance for at least 15 minutes after the WBV intervention programme.

KEY WORDS: Vibration training, flexibility, muscle strength, gymnastics

INTRODUCTION

Vibration can be artificially produced when a person stands on a vibration platform that generates vertical sinusoidal vibration at a frequency in the range 35-50 Hz. These mechanical stimuli are transmitted as the result of vibration, 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)" [17]. Whole body vibration (WBV) training is a new neuromuscular type of exercise that may produce benefits which can be useful in training and has been reported to be an effective method to enhance athletic performance [9,18]. The main argument for using vibration for muscle training is based on the assumption that strength improvements can easily be achieved during a short time [7]. Several studies have shown that WBV training improved muscle strength or muscle performance [4,12,14,19,25]. Previous studies which investigated the effects of WBV on the general population and untrained or elderly individuals have shown increases in explosive strength of lower limbs [8,10,] and flexibility with or without stretch-

ing [14,15, 16,21,22]. Further, some studies that have been focused on sports have examined the vibration effect on flexibility in high level gymnasts [16,21,22] or elite female synchronized swimmers [22], whereas others have examined the acute effect of a WBV programme on muscle performance of female athletes [6,8,13,16]. In addition to the above noted positive effect of vibration, recent studies reported that transmission and attenuation of vibration accelerations in children is very similar to that of adults [5]. However, scientific evidence on the efficacy of vibration training in young artistic gymnasts is lacking. Previous research findings with young female adults [12] have shown that the WBV increased strength similarly to a traditional resistance training (RT) programme (WBV: 16.6% in isometric and 9% in dynamic strength vs 14.4% and 7% respectively). Therefore, the purpose of this study was to examine the acute effect of a single bout of two different training methods – whole body vibration (WBV) and no vibration group (NVG) – on flexibility and explosive strength of lower limbs in young competitive

artistic gymnasts aged 9 to 12 years old. The hypothesis of this study was that WBV will improve flexibility and explosive strength based on previous findings which support that low vibration stimulus improved flexibility [8,13,15] and explosive strength [4,24].

MATERIALS AND METHODS

This investigation was designed to assess the possible beneficial effects of WBV on young competitive artistic gymnasts performed sit and reach test (S&R), squat jump (SJ), counter movement jump (CMJ), and single leg squat jump on right leg (RL) and left leg (LL).

Subjects

Thirty-four young competitive artistic gymnasts, 15 males and 19 females, free from injuries (age = 9.22 ± 1.34 years, weight = 30.25 ± 4.35 kg, height = 132.90 ± 5.33 cm, and body fat percentage = 17.29 ± 4.14), volunteered to participate in this study. The participants were randomly assigned to the vibration group (VG) and no vibration group (control conditions: NVG). One week prior to the study, a familiarization session and measurements of anthropometric characteristics were performed. Accordingly, baseline assessments revealed no group effect according to age, body mass, body height and % body fat ($p > .05$). However, two participants from the VG withdrew from the study due to personal reasons. All the remaining participants in the VG ($N = 15$) and NVG ($N = 17$) had 5 and 3 years training and competition experience, participating in training 6 days per week, 3 hours per day, and had no previous experience in WBV. Written informed consent was obtained from their parents. The vibration protocol consisted of a single bout of WBV training, which will be discussed in detail herein. Our protocol was different from that of Bressel et al. [5]. The subjects were exposed to vibration for a short time when they were in motion and they did not remain in a standing position – on the contrary, the exercises were performed dynamically. Secondly, the exposure to the vibration was 2 min in total (4 sets * 30 s). And finally, the training background of the gymnasts was different, as our subjects were trained for a long time. 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.

Procedures

WBV Treatment. Participants in the VG were exposed to vertical sinusoidal mechanical WBV while standing on the commercially available Power Plate® Next Generation WBV platform (Power Plate North America, Northbrook, Illinois), whereas participants in the NVG performed the same protocol with the WBV device turned off. Previous research studies have confirmed that the WBV protocol used in the present study improves both flexibility [8,13,15] and explosive strength [4,24]. The frequency of the vibration was set at 30 Hz and 2 mm amplitude for a total time of 2 min. The VG participants were exposed to a single bout of WBV training using different execution forms of three exercises. In the first exercise, they

performed one squat every 4 s for the total time according to the experimental design (6-8 squats total) to a depth of approximately 90° of knee flexion. Participants were instructed to move through the eccentric portion of the movement for 2 s and the concentric portion for two seconds. In exercises two and three, the participants, standing on one leg, flexed their knee to a depth of approximately 120° of knee flexion and were instructed to move as in the previous exercise. The duration of 30 s was used in the hope of improving the performance enhancement reported by Cormie et al. [10]. During the whole 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. Training load on the vibration platform for the two groups was as follows: two sets of 30 s for the 1st exercise and one set of 30 s for the 2nd and 3rd exercise with a rest of 30 s, to provide a proper time for relaxation. As there are no scientifically based WBV programmes, the training programme in the present study was based on similar protocols that resulted in significant changes in muscle performance [12,24]. Certainly, there is congruency between the strength and flexibility tasks and the intervention programme. However, these tasks were selected because they were perceived as important for all artistic gymnasts. For example, each one of the strength tasks may be seen in several balance beam and floor exercises. To avoid this limitation, we used a control group as well, which was exposed to the same intervention, without the WBV, and tested in the same strength and flexibility tasks. Therefore, we may conclude with confidence that the differences in strength and flexibility between the VG and the NVG may be due to the intervention programme using the WBV technique. A battery of tests was performed at the start baseline (pre-test), immediately after (post-test 1) and 15 minutes after the end of WBV exposure (post-test 15). 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 uneventful familiarization trial. The order of the performance tests was the same in every test session.

Flexibility was assessed with the sit and reach test using a Flex-Tester box (Cranlea, UK). The participants, 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 holding the greatest stretch for 2 s [13]. The investigator ensured that there were no jerky movements on the part of the participant and that their fingertips remained at the same level and the legs flat. The score was recorded as the distance before or beyond the toes. The test was repeated twice with a rest period of 10 s [8], and the best trial of the two allowed was recorded to the nearest 1.0 cm for statistical analysis. The reliability of flexibility was 0.994.

Jumping performance was assessed using the squat jump (SJ), the counter movement jump (CMJ) and single leg squat jump (right leg (RL) and left leg (LL)). Vertical jump tests were conducted on a switch mat [2] connected to a digital timer (accuracy ± 0.001 s, Ergojump, Psion XP, MA.GI.CA. Rome, Italy), which recorded the

flight time (tf) of each single jump. In order to avoid upper body work and to minimize horizontal and lateral displacements the hands were kept on the hips through the tests. The rise of the centre of gravity above the ground (h in m) was measured [3] from flight time (tf in seconds) applying ballistic laws: $h = \frac{1}{2} g \cdot t^2$ (m), where g is the acceleration of gravity ($9.81 \text{ m} \cdot \text{s}^{-2}$). 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° [2] that was maintained for 2 s before jumping vertically. 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 same regime as previous for SJ was followed. The single leg squat jump (right and left) was performed under instructions that were given for the two previous exercises (SJ & CMJ). The participants were instructed to perform two maximal trials, in all tests, with a rest period of 10 s between trials, and the best jump was considered for further statistical analysis.

Statistical Analyses

Four 2 X 3 ANOVAs were used to examine the interaction effect between group (VG vs NVG) and time (pre, post 1, and post 15) with respect to sit and reach (S&R), squat jump (SJ), counter movement jump (CMJ), right leg (RL) and left leg (LL) explosive strength. SPSS v.18 was used to test the above hypotheses. The t-parameter estimates examined the differences between groups in the three separate measurements (group effect) while the repeated measures ANOVA examined the differences across time (time effect). The eta squared values presented the estimated effect sizes and the level of significance was set at $p < 0.05$. All values are presented as means \pm SD. Percent changes in all examined variables from baseline following WBV exercise were calculated.

RESULTS

The participants in the VG were assessed in strength and flexibility at baseline, 1 min and 15 min after the WBV. The participants in the NVG were assessed at the same time following their respective training protocol. The assessments of both groups, across time, are presented in table 1.

TABLE I. MEANS AND SDS ACROSS GROUPS AND TIME WITH RESPECT TO THE MEASUREMENTS USED

Tests	VG (n=15)			NVG (n=17)		
	Pre	Post 1	Post 15	Pre	Post 1	Post 15
S&R (cm)	29.46 \pm 5.96	31.33 \pm 5.27*	31.33 \pm 5.38*	29.41 \pm 6.56	30.23 \pm 6.67	30.23 \pm 6.91
SJ (cm)	22.68 \pm 3.20	24.37 \pm 4.28*	22.83 \pm 3.66*	23.30 \pm 4.21	23.03 \pm 4.71	22.93 \pm 5.27
CMJ (cm)	23.65 \pm 3.67	25.18 \pm 4.16	24.73 \pm 4.31	24.53 \pm 5.44	24.16 \pm 4.76	23.84 \pm 5.02
RL (cm)	12.074 \pm 2.57	13.12 \pm 3.14	13.33 \pm 3.19	13.09 \pm 2.82	12.27 \pm 2.65	12.48 \pm 3.05
LL (cm)	12.07 \pm 2.44	12.87 \pm 2.52	12.73 \pm 2.88	12.00 \pm 3.02	12.07 \pm 3.20	12.17 \pm 3.36

Note: VG: Whole-Body Vibration group ,NVG: No Whole-Body Vibration group

Sit and Reach

No significant interaction effect between group and time was found with respect to flexibility test after the end of the intervention programme ($F_{(2,29)} = 1.787, p=0.185, \eta^2=0.110$). The repeated measures ANOVA revealed significant differences with respect to time ($F_{(2,29)} = 11.885, p=0.000, \eta^2=0.450$). The differences were significant between pre and post 1 ($F_{(1,30)} = 20.620, p=0.000, \eta^2=0.399$), but not between post 1 and post 15 ($F_{(1,30)}=0.000, p= 1.000, \eta^2=0.000$). Inspection of mean scores revealed that the mean S&R score at post 1 was significantly higher than the mean score at pre-test. Examination of mean scores (Table 1) revealed that both the VG and NVG improved from pre to post 1 assessments. The improvement for the VG however was greater (6.35%) than that for the NVG (2.79%). Further, both groups maintained the increased flexibility at follow-up, 15 min later.

SJ

A significant interaction between group and time was found with respect to SJ ($F_{(2,29)} = 3.870, p=0.032, \eta^2=0.211$). The t-parameter estimates, however, revealed no significant differences between groups at pre-test ($t=0.463, p=0.646, \eta^2=0.007$), at post 1 ($t=0.837, p=0.409, \eta^2=0.023$) and post 15 ($t=0.063, p=0.950, \eta^2=0.000$). The repeated measures ANOVA revealed significant differences between a) pre and post 1 ($F_{(1,30)}=8.564, p=0.011, \eta^2=0.380$) and b) post 1 and post 15 ($F_{(1,30)}= 7.576, p=0.016,$

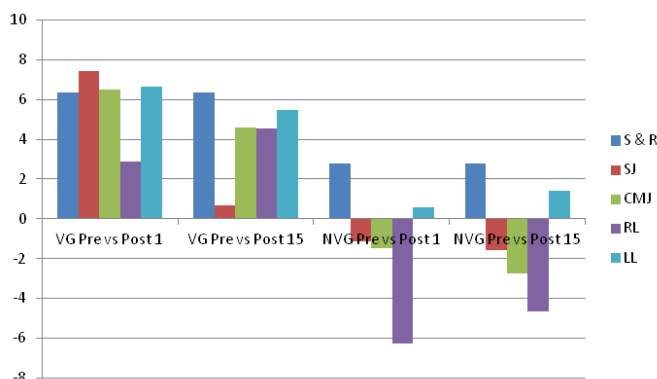


FIG. 1. PERCENT CHANGES (%) IN ALL EXAMINED VARIABLES FROM BASE-LINE FOLLOWING WBV PROTOCOL
Note: VG - vibration group, NVG - no vibration group

$\eta^2=0.351$) for the VG. Inspection of mean scores revealed that the mean SJ score at pre was significantly lower compared to mean scores at post 1, and mean score of post 1 was significantly higher compared to mean score of post 15 (table 1). The differences, however, were not significant for pre vs post 1 ($F_{(1,30)}=0.387$, $p=0.547$, $\eta^2=0.024$) and post 1 vs post 15 ($F_{(1,30)}=0.040$, $p=0.843$, $\eta^2=0.003$) for the NVG (table 1). The corresponding percent improvements for the VG and NVG were 7.45% and -1.16%, respectively. Further, the VG maintained the initial values 15 min after the end of vibration training with an improvement by 0.66%, whereas the NVG failed to maintain the baseline values in post-test assessments (-1.16% and -1.59%, respectively) (figure 1).

CMJ

No significant interaction between group and time was found with respect to CMJ ($F_{(2,29)}=2.200$, $p=0.129$, $\eta^2=0.132$). Further, the main effect was not significant for time ($F_{(2,29)}=1.760$, $p=0.190$, $\eta^2=0.108$) and therefore no post hoc analysis was conducted. Although no significant differences were found between groups in CMJ, the VG approached a significant level of improvement ($p=.061$), by an increase of 6.51% and 4.57% in post-vibration treatments. In contrast, the NVG failed to improve CMJ performance and a decrease by -1.47% and -2.77% was observed in post-vibration treatments (figure 1). It is noted that WBV training has a positive effect to maintain for 15 minutes the initial level of CMJ performance, whereas a progressive decrease appeared in the NVG.

RL and LL

No significant interaction between group and time was found with respect to RL ($F_{(2,29)}=1.623$, $p=0.215$, $\eta^2=0.101$) and with respect to LL ($F_{(2,29)}=0.858$, $p=0.434$, $\eta^2=0.056$). Further, the main effect was not significant for RL time ($F_{(2,29)}=0.266$, $p=0.768$, $\eta^2=0.018$) and for LL ($F_{(2,29)}=1.442$, $p=0.253$, $\eta^2=0.090$) and therefore no post hoc analysis was conducted.

In addition, no main effect was found for single leg squat performance for each group. It is noteworthy that RL performance, which was the dominant leg for all participants, in the VG revealed a progressive improvement in post-vibration treatments (2.90% and 4.54% for post-test immediately after, and 15 minutes later, respectively), whereas the NVG failed to maintain the baseline values (pre-test values) in post-test assessments (-6.26% and -4.66%, respectively) (figure 1). Also, although each group improved LL performance, percentage improvements were significantly higher in the VG (6.63% and 5.47%) compared to the NVG (0.58% and 1.42%) in post-vibration treatments.

DISCUSSION

The results of this study indicated that a single bout of WBV significantly improves flexibility and squat jump (SJ) performance immediately after the end of the intervention programme. This effect

was maintained for about 15 minutes after the intervention, which was not evident in the NVG. This is one of the first studies to examine the effects of an acute bout of WBV on flexibility and explosive strength of lower limbs in young competitive artistic gymnasts. Results of the present study support previous findings indicating that an acute bout of WBV may improve an athlete's flexibility [8,13] and jump height [8,13,16]. Specifically, the improvement by 6.35% in sit and reach test is lower compared with those of Cochrane and Stannard [8] and Fagnani et al. [13], who found an improvement of 8.7% and 13% respectively. Further, our finding is in agreement with the results of Kinser et al. [16], who examined split flexibility in young gymnasts using a local vibration device, and those of Jacobs and Burns [15]. This flexibility improvement following WBV suggests that the vibration exposure may have activated the Ia inhibitory interneurons of the antagonist muscle [20]. Further, the short duration and the light intensity of the intervention programme applied in our study produced a greater percentage improvement in flexibility compared to the traditional stretching programme used by gymnasts (Sands and colleagues [21]).

The significant effect that was revealed in the present study in SJ performance was verified with an increase by 7.45% in the VG. Further, an improvement in all examined strength variables was observed in post-vibration treatment in the VG (CMJ: 6.51%; RL: 2.90%; LL: 6.63%), whereas the corresponding percentage changes in the NVG were -1.47%, -6.26% and 0.58% respectively. The jump height of the VG during the CMJ and single leg squat jump (RL and LL) in the present study increased in post-test treatments compared to baseline values and significantly differed from those observed in the NVG immediately after and 15 minutes after the end of vibration. Our findings verify previous data indicating an improvement by 8.1-8.4% [8,13]. Further, the current finding of enhanced explosive strength of lower limbs is consistent with previous results that found acute improvements in vertical jump ability [1,4,10,11,24,25]. In contrast, our results disagree with the finding obtained by Rittweger et al. [18], who reported a significant decrease in jump height by 9.1% after vibration, and other studies that found no change in jump height [6,16].

Limitations

Certain limitations do not allow the generalization of the present findings without caution. First, the participants were only young gymnasts, at the age of 9 to 12 years old. Second, the duration of the vibration exposure was limited (15 s, for 5 exercises). Third, only the acute effect was examined and not the long-term effect. Finally, the effect of the vibration exposure with regard to other important variables, such as speed, balance and agility, needs to be examined in the future as well.

Recommendations for practitioners

The use of whole body vibration as a warm-up method may be incorporated during the training of young gymnasts. A single bout of

whole body vibration seems to be an effective tool to improve flexibility and strength. In the future, researchers may examine the long-term effect of whole body vibration in young gymnasts, in competitive athletes, and possibly compare the vibration to other traditional methods of training strength and flexibility.

CONCLUSIONS

The present study indicates an acute effect of using WBV in gymnasts who possess a level of flexibility and explosive strength of lower limbs. Further, WBV may prove effective as a pre-training activity in gymnastics sports where flexibility and muscle strength are dominant factors. Conclusively, a training unit of 120 s WBV led to greater

improvement in flexibility and explosive strength of lower limbs in young artistic gymnasts compared with those following traditional body weight training. In addition, research is needed to reveal whether different frequency and amplitude and/or longer exposure to the vibration stimuli have an additive effect to maintain this improvement for longer time in trained artistic gymnasts.

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