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Muscular Performance is Improved by Long-Term Whole-Body Vibration in Comparison to a Traditional Training Program

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Abstract

The current study aimed to explore the effect of long-term Whole-Body Vibration (WBV) in comparison to traditional training on muscular performance. Thirty healthy physical education students were randomly allocated into a Vibration Group (VG, n=13), which underwent a whole-body vibration training program with external load, and a Traditional Group (TG, n=17), which received the same training program without a vibration load. The study was composed of pre-test assessments, a 4-week intervention phase, and post-test assessments. During the intervention phase, the VG and TG performed three training sessions per week, including six sets of 30-sec squats with external loads. Assessments included: Maximal isometric muscle strength; Power (assessed by Squat Jump); Reactive strength (assessed by Counter-Movement Jump and Drop Jump); and Muscular endurance. The results revealed significant improvements in all measured variables among the participants in the VG from the pre-to post-tests ($p<0.05$). Among the TG participants, significant differences between the pre- and post-tests were found only in the Squat Jump and the Counter-Movement Jump ($p<0.01$). A significant Group X Time interaction was found in the Drop Jump test, implying greater improvement in the VG following the intervention. The findings suggest that it would be beneficial for athletes to train with WBV to improve different strength and performance components, rather than traditional resistance training, which has the disadvantage of being very specific and time-consuming.

Keywords: Whole-body vibration; Strength; Power; Reactive strength; Drop jump; Plyometric; Jump performance

Introduction

Resistance training, which uses a wide range of resistive loads–including body mass, free weights, and machine-based training, has become a fundamental part of athlete's physical preparation and development in many sports. However, it is well-documented that training-induced gains are reduced with increasing training experience. Thus, more advanced programs are needed for continuous progressive improvement [1,2].

Regarding advanced programs, there is discussion among coaching researchers about the importance of the specificity of the resistance training implemented. General resistance training stimulates different muscles and is usually aimed at increasing the muscles involved in the sport's skills. On the contrary, specific resistance training provides very similar stimuli to actual skills performed during competitions, and thus requires a separate time investment, specific to each muscle group involved in the performance [3].

One of the advanced resistance training methods that have become popular among athletes and coaches is the Whole-Body Vibration (WBV) training method. WBV is based on mechanical stimuli which are applied while the athlete stands on a platform that generates vertical or horizontal sinusoidal vibrations. These mechanical stimuli are transmitted into the body and stimulate the primary endings of the muscle spindles, which in turn activate α-motor neurons, resulting in muscle contractions known as tonic vibration reflex [4,5].

The WBV method has become a common training method for improving muscular strength and power [6-12], and is based on several mechanisms. It is also used for improving athletic performance [13,14], thus it could be considered as both a specific and a general advanced resistance training method. However, its effect on various components of strength and performance compared to traditional resistance training is inconsistent [15-19], as different studies report diverse methods, different vibration protocols, and different measurements [20]. Thus, the purpose of the current study was to explore the effect of long-term WBV training in comparison to traditional specific resistance training on various components of strength and athletic performance among physical education students.

Materials and Methods

Participants

Thirty healthy male physical education students volunteered to take part in the study. Their mean age was 24.00 ± 2.53 years, mean weight was 77.00 ± 8.68 kg, and mean height was 181.18 ± 7.00 cm. Participants were informed about the study protocol and signed an informed consent before participation. The Ethical Committee of the German Sport University Cologne approved the study, which was performed in consensus with all Helsinki requirements, and was conducted with the understanding and the consent of the human subjects. Inclusion criteria for participating in the study were: 1. Training regularly (at least twice a week), and 2. Having experience in resistance training with free weights. None of the participants took any food supplements or prescription medications while participating in the study. Exclusion criteria were a previous history of fractures or of other bone injuries.

Procedures

The study lasted six weeks. In the first week, two pre-test assessments were performed, followed by four weeks of the intervention phase, and an additional one week in which the participants partook in two post-test assessments. Using a controlled study design, the participants were randomly assigned to one of two study groups, after matching for strength assessments according to the pre-test assessments [13]. The Vibration Group (VG), which performed WBV during the intervention phase (n=13), and the

Traditional control Group (TG), which performed the same training program but without vibration loads (n=17).

The participants were asked to avoid any additional physical activity during the study (other than that in the study program).

During the study, seven participants who belonged to the TG were excluded, as they did not keep to their physical activity routine and added different training methods during the study period, and one participant from the VG missed the post-testing assessments.

Thus, only 22 participants were included in the final analysis: 12 from the VG and 10 from the TG.

Training protocol

During the 4 week intervention phase, the participants performed three training sessions per week, with a minimum of 48 hours between sessions.

All training sessions were performed at a gym while wearing sportswear and sneakers, during morning hours (2-3 hours after breakfast), with an average air temperature of about 18°C–22°C. The participants were instructed to drink 500 cc of water 30 min before each training session.

The training protocol was based on traditional strength training methods [21].

Each training session lasted approximately 40-50 min, beginning with a standard warm-up, followed by the training phase and a recovery phase. The training phase was composed of six sets of 30 sec exercises and a one-minute rest.

The exercise was based on dynamic back squats shoulder-width apart (between 10-12 repetitions) with external loads, using a special barbell (the hands could touch the device's support handle lightly and maintain stability).

The external load was adjusted to 40% of 1RM (based on strength evaluations assessed during the pre-test), considered a medium training intensity for athletes [21].

During the training session, the participants in the VG were standing on the WBV platform (Power Plate©) with constant vibration amplitudes in a vertical direction, at 4 mm.

The frequency of the vibrations was constant during each training session, and increased from 30 to 40 Hz after every four sessions.

Participants in the TG performed the same program on the gym's surface ground, without a vibrations load. It should be noted that during the training session, the participants were supervised by two assistants who were always present.

Table 1 presents the training progress over the 4-week program.

Training protocols along the intervention phase								
				Meso cycle of 4 weeks				
Groups	Pre-test		Standard loads	Sessions 1-4	Sessions 5-8	Sessions 9-12	Post-test	
VG	1	2	Exe: dynamic back squatTrain-freq: 3 X wk -1, 6 sets, Each Set included: 10-12 rep/30 sec External loads: 40% 1RM Resting time between Sets: 60 sec	4mm	4mm	4mm	1	2
				40Hz	35Hz	30Hz		
TG	1	2		X	X	X	1	2

Table 1: Training protocols along the intervention phase.

Figure 1: Training phase dynamic back squat; Left side: On the vibration plate (VG); Right side: On the ground without a vibration loads (TG).

Strength assessments

Based on the Bump and the Burleymodels [21,22], the strength and performance components measured in the current study were: maximal isometric strength, power (assessed by Static Vertical Jump), reactive strength (assessed by Dynamic Vertical Jump), and muscular endurance. Accordingly, pre- and post-training assessments included the following tests: Maximali sometric strength–static leg press on the isokinetic "Desmotronic" machine, which was performed in an upright sitting position (seat-back angle 85°C), with the knee angle at 120°C. During three successive trials (with 30-60 sec break), the participant was asked to produce maximum static contraction against rigid resistance. Each trial lasted up to 5 sec. Power was assessed by Squat Jump (SJ) height–a vertical jump performed from a squat (knee angle 90°) with the feet at hip distance apart, with no arm movements. Three SJs were performed with a 1 min break in between. Following each performance, the participants received feedback about their jump height (cm) and jump technique. The highest achievement was used for analysis.

Reactive strength was assessed by the Counter-Movement Jump (CMJ) and the Drop Jump (DJ) height. The CMJ was performed like the SJ with a fast flexion before the vertical jump. Three CMJs were performed with a 1 min break in between. Following each performance, the participants received feedback about their jump height (cm) and jump technique. The highest achievement was used for analysis. The DJ was performed by dropping from a box 40 cm high and, upon landing, jumping for a maximum vertical height with minimum ground contact time. Three DJ were performed with a 1 min break in between. Following each performance, the participants received feedback about their jump height (cm) and the jumping technique. 1RM evaluation–this value was calculated based upon the results of the 10RM back squat. The 10RM test was performed by knee extensions (dynamic back squat; the distance between the bench and ground was 52 cm, with the aim that all participants perform the same range) with a unique barbell that featured angled iron strips. An additional load was then increased every 2 min up to the individual maximum. Maximum 10RM was regarded as the load at which ten repetitions could be performed. Based on traditional methods, 1RM was calculated [23]. Maximal muscular endurance–maximum repetition number of knee extensions that could be achieved with a 40% load of 1RM [23].

Each assessment session began with a warm-up divided into a 5 min general and a 5 min specific warm-up for the respective jumps (SJ, CMJ, and DJ). Subsequently, the participants performed 5 min of flexibility exercises. During each of the two assessment time points, maximal isometric strength and all jump performances were performed, and the average between the two assessments was used for analysis. The maximal muscular endurance assessment was not performed during Pre-test 2 and Post-test 2 as it was based upon the 10RM assessment that was performed during the Pre-test-1 and Post-test-1 assessments.

Statistical analysis

Data were analyzed using the SPSS (SPSS Inc., Chicago, IL) statistical software package. Student t tests were used to examine differences between groups before the intervention phase, and a Group X Time repeated-measures Analysis of Variance (ANOVA) was used to examine within-group changes, and to investigate differences between groups over the time points (Pre-test-1 and 2 and Post-test-1 and 2 assessments) the Turkey's post hoc procedure was performed to identify the source of difference. All tests were two-tailed, and an alpha level of 0.05 was required for significance. Cohen's d procedure was used to evaluate the intervention effect sizes. Values are expressed as means SD.

Results

Pre-test assessments

There were no differences in any of the variables assessed between the groups prior to the training phase ($p>0.05$).

Post-test assessments

Changes in the assessed variables pre and post the intervention phase of both groups is presented in Table 2 and Figure 2. As can be seen in Table 2, all performances improved significantly from pre-test to post-test among the VG ($p<0.05$), but not among the TG. For the TG group only two tests significantly improved from pre-test to post-test (SJ and CMJ) ($p<0.01$). As can be seen in Table 2, on the maximal isometric strength the VG had significant improvement ($p<0.05$), with no significant change among TG; on the maximal endurance test the VG showed significant improvement ($p<0.01$) with no significant change among TG; on the SJ and CMJ tests both VG and TG showed significant improvement ($p<0.01$); on the DJ test the VG showed significant improvement ($p<0.01$), with no significant change among the TG. Additionally, significant groups X time interaction was found ($F1, 20=6.62$, $p<0.018$).

Vibration group (VG) N=12								
[Variable]	Pre	Post	%	ES	time F (1, 20)	p	time *group F (1, 20)	p
Maximal isometric strength (N)	4439.2 ± 1058.43	5093.6 ± 1149.15*	14.74	0.62	7.88	<0.05*	1.75	0.2
Maximal muscle endurance (rep)	27.82 ± 9.57	38.82 ± 11.05**	39.54	1.15	9.07	<0.05*	0.67	0.42
Squat Jump (cm)	38.7 ± 4.68	45.56 ± 3.68**	17.72	1.47	96.23	<0.001**	0.05	0.82
Counter-Movement Jump (cm)	41.89 ± 4.85	46.77 ± 3.62**	11.66	1.01	65.58	<0.001**	0.16	0.69
Drop Jump (cm)	31.54 ± 4.19	36.76 ± 4.66**	16.53	1.24	10.75	<0.05*	6.62	0.018*

Traditional group (Control group) (TG) N=10				
Variable	Pre	Post	%	ES
Maximal isometric strength (N)	4683.30 ± 680.01	4918.50 ± 864.92	5.02	0.35
Maximal muscle endurance (rep)	34.50 ± 11.60	40.80 ± 23.10	18.26	0.54
Squat jump (cm)	38.93 ± 5.91	45.48 ± 6.04**	16.83	1.11
Counter-Movement jump (cm)	42.99 ± 5.85	47.42 ± 7.10**	10.29	0.76
Drop Jump (cm)	34.06 ± 6.55	34.69 ± 6.45	1.85	0.1

Table 2: Changes in strength components among VG versus TG (means ± SD). *: Significant differences between groups (p<.05); **: Significant differences between groups (p<.01); ES: Effect Size (Cohen's d).

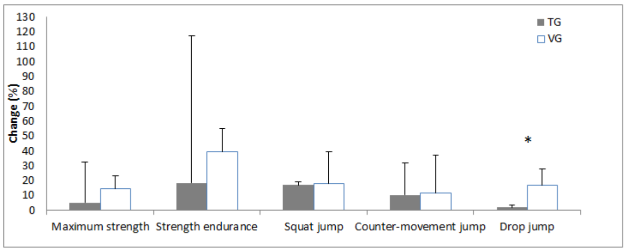

Figure 2: Changes in strength performance among the VG versus TG following the intervention phase. Notes: Significant Group × Time interaction (p<0.005).

Discussion

The purpose of the current study was to explore the effect of long-term WBV training compared to traditional specific (dynamic back squat) resistance training on various components of strength and athletic performance among physical education students. This study's main findings point to a general significant improving effect of the strengthening program with the WBV approach, with only two specific components that showed significant changes among participants in the TG.

The results found in the present study are in line with findings that emerged in other studies which found a specific improvement in the performance of the task that participants practiced during the intervention phase [24,25]. Dynamic back squat training that progressed during the intervention phase of the current study, using a higher load each week, improved the performance of the vertical jump. Both SJ and CMJ are performed in almost the same manner that the squat exercises were performed (except for the actual jump). The specific improvement due to squat training is consistent with the specificity principle that underlies many types of resistance training among athletes and coaches. According to this principle, to improve strength, one should practice resistance exercises designed specifically to improve the strength of one joint or several joints. This type of training requires the investment of time for each component individually [3]. In contrast, the accompanying dynamic back squat training with WBV has led to an improvement in additional performances beyond vertical jumping, raising the possibility that there may be a transferal from one training mode to other abilities and performances. This finding regarding improvement in a variety of components following WBV-trained back squat training are in line with previous results about the effect of long-term WBV on power, as represented by SJ achievements [14,20,26-29]. A possible explanation for this positive effect is based on the fact that the SJ is mainly achieved by the requirement of Fast-Twitch (FT) fibers. The higher the proportion of FT muscle fibers activated in a specific movement, the higher the jump is [30]. It was found that WBV training irritates the neural system in a way that causes higher and faster motor units' requirement [4,5]; thus, training with WBV improves the motor units' requirement and accordingly improves performances that are based upon the fast motor units' requirement.

Although on both SJ and CMJ the improvement found in the current study was almost the same for VG and TG, the fact that the participants from VG had significant improvements in the DJ is of practical importance for athletes and coaches. Reactive strength, which is the main component that affects DJ, is very important in sports, including running at high velocity or rapid changes of direction in gymnastic and ball games. DJ performance is based upon the ability to recruit concentric contraction following landing from a drop of 40 cm and a very short ground contact time [31]; thus, the musculo-neural system has to adjust to changes in the direction of contractions very quickly. One possible explanation for changes in that ability following WBV training is based on biomechanical properties of the muscles, and on the neural system's possible change [4,26,32]. This change enables higher jumps through improved biomechanical means (better storage of kinetic energy over the flexible muscle component) and neurophysiological means (improved stretch-shortening cycle; SSC) [33]. Both CMJ and DJ are based on optimal use of the SSC [32]. The SSC is defined as the combination of eccentric followed by concentric contractions of the same muscle (also known as plyometric muscle action), which causes a higher amount of force during the concentric phase, compared with the concentric contraction performed from a static position [34,35]. Based on our results and those of several others, it is reasonable to assume that WBV training leads to improved performance based on SSC actions [13]. The positive effect of chronic WBV training on these actions may be explained by the fact that during WBV exercise, the muscles (with other soft tissues) have to regulate the transmission of the vibrations through the body. During the intervention phase, those muscles change their responses to external forces by adapting their biomechanical characteristics and changes that occurred in the neural system [36]. The positive effect of WBV training on maximal and endurance strength among VG participants found in the current study may be explained by the metabolic effect of WBV [36]. WBV training has shown metabolic responses similar to other forms of resistance training that cause fatigue and impaired neural performance immediately following the training. However, after a 20 sec rest, the muscles' performance was recovered. Additionally, chronic WBV training led to a reduction of blood viscosity and increased blood speed through the arteries [17,37]. The irritation applied by the vibrations during the VG intervention in the current study is assumed to be significant, as those two variables (maximal and endurance strength) did not improve significantly among participants in the TG. These findings align with Rønnestad [38], who reported that WBV led to improvement in squat 1RM compared with no vibration in both trained and untrained participants. Such evidence was also suggested in a systematic review by Rehn et al., [30]. In contrast, a study by Weier et al., [12] studied untrained participants assigned to loaded squat training with or without WBV (f=35 Hz; A=2.5 mm) for four weeks. They found significant increases in 1RM squat over time, but detected no differences between groups. However, Rosenberger et al., [11] trained recreationally active subjects with six weeks of squatting with heavy loads. They found no difference in thigh muscle hypertrophy or strength performance between those who trained with progressively intense WBV and those who did not. Preatoni et al., [9] compared two groups of high-level female athletes undergoing eight weeks of periodized squatting with a low-intensity load without or with WBV (f=25–40 Hz; a=4 mm). They found no differences between groups in isometric or dynamic maximal force output or power generation as measured by a vertical jump performance test. Finally, Goodwill et al., [7] compared two training groups for three weeks who performed single-leg heavy squats with or without WBV (f=35 Hz; a=2.5 mm) and showed no differences in maximal strength assessed by the 1RM test.

It should be noted that while the improvement found in DJ among VG participant in the current study is supported by previous studies [27,39,40], Spitzenpfeil [15] found no improvements of DJ following long-term WBV training, while Ziegler [29] reported a decline of about 4% in DJ following WBV. Additionally, while in the current study CMJ was improved significantly among both groups (VG and TG), Ziegler [29], Rehn et al., [30], Torvinen et al., [41] and Berschin et al., [42] found that strength training with vibration loads was more effective in comparison to a traditional training program on CMJ performance (effect size=0.77). In contrast, Spitzenpfeil [15], Cochrane et al., [16] and Rittweger et al., [17] and Rittweger et al., [18] reported a decline in the SJ performance among the WBV groups. Kvorning et al., [19] also showed no additive effect of WBV (f=20–25 Hz; amplitude=4 mm) on strength and jump performance after nine weeks of heavy squat training in relatively untrained subjects.

As was mentioned earlier, the different results between studies may have used various WBV protocols. The limitation of the current study is that the WBV protocol used in the current study was based on one certain vibration amplitude and specific progressive frequencies. Certain amplitudes in certain frequencies may be needed for the improvement of each variable.

Conclusion

Based on the current study's results, we can conclude that a 4 week resistance training program with WBV and medium external load (back squat with 40% 1RM) has a positive effect on different components of strength and performance. Thus, athletes and coaches who want to upgrade their training programs can consider advanced WBV resistance programs, as they may improve different components of strength and performance, over the same period of time of traditional training. Future studies should evaluate the effect of the same training protocol with different vibration amplitudes and frequencies.

Conflict of Interest

The authors declare no conflict of interest.

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