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Research Article

WHOLE BODY VIBRATION: ACUTE AND RESIDUAL EFFECT ON THE EXPLOSIVE STRENGTH

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ABSTRACT
The whole body vibrations (WBV) it is nowadays one of the most widely used methods for improving the explosive strength. This seems to produce similar effects than those found after applying a eccentric-concentric cycle. In this study, 12 subjects participating in recreational physical activity were allocated to 5 sets of 60 s of WBV exposure, using a frequency of 30 Hz, and 2.5 mm of amplitude, maintaining an static position (110 ° bending knees) on a vibratory platform (Galileo Fitness®; Novotech, Germany). The results showed an increase (not significant) in SJ (+1.76 ± 4.05 cm) and CMJ (+1.10 ± 3.20 cm) in the post-test conducted just after the vibration. The values of the post-test performed 30 min after SJ remained above the pre-test ones but just below the immediate post-test ones (+0.42 ± 4.43 cm). By contrast, the values in CMJ dropped below the pre-test ones (-0.12 ± 2.45 cm). Based on these data it seems that when the frequency is not high it is necessary to use greater amplitude in order to achieve the desired effects. The effect achieved after the vibration is transient, not remaining after 30 min.

Key words: Whole body vibrations (WBV), Counter-Movement Jump (CMJ), Squat jump (SJ), Explosive Strength.

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INTRODUCTION

Whole body vibration (WBV) is nowadays one of the main lines of research due to the multiple possible effects on the body (Cardinale & Bosco, 2003). Some studies have shown how low amplitude and high frequency vibration can improve strength, balance and hormonal profile (Bosco et al., 1998, 1999a, 1999b, 1999c, 1999d, 2000; Delecluse, Roelants, & Verschueren, 2003; Rittweger, Beller, & Felsenberg, 2000; Rubin et al., 2001; Verschueren et al., 2004; Ward et al., 2004; Torvinen et al., 2002a; Cardinale & Bosco, 2003; Di Loreto et al., 2004; Kvorning et al., 2006, Bazzet-Jones, Finch & Dugan, 2008; Da Silva et al., 2009) between other outcomes.

In the WBV training the subject is placed on the platform adopting a bilateral squat for a period of time. Platforms currently in use provide a sinusoidal vibration that is transmitted to the body by stimulating sensory receptors, mainly muscle spindles. This causes the activation of α-motorneurons and initiates a muscular contraction comparable to that produced by the tonic vibratory reflex (TVR; Hagbarth & Eklund, 1965).

Vibration features of the WBV must be defined, therefore parameters such as frequency used (cycles per time unit, measured in Hz), amplitude (half the difference between the maximum and minimum value of the periodic oscillations, measured in mm), magnitude or acceleration (derived from the frequency and amplitude what is obtained indirectly through the formula suggested by Wilcock et al. (2009), a = (2πf)2/2g√2) and the duration (Cordo et al., 1995; Luo, McNamara, & Moran, 2005) should be controlled. Frequencies used for these exercises ranging from 15 to 44 Hz, while amplitudes are between 3 to 10 mm. Finally, the vibration caused a disturbance of the mass centre during the intervention due to the acceleration values ranging from 3.5 to 15 g (where g is the gravity = 9.81 m/s2) which has been suggested to increased strength development (Cardinale & Bosco, 2003). With regard to the duration, short exposures, for example 4 to 5 min divided into sets of 1 min with the same rest period between sets, are enough to improve muscle strength (Rittweger et al., 2000). In general, intermittent programmes for no more than 30 min can be recommended. However, increments in the length of vibration could trigger the onset of fatigue (Cardinale & Bosco, 2003) and also, longer applications may trigger the inhibitory feedback (e.g. Golgi complex) or reduce the sensitivity of muscle spindles (Cardinale & Bosco, 2003).

Due to the large number of parameters one must to control when prescribing a WBV training programme, any small change in one of them can lead greater neuromuscular changes. Thus, in relation to muscle power, different studies showed significant improvements after acute exposure (Bosco et al., 2000; Torvinen et al., 2002b; Cardinale & Lim, 2003; Cochrane & Standard, 2005; Cormie et al., 2006, Da Silva et al, 2006; Bazett-Jones et al., 2008; Da Silva et al., 2009; Bedient et al., 2009) however, other authors found no improvements or even decrements in some outcomes after WBV exposures (Torvinen et al., 2002a; Cochrane, Legg, &Hooker, 2004; Bosco et al., 1999c; Ritweger et al., 2000; Cardinale & Lim, 2003; Da Silva et al., 2006; Bazett-Jones et al., 2008; Bedient et al., 2009).

Based on the aforementioned data, it is necessary to further analyze the effects of different WBV protocols on these variables in order to establish a possible dose response relationship between those parameters. Therefore, the aim of the current study is to determine the acute and residual

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effect (after 30 min) of a single session of WBV on explosive strength assessed by countermovement jump (CMJ) and squat jump (SJ).

MATERIAL AND METHODS

Subjects
Twelve subjects (22.9 ± 5.1 years) participating in recreational physical activity were involved in this study. They all signed informed consent and the protocol was approved by the ethics committee of the University of Seville. Exclusion criteria include the existence of cardiovascular, respiratory, abdominal, urinary, musculoskeletal or chronic diseases, as well as the presence of prostheses. Participants taking any medication that could affect the musculoskeletal system were also excluded.

Procedures
All participants were invited to attend a familiarization session before the study where they were instructed how to perform SJ and CMJ jumps as well as the platform working with the protocol used on the study. All attend to three pre-test sessions and results were correlated in order to obtain the reliability ($r > 0.85$). The third pre-test was taking as baseline.

After each intervention one post-test was carried out, analyzing the same parameters in order to identify possible variations between both tests. The assessment it was performed just after the vibration and after 30 min in order to determine the residual effect due to several authors found that the effect of mechanical vibrations is transitory (Torvinen et al., 2002, 2002a, 2002b; Cormie et al., 2006; Bendiet et al., 2009).

During the three weeks before the study started it was not allowed the training of the explosive strength or the jump ability. Alcohol consumption or strenuous physical activity it was not allowed the day before each test.

With regard to the protocol it was used the Galileo Fitness® platform (Novotech, Germany), with a frecuency of 30 Hz and an amplitude of 2.5 mm. The gravity obtained was 9.1 g. Participants stood with both knees in 120 ° isometric knee flexion (half squatting position) as measured by a goniometer. The duration of vibration used for this study was 5 sets of 60 s with another 60 s rest between bouts.

Every subject performed three CMJ and another three SJ in accordance with the protocol proposed by Cronin & McLean (2000). Each jump was recorded with precision of 0.1 cm. Rest time was 30 s between two consecutive jumps. If the difference between jump's heights was more than 5% another attempt was performed. The best of the three attemps was recorded. All the jumps were performed on an Ergo Tester ® contact platform (Globus, Italy).

Statistical Analysis

All data were typed on a database and then analyzed using SPSS 15.0 for Windows. Normality of data was initially tested using the Kolgomorov–Smirnov test. Pearson correlation coefficients were used to assess the linear relationship between outcomes. Differences between the baseline

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characteristics of the participants were tested using analyses of variance (ANOVA) for continuous variables. Changes in the dependent variables resulting from the exercise intervention were assessed by repeated-measures ANOVA. We report effect sizes in Cohen's d, which can be derived directly from r values. Cohen's d represents the standardized mean difference between the acute and residual effects (effect sizes of .20 are small, .50 are medium, and .80 are large). Results are expressed as means ± standard deviation or 95% confidence interval and for all tests the significance level was set at $p < 0.05$.

RESULTS

All subjects completed the study without any side effect nor any adverse reactions or fatigue after the vibration. Most of the subjects reported that WBV mainly stimulated their lower limbs. With regard to the test after the vibration, the immediate post-test data showed an acute increment in both jump tests. However, there were not significant differences (Table 1).

Table 1. *Comparison between the results obtained from the jump´s acute effect after the test.*

	Paired analysis	Mean	SD	*d*	*r*	*p*
Pair 1	**HSJpre3 (cm)**	26.13	4.33	0.39	0.19	0.20
	HSJpostAG1 (cm)	27.89	4.63			
Pair 2	**HCMJpre3 (cm)**	34.05	5.38	0.21	0.10	0.31
	HCMJpostAG1 (cm)	35.15	5.15			

HSJpre3: Jump height in SJ from pre-test; HSJpostAG1: Jump height in SJ just after the test; HCMJpre3: Jump height in CMJ from pre-test; HCMJpostAG1: Jump height in CMJ just after the test. d: Cohen´s Standard; r: effect size

Regarding the residual effect, the improvement obtained remains in SJ, although below the post-test´s values. CMJ results drop below the pre-test´s values (Table 2).

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***Table 2.** Comparison of the data obtained from the residual effect after the jump with the pre-test.*

	GROUP 1	Mean	SD	*d*	*r*	*P*
Pair 1	**HSJpre3 (cm)**	26.13	4.33	0.10	0.05	0.77
	HSJpost301 (cm)	26.55	4.23			
Pair 2	**HCMJpre3 (cm)**	34.05	5.38	0.02 *	0.01 *	0.88
	HCMJpost301 (cm)	33.93	4.93			

*HSJpre3: Jump height in SJ from pre-test; HSJpost301: Jump heiht in SJ 30 min after the test; HCMJpre3: Jump heght with CMJ in pre-test; HCMJpost301: Jump height with CMJ 30 min after the test. d: Cohen's Standard; r: effect size. * Negative effect.*

DISCUSSION

In the last years, the vibrating platforms devices have become widely used by athletes. It has been promoted the commercial use of the WBV as an attractive and effective complement to the training against resistance although the results presented in this regard are contradictory (Bazett-Jones, 2008).

In this study, the results did not produce statistically significant changes in either of the two jump tests after the experimental situation; however the increments found were notables, increasing by 6.74% SJ and 3.23% in CMJ. These results contrast with those obtained previously by Torvinen et al., (2002a) in a study with similar characteristics. Authors ran the trial with 16 volunteers who performed 4 bouts of 1 min each, at a frequencies of 25-30-35-40 Hz and 2 mm of amplitude. The post-test carried out 2 min after vibration showed no significant increase in the CMJ (2.2%). In the same line, Cormie et al. (2006), found after the application of a WBV session at 30 Hz and 2.5 mm non-significant increments in CMJ (0.7%) compared with baseline data. Bazett-Jones et al. (2008) analyzed the effects of various combinations of frequencies and amplitudes in men and woman (30 Hz, 2-4mm, 40 Hz, 2-4 mm, 35 Hz, 4-6 mm, 50 Hz, 4-6 mm). For the men group none of the combinations provided statistically significant improvements in CMJ heights.

Da Silva et al. (2006), in their work, maintained the same stimulation frequency (30Hz), but with higher amplitude (4 mm) found significant changes. Results showed an improvement of 3.37% for SJ ($p < 0.001$) and 14.36% for the CMJ ($p < 0.01$). On the other hand, Martínez et al. (2007) analyzed the effect from a single bout of 1 min on the SJ ability in 15 healthy subjects. They used small amplitudes (2 mm), while the frequency was much higher (50 Hz). Authors showed a significant improvement after 2 min ($p < 0.05$). Moreover, with high frequencies and amplitudes (40 Hz and 4 mm), Cardinale and Lim (2003) studied the effect of WBV on SJ and CMJ jumps. Data from post-test were lower than those obtained in the pre-test. While the decrement observed

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in SJ was not statistically significant (- 4%, p = 0.07) the one in CMJ experienced a statistically significant decrement (- 3.8%, p <0001).

It seems therefore, that when vibration does not produce fatigue and is of brief duration it can produce an increase of nervous system signals and facilitate the strength generation (Cardinale & Bosco, 2003). On the other side, when the opposite occurs, ie. the vibration supposed a stressful stimulus that causes fatigue, the power generation decreases. The results suggest that when the frequency is 30 Hz greater amplitude than the one used in the current study is needed to achieve significant acute improvements in jumping ability, whereas when the frequency is greater, lower amplitudes should be used to avoid muscle fatigue.

Regarding the residual effect, some authors suggest that the vibration effect seems to be transitional on the muscle performance (Torvinen et al., 2002a). These authors found in their studies that the higher increments founds 2 min after the CMJ were not present 60 min after them (Torvinen et al, 2002a, 2002b). In our case, the residual effect was measured at 30 min, showing an increment for SJ (1.61%) with regard to the pre-test, although just 6.74% was found in the immediate post-test. The CMJ drop below the pre-test level (-0.35%). Similar results were observed by Cormie et al. (2006) in both jump height and power generated in CMJ (-0.5%) in the post-tests performed 15 and 30 min after the vibration. Our results also contrast with the ones presented by Torvinen et al (2002a), who used the same amplitude (2 mm). So, after 60 min there was a fall below the pre-test level in CMJ. Bendiet et al. (2009) also showed that the effect of WBV on jumping ability measured with CMJ was maximum 1 min after exposure, while after 5 min benefits showed a gradual decline (maximum after 10 min).

CONCLUSIONS

Several studies have tried to understand the acute and residual effect of WBV, although, due to numerous factors to be checked when using this training method, today is difficult to determine which are the most accurate parameters one must have into account to obtain the greatest results.

The results obtained in this study let us to go further in the study of WBV. Thus, it seems that when the frequency used is not high is necessary to use greater amplitudes to achieve wider benefits on explosive strength. On the other hand, improvements found were not maintained after 30 min, so one may consider that the effect reached with the WBV training is transient.

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