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Acute effects of whole body vibration on functional capabilities of skeletal muscle

Los efectos agudos de la vibración corporal total sobre las capacidades funcionales del músculo esquelético

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Abstract. The focus of this research was to evaluate the effect whole body vibration (WBV) on measures of muscular contractile function. In addition, this research was conducted to compare the effects of WBV on athletes versus non-athletes. Nineteen male, non-athlete college students, as well as eighteen male Division I collegiate athletes participated in this research. All participants completed 2 conditions, vibration and no vibration, in a randomized order. Participants were exposed to either a 2-minute bout of vibration or a 2-minute no vibration condition. Immediately following both conditions, participants were tested for peak vertical jump height, isokinetic peak torque and average power of knee extensors and flexors, and anaerobic power during a 30-second maximal effort cycle task. Results showed a significant improvement in knee flexion peak torque at 6.28 rad·sec^{-1} in the athlete group following the vibration condition. Results also showed a trend toward a significant improvement in knee extensor and knee flexor average power at 6.28 rad×sec^{-1} in the athlete group following the vibration condition. There were no significant changes in any isokinetic measure for the non-athlete group. There were no significant changes in vertical jump or anaerobic power for either group. This may be due in part to the complexity of the dose-response relationship, which is largely dictated by the parameters of vibration frequency, amplitude, and duration. However, previous studies have found positive results using similar protocols as the present study. Practically speaking, the use of WBV prior to exercise may result in facilitated contractile and athletic performance. Consequently, this study sought to describe the impact of using WBV prior to exercise on muscle function.
Key Words. Performance enhancement; Athletes; Power; Muscle Performance
Resumen. El objetivo de esta investigación fue evaluar el efecto de la vibración de cuerpo entero (WBV) sobre parámetros de la función contráctil muscular. Además, esta investigación se realizó para comparar los efectos de la WBV en atletas en comparación con no atletas. Diecinueve hombres, estudiantes universitarios no deportistas, así como 18 hombres, atletas de División I universitaria participaron en esta investigación. Todos los participantes completaron dos condiciones en orden aleatorio: la vibración y la ausencia de vibración. Los participantes fueron expuestos a 2 min de vibración o una condición de no vibración por dos minutos. Inmediatamente después de ambas condiciones, a los participantes se les midió la altura pico de salto vertical, el torque pico isocinético, la potencia media de extensores y flexores de la rodilla y la potencia anaeróbica durante una tarea de ciclo de esfuerzo máximo 30 s. Los resultados muestran una mejoría significativa en el torque pico de la rodilla a 6.28 rad·sec^{-1} en el grupo de deportistas luego de la condición de vibración. Los resultados también muestran una tendencia hacia un aumento significativo en la potencia promedio de los flexores y extensores de la rodilla a 6.28 rad·sec^{-1} en el grupo de deportistas luego de la condición de vibración. No hubo cambios significativos en las variables isocinéticas en el grupo de no atletas. Tampoco hubo cambios significativos en el salto vertical ni en la potencia anaeróbica en ambos grupos. Esto puede explicarse en parte a la complejidad de la relación de dosis-respuesta, la cual está ampliamente determinada por los parámetros de frecuencia, amplitud y duración de la vibración. Sin embargo, estudios previos han encontrado resultados positivos utilizando protocolos similares a los del presente estudio. En términos prácticos, el uso de WBV antes del ejercicio puede resultar en una mejor contractilidad y rendimiento deportivo. En consecuencia, este estudio trató de describir el impacto del uso de WBV antes del ejercicio en la función muscular.
Palabras claves. mejora del rendimiento, atletas, potencia, rendimiento muscular

Introduction

In athletics, the area of performance enhancement is ever expanding. One category in particular that receives a great deal of interest in the literature is ergogenic aids. Ergogenic aids are external influences that are used in an attempt to improve performance. These include mechanical, pharmacological, psychological, physiological, and nutritional aids. Whole body vibration (WBV) is a technology that has recently been investigated as a mechanical ergogenic device. WBV has been studied in both chronic and acute settings, with acute applications being more geared toward the enhancement of muscular performance. While the focus of the current study is on the acute effects of WBV, it should also be noted that there has been significant research investigating prolonged WBV use. These studies have examined various age groups and have found WBV to have positive effects on muscle strengthening, balance, and bone density (Bogaerts et al., 2007; Jordan et al., 20109, Verschueren et al., 2006).

Acute applications of WBV have been shown to be successful in improving muscular performance (Bosco et al., 2000; Cochrane & Stannard, 2005; Cochrane et al., 2008; Cormie et al., 2006; Gerodimas et al., 2010; McBride et al., 2010). Studies have shown that acute use of WBV can have a positive effect on vertical jump, isometric squat peak force, muscle twitch torque, maximal voluntary contraction, peak isometric torque, neuronal excitability, neuromuscular response, and hormone release. The acute hormonal changes seen following WBV may serve to facilitate training-related fitness gains.

In a study of elite female field hockey players, Cochrane and Stannard (2005) examined the acute effects of WBV on arm countermovement vertical jump (ACMVJ), flexibility, and grip strength. This study compared the effects of a WBV to that of stationary cycling and a non-vibrating control condition. A positive condition*time interaction was found for ACMVJ as well as flexibility with the WBV condition eliciting a superior response for ACMVJ and flexibility. Given these improvements in ACMVJ and flexibility, the researchers suggest that WBV may be an effective means of warming up. In a similar study of potential warm up modalities, Cochrane et al. (2008) compared the effects of WBV to stationary cycling and a hot water bath passive warm-up. All three interventions showed a significant increase in CMVJ peak power and height, but WBV increased temperature of the leg muscles more rapidly than the cycling or hot water bath. Because of this, the researchers again noted the potential for WBV to be used as a warm up prior to athletic competition. Much like the results of Cochrane and Stannard (2005) and Cochrane et al. (2008), Cormie et al. (2006) also found WBV to improve CMVJ in moderately resistance trained males.

Concomitant with the importance of performance enhancement is the necessity to understand the neuromuscular effects of WBV. In order to shed light on this area, Bosco et al. (2000) measured average velocity, acceleration, average force, and power during a leg press exercise. The researchers posited that neuromuscular activation caused by WBV might lead to improved neuromuscular function. The results showed a significant increase in power output of the leg extensor muscles, as well as a significant increase in ACMVJ following WBV. The researchers attributed these results to a potential increase in neuromuscular efficiency due to the WBV. In a related study, McBride et al. (2010) also investigated the neuromuscular response following a bout of WBV. The researchers found that the WBV group significantly increased peak force during maximal voluntary contraction of knee extensors by 9.4% immediately

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post and 10.4% eight minutes post vibration. The findings of these studies support the hypothesis that WBV positively impacts neuromuscular function of the lower limb.

Because it is a new ergogenic modality, there is a need to explore and further clarify the appropriate dosing for WBV. To elucidate the relationship between WBV duration and effect, Stewart et al. (2009) investigated the impact of vibration duration on the effectiveness of WBV. Participants were pre-tested for peak and mean torque of the knee extensor muscles. All subjects then completed three sessions lasting 2, 4, and 6 minutes, which were administered in a balanced, randomized order. Peak and mean torque were recorded during three maximal 2-second contractions. The data showed that only the 2-minute vibration protocol led to significant improvement in peak and mean torque. Both the 4-minute and 6-minute protocols had a significant, negative effect on torque output. Given these results it is evident that contractile function can be improved by WBV, but optimal WBV duration has yet to be established.

Despite the prevalence of positive results, the findings in regard to the acute effect of WBV on muscular performance have been inconsistent. Studies have found that exposure to WBV does not necessarily improve muscular performance, and in some cases can even produce a significant decrease in knee extensor and knee flexor MVC (de Ruiter et al., 2003; Erskine et al., 2007; Jordan et al., 2010). Studies using similar measures have shown very different outcomes, and it is not presently apparent why this is. It is clear that this is an area that warrants continued investigation given the number of studies that have found positive results. Therefore, the purpose of this investigation was to describe the effects of WBV on muscle performance among collegiate athletes and non-athletes.

Methods

Experimental Approach to the Problem

This study was a repeated measures design, with the condition being administered in a randomized and counterbalanced fashion. The study protocol required participants to complete two sessions, one for each condition. The two conditions were vibration and control. The protocol was identical for both conditions with the only difference being whether or not vibration was administered. The order of the performance tests was identical for all participants and sessions. The test order was designed to minimize the impact one test might have on another.

Subjects

Nineteen, non-athlete college men, as well as, 18 Division I collegiate athlete men agreed to participate in this study. See Table 1 for descriptive information concerning the sample. The non-athlete participants were recreationally active, but were not participating in any competitive sports. Before testing, all participants signed an informed consent form that was approved by the University's Institutional Review Board prior to participation in the study. Participants also received a twenty-dollar gift card as compensation for their participation.

Table 1.
Participant Characteristics (Means ± Standard Deviation)

	Athlete (n = 18)	Non-athlete (n = 19)
Age (years)	19.8 ± 2.8	21.2 ± 1.9
Height (cm)	186.4 ± 8.4	178.7 ± 9.2
Weight (kg)	97.7 ± 21.1	80.2 ± 14.1
Percent body fat	16.8 ± 6.5	13.2 ± 6.0
BMI (kg/m^2)	28.0 ± 5.4	24.8 ± 2.7

Measures

A vertical jump test was used as a functional measure of anaerobic power. Data was collected using a Just Jump vertical jump testing mat (Probotics, Inc. Huntsville, Alabama). Participants stepped onto the mat and were instructed to jump as high as they could whenever ready. Three measurements of maximal jump height were recorded. The control module for the mat records contact time between liftoff and landing, and uses this time in air to calculate height jumped. Leard et al. (2007) found the Just Jump timing system to be a valid measure of vertical jump when compared with a three-camera system (r = 0.967, $p < 0.001$).

The Biodex™ System 2 Isokinetic Dynamometer was used to measure peak torque and average power, which are measures of skeletal muscle contractile function. In an isokinetic assessment the participant gives maximal force against a device that limits the speed at which a movement can be performed. The six speeds used in this testing were 1.05, 2.09, 3.14, 4.19, 5.24, and 6.28 radians · sec^{-1}. Three repetitions were performed at each speed.

The Wingate anaerobic cycle test was also used to measure anaerobic power as well as anaerobic capacity. This test required the participant to pedal a stationary bike for thirty seconds at maximal effort against a resistance defined as 7.5% of the participant's bodyweight. This test measured peak power and power drop.

Apparatus

The vibration platform used in this study was a NitroFit Deluxe™ model (Medvibe LLC, Scottsdale, Arizona). This device vibrates in a sinusoidal manner, with the axis of rotation between the feet. For this research, the platform generated vibrations at a 13 mm peak-to-peak amplitude. Frequency was set at a 30 Hz level, which was found by Cardinale, & Lim (2003) to be the frequency of vibration that elicited the greatest EMG activation of the vastus lateralis muscle when in a half squat position.

Procedure

Upon arriving at the laboratory for their first session, participants read and signed an informed consent form. Participants also completed a physical activity questionnaire, which asked them to report about their current, regular physical activity habits (e.g. running, biking, weight training etc.). Anthropometric measures of height, weight, body mass index (BMI), and percent body fat were then recorded. Percent body fat was measured using an Omron Body HBF-306C Body Fat Analyzer (Omron, Kyoto, Japan). Participants were then subjected to either the vibration or no vibration condition, with order dictated by random assignment.

The Vibration treatment protocol required participants to stand on a vibration platform (with their shoes off) at 120º of knee flexion while holding on to handles affixed to the vibration apparatus. After two minutes of vibration, participants were instructed to put their shoes back on and complete three vertical jumps for maximal height on the Just Jump vertical jump testing mat (Probotics, Inc. Huntsville, Alabama). Contractile function of the knee extensors and flexors was then measured on a Biodex System 2 Isokinetic dynamometer. Participants were asked to perform repetitions of maximal effort knee extension and flexion at six speeds: 1.05, 2.09, 3.14, 4.19, 5.24, and 6.28 radians · sec^{-1}. Order of speeds was randomly assigned for each participant in order to eliminate any potential ordering effect. For each trial, participants were told to put their arms across their chest as to not brace against the machine and to begin with their leg in a flexed position. They were then instructed to begin when given a verbal signal of «3, 2, 1, Go» from the tester and to stop when given a verbal signal of «relax». One minute of rest was given between each of the six trials.

After completing measures on the Biodex, participants were then asked to complete a 30-second Wingate anaerobic cycle test. Participants then returned to the lab no less than 48 hours later to complete the other protocol (vibration or no treatment). Sessions were scheduled such that each one took place at a similar time of day to account for diurnal variations.

Statistical Analyses

Comparisons between the vibration and no vibration condition were made using a Repeated Measures General Linear Model (RM GLM). A significance level of $p < 0.05$ was selected a priori.

Results

Vertical Jump

Results from the RM GLM did not reveal a significant condition or group*condition interaction for either maximal vertical jump or average vertical jump (all p's > .05).

Isokinetic Peak Torque

Results from the RM GLM did not reveal a significant condition or group*condition interaction for isokinetic peak torque of knee extensors at 1.05, 2.09, 3.14, 4.19, 5.24 or 6.28 radians · sec^{-1} (all p's > .05). See Figure 1 for results.

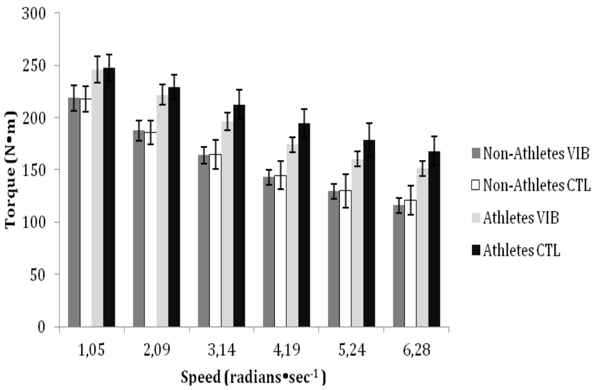

Figure 1. Knee extension peak torque

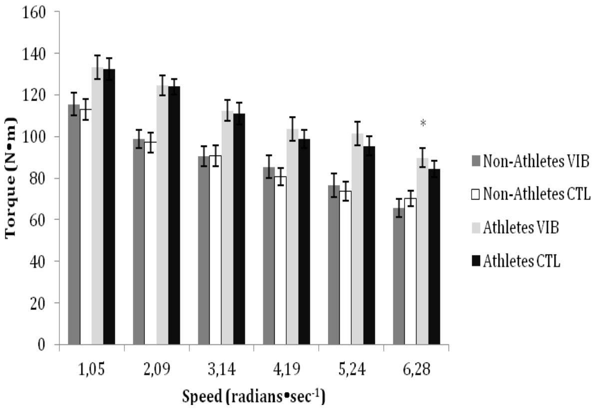

Figure 2. Knee flexion peak torque

Results from the RM GLM did not reveal a significant condition or group*condition interaction for isokinetic peak torque of knee flexors at 1.05, 2.09, 3.14, 4.19, or 5.24radians · sec^{-1} (all *p's* > .05). However, at

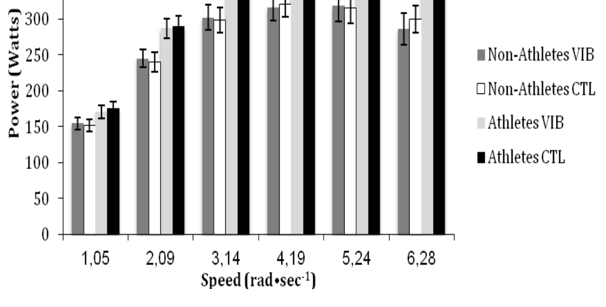

Figure 3. Knee extension average power

6.28 radians · sec^{-1} a significant condition*group interaction was found (*p* = .003). See Figure 2 for results.

Isokinetic Average Power

Results from the RM GLM did not reveal a significant condition or group*condition interaction for isokinetic average power for knee extensors at 1.05, 2.09, 3.14, 4.19, 5.24, or 6.28 radians · sec^{-1} (all p's > .05). However, at 6.28 radians · sec^{-1} a trend for significance was found for the group*condition interaction (*p* = .059). See Figure 3 for results.

Results from the RM GLM did not reveal a significant condition or group*condition interaction for isokinetic average power for knee flexors at 1.05, 2.09, 3.14, 4.19, 5.24, or 6.28 radians · sec^{-1} (all p's > .05). However, at 6.28 radians · sec^{-1} a trend for significance was found for the group*condition interaction (*p* = .072). See Figure 4 for results.

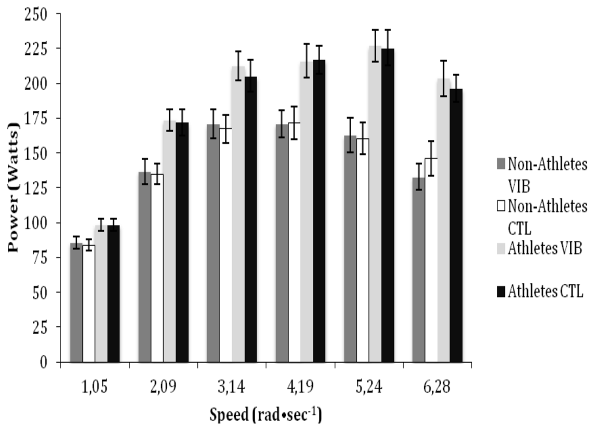

Figure 4. Knee flexion average power

Wingate

Results from the RM GLM did not reveal a significant condition or group*condition interaction for peak power for the Wingate test (all p's > .05).

Discussion

This research sought to describe the acute effects of WBV on measures of muscular performance. While research comparing the effects of WBV on athletes and non-athletes is limited, there have been a number of studies showing WBV to be successful in improving muscular performance (Bosco et al., 2000; Cochrane & Stannard, 2005; Cormie et al., 2006; Gerodimas et al., 2010; McBride et al., 2010). It was hypothesized that the athletes would have a more pronounced positive response to the WBV than the non-athletes due to the differences in training history. Athletes often perform high-speed training in order to simulate the speeds at which they move during competition. This type of training would cause the athletes to have different contractile characteristics than those in the non-athlete group, which might affect the response to WBV.

This study found no changes in peak vertical jump height or average vertical jump height associated with acute WBV use. These results support the findings of Gerodimos et al. (2010), who looked at a range of vibration frequencies and amplitudes and found no improvement in vertical jump. However, this is in contrast to previous studies, which have found WBV to increase vertical jump (Bosco et al., 2000; Cochrane et al., 2008; Cormie et al., 2006). The present study also found no changes in Wingate test performance. These results support the findings of Cochrane et al. (2008) who found no significant differences in peak power for the five-second maximal cycle test following WBV. The researchers hypothesized that the warming produced by WBV may not have been enough to produce positive changes in a maximal cycling effort. If temperature increase is the primary mechanism by which maximal cycling would be affected, then this current research may not have elicited enough of a temperature increase to see improvement in the Wingate test.

Another possible explanation as to why no effect was seen in vertical jump and Wingate tests may be due to inadequate stimulation of post activation potentiation. As stated by Bazett-Jones, Finch, and Dugan (2008), for post activation potentiation to occur following contractile activity there must be a net balance in favor of actions that cause potentiation rather than those that cause fatigue. It may be the case that a small adjustment to vibration parameters can lead to entirely different results. There have not yet been enough studies conducted to fully understand the relationships of these parameters.

The present study found a significant group*condition effect for knee flexion peak torque at 6.28 radians·sec^{-1}. This supports the results of McBride et al. (2010), who found that WBV significantly increased peak force during MVC of the triceps surae muscle complex. While not the same muscle group, these results show that WBV can acutely enhance contractile function of leg muscles during maximal efforts.

At 6.28 radians·sec^{-1}, athletes in the present study performed better in measures of knee flexion peak torque following acute WBV. At this speed, it is not surprising that the athletes responded better than the non-athletes. The training programs of athletes often require high-speed movements and rapid muscle contractions. This may prime the neural connections to respond more positively to the high-speed contractions induced by WBV. It has been hypothesized that the rapid muscle contractions induced by WBV may affect the interneurons within the spinal cord, leading to reciprocal inhibition (Norlund & Thorstensson, 2007). This inhibition of antagonistic muscles may allow for greater maximal contraction at higher speeds. However, it is not currently known if past training history affects this mechanism. It is possible that training may have a significant impact in this area.

The present study also found a trend toward a significant group*condition interaction for knee extension average power at 6.28 radians·sec^{-1}. This result supports the findings of Bosco et al. (2000) whose results showed a significant increase in power output of the leg extensor muscles during maximal dynamic leg presses. The vibration parameters in that study were set to 26 Hz frequency and 8 mm peak-to-peak amplitude, which were similar to the parameters of the present study. However, Bosco et al. (2000) utilized a 10-minute non-continuous total vibration duration, while the present study used a 2-minute continuous total duration. Although both studies showed improvement in power output of the leg extensors after acute WBV, the results of the present study suggest that benefits may be had at much shorter durations relative to the findings of previous research.

Two key limitations should be taken into account when interpreting the results of the present study. Firstly, many of the athletes that participated in this research were freshman football players. This is somewhat problematic because they potentially came from very different high school training programs. It would have been beneficial to have a majority of upperclassmen participants, as it would ensure that all the subjects had participated in the same training program prior to this research. Secondly, our athlete group was also disproportionately made up of football players. It is possible that athletes of other sports may have responded differently to the vibration. Having a fairly homogenous athlete group makes it difficult to generalize these results to other sports, and also calls for further research to be conducted on athletes of various sports.

Currently, there are a number of unanswered questions surrounding the use of WBV as a mechanical ergogenic. To better understand WBV and its potential for performance enhancement, future research should continue to shed light on the effects of protocol variation. The effects of frequency, duration and amplitude need to be exhaustively researched in order to have a more comprehensive understanding of the possible impact of WBV as a mechanical ergogenic. There are numerous combinations of these parameters, and the potential for significantly different effects. If it can be determined which parameters are most efficient at eliciting beneficial muscle activation, it would make the reproducibility of results much easier. At this stage of the research it is difficult to make definitive conclusions about the effectiveness of WBV given how much has yet to be explored.

The findings of this study may have important implications in regard to preparation for athletic events. In athletic competition, anaerobic power and high-speed movements, such as sprinting, are often of utmost importance. Nesser, Latin, Berg, and Prentice (1996) found knee flexion peak torque at 7.85 radians·sec^{-1} to be a significant predictor of 40-meter sprint time. It was also noted that hamstring strength is particularly important in the acceleration phase of sprint performance. This finding lends support to the idea that improving high-speed force output of the hamstring muscles could lead to improved sprint performance. Newman, Tarpenning, and Marino (2004) also found that single-sprint performance to be correlated with both knee flexor and extensor peak torque at 1.05, 2.62, and 4.19 radians·sec^{-1}. Because hamstring strength is integral to sprint performance, it would not be surprising to see WBV mediated improvements in hamstring force output lead to improved sprint speed. In addition to use as a pre-competition aid, WBV could potentially be used as a pre-training aid in order to accrue long-term benefits due to acute enhancements that improve individual training sessions.

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