THE EFFECTS OF WHOLE BODY VIBRATION ON VERTICAL JUMP, POWER, BALANCE, AND AGILITY IN UNTRAINED ADULTS

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ABSTRACT

Background: Despite the increased use of whole body vibration among athletes, there is limited literature on its acute effects within heterogeneous populations such as untrained adults or recreational athletes.

Hypothesis/Purpose: The purpose of this study was to investigate the acute effects of whole body vibration on vertical jump, power, balance, and agility for untrained males and females. It was hypothesized that there would be an effect on each outcome variable.

Study Design: Quasi-experimental, pretest-posttest design.

Methods: Twenty males and sixteen females, mean age 24.5 years, were assessed for vertical jump height and power as measured by the Myotest accelerometer, balance as measured by the NeuroCom Balance Master System, and agility as measured by a modified T-test. Each session consisted of a five-minute treadmill warm-up, a practice test, a baseline measurement, a two-minute rest period, whole body vibration at 2 mm and 30 Hz for 60 seconds, and a final measurement. Three different counterbalanced testing sessions were separated by a minimum of 48 hours in between sessions to minimize fatigue.

Results: Significant differences existed for both genders for main effect of time for Agility ($p = 0.022$); end point excursion Left ($p = 0.007$); and maximum endpoint excursion Left ($p = 0.039$). Differences for main effect of gender revealed females performed better than males in the following respects: end point excursion Right ($p = 0.035$); end point excursion Left ($p = 0.014$); maximum endpoint excursion Right ($p = 0.024$); and maximum endpoint excursion Left ($p = 0.005$). Males performed better than females in two respects: Agility ($p < 0.0005$) and Power ($p < 0.0005$). A significant interaction was observed between time and gender for vertical jump ($p = 0.020$). Simple main effects revealed males jumped higher than females during both pre and post intervention, $p < 0.0005$. Females had a significant decrease in the vertical jump post intervention ($p = 0.05$).

Conclusion: Results indicated that whole body vibration produced significant differences in the main effect of time and agility, and end point and maximum end point excursion Left for both genders, acutely. Females performed better in balance compared to males and poorer in vertical jump, but males performed better in agility and power.

Key Words: Agility, Balance, Jump Height, Power, Whole Body Vibration

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INTRODUCTION

In recent years, there has been an increased interest in the use of whole body vibration (WBV) to increase athletic performance, but also as it relates to untrained adults or recreational athletes.¹⁻⁷ The potential benefits suggest that WBV could be a practical warm-up before exercise.^{8,9} Current research is conflicting on whether or not WBV has a significant effect on vertical jump height, power, balance, and agility. Though many studies show improvements after exposure to WBV, some literature shows no improvement in performance following WBV.^{1,2,4,10-13} The differences in findings may be due to the use of different frequencies (25-50 Hz), amplitudes (2-10 mm), and duration of WBV (30 sec-10 min).

Armstrong et al.¹⁰ found that the most appropriate time to assess vertical jump height is within five minutes of WBV, because after that time the effects begin to decrease. Although they found no difference between different frequencies (30, 35, 40 or 50 Hz) and amplitudes (2-4 or 4-6 mm), they did find that the use of WBV causes an increase in vertical jump height in a heterogeneous sample (minimally active students to intercollegiate athletes) of male and female college students. While investigating male and female competitive basketball players, Colson et al. found that a WBV training session in conjunction with a conventional basketball training program resulted in increased knee extensor strength, but no change in countermovement jump height.¹ The training program for the experimental group in this study included twelve 20-minute WBV sessions with an amplitude of 4 mm and frequency of 40 Hz. One major limitation of this study was that the control group did not undergo the same four-week training regimen without the WBV that the experimental group received; as such, they were not able to determine if the WBV or the training regimen influenced change.

Davoodi et al. found that one session of WBV significantly increased vertical jump height ($p=0.009$) in non-athletic healthy male students.¹¹ During the single session of WBV, participants received eight bouts of vibration with a frequency of 30 Hz and an amplitude of 10 mm. The bouts lasted for one minute each with a one-minute rest period between bouts. Total treatment time was 15 minutes, followed by a five-minute

rest period before retesting. Hawkey found that following a six week WBV training program, there was a significant increase in jumping performance in healthy, recreationally active, male undergraduate students.¹² Participants in this study followed a six-week WBV training program that included one session per week. The frequency ranged from 35 Hz to 45 Hz while the amplitude remained at 2 mm. The duration of each session alternated between 3 sets of 60 seconds to 3 sets of 70 seconds.

Ebben et al. found that WBV has no acute effect on, and in some cases impairs, dynamic stability in NCAA Division One female basketball players. They followed 11 participants who underwent a two minute intervention with an amplitude of 4 mm, which consisted of 30 seconds at 30 Hz, followed by 60 seconds at 40 Hz, and finally 30 seconds at 50 Hz.² The participants performed trials of bilateral, right leg, and left leg countermovement jumps before and after the intervention, taking off and landing on a force platform, which recorded kinetic data. Pojskic et al. found that WBV was significantly better at improving countermovement jump, 15 meter sprint time, and agility using a T-test in healthy male college football players.⁴ They concluded that body weight loaded WBV is better at improving these variables over an unloaded preconditioning protocol. Participants underwent 4 sessions within 10 days at 50 Hz and 4 mm. See Table 1 for a summary of these studies and their results.

While some of these and many other longitudinal research studies examined highly trained athletes,^{3,5,14,15} there is limited research on the acute effects of WBV on more heterogeneous populations such as untrained adults or recreational athletes. Therefore, the purpose of this study was to examine the acute effects of WBV on vertical jump, power, balance, and agility for untrained males and females. It was hypothesized that there would be a change in each of the four performance variables following an acute bout of WBV.

METHODS

Participants

Thirty-six untrained male and female adults (age 24.5 years $\pm$ 2.2 SD) participated in the study.

Table 1. Prior studies discussed in the introduction along with pertinent variables and results.

Study	Participants	Measures	Parameters	Results
Armstrong, et al. ¹⁰	Male and female college students, training level not indicated	Countermovement jump	Freq: 30, 35, 40, or 50 Hz Amp: 2-4 mm or 4-6 mm Duration: single session, 1 min	CMJ (+)
Colson, et al. ¹	Male and female college basketball players	Countermovement jump; Squat jump; Drop jump; 30s rebound jump; Strength; 10-m sprint	Freq: 40 Hz Amp: 4 mm Duration: 3x/wk for 4 wks, 20 min sessions	CMJ (-) Squat jump (+) Drop jump (-) 30s RJ (-) Strength (+) 10-m sprint (-)
Davoodi, et al. ¹¹	Adult male students, untrained	Vertical jump; Distance jump; Flexibility	Freq: 30 Hz Amp: 10 mm Duration: Eight 1 min sessions within 10 min	Vert jump (+) Dist jump (-) Flexibility (+)
Hawkey ¹²	Adult male students, trained	Countermovement jump	Freq: 40 and 45 Hz Amp: 2 mm Duration: 1x/wk for 6 wks, 3x60s or 3x70s each session	CMJ (+)
Ebben, et al. ²	Female collegiate basketball players	Countermovement jump (bilateral, right leg, left leg)	Freq: 30, 40, and 50 Hz Amp: 4 mm Duration: single session, 2 min	Bil CMJ (-) Rt CMJ (-) Lt CMJ (-)*
Pojksic, et al. ⁴	Male collegiate football players	Countermovement jump; 15-m sprint; Agility	Freq: 50 Hz Amp: 4 mm Duration: 4 sessions within 10 days, 5x60s per session	CMJ (+) 15-m sprint (+) Agility (+)

Key: (+) = significant improvement; (-) = no significant change; (-)* = decline in performance

Untrained was defined as individuals who are not collegiate or professional athletes. An a-priori power analysis was conducted in order to determine the minimum number of participants necessary to ensure sufficient power. Using a power of 0.8 and a large effect size of 0.4, the minimum number of subjects required was determined to be 26. In order to account for an approximate 15% attrition rate, a total of 36 participants was obtained.

The inclusion criteria consisted of being between 18 and 40 years of age and being able to speak and understand English well enough to comprehend the consent form and instructions. Participants were excluded if they were pregnant, suffered from

an orthopedic injury within the prior six months, had severe osteoporosis, a severe heart condition, an acute thrombosis, a pacemaker, or cancer. Each group served as their own control group by performing a pretest before being exposed to WBV. Confidentiality was maintained through a numbering system. All information was stored on a password-encrypted computer for the duration of the study.

The study was approved through the University Institutional Review Board. All participants gave verbal approval and signed informed consent that explained the risks, benefits, and procedures of the study prior to participation.

Equipment

A Power Plate (Pro5, Performance Health Systems, Northbrook, IL) vibration plate was used in the study. The Pro5 produces a linear vibration and can be set to different amplitudes, frequencies, and durations. Amplitude is the amount of linear displacement caused by the power plate and is measured in millimeters. Frequency is the number of oscillations per unit time and is measured in hertz (sec^{-1}). Duration is the length of time that the vibration occurs and is measured in seconds. The settings used in this study included an amplitude of 2 mm, a frequency of 30 Hz, and a duration of 60 seconds. This protocol was developed based on other studies that utilized vertical jump, power, balance, and agility variables in their research.^{10,16,17}

The Myotest (Myotest Pro 2, Myotest SA, Sion, Switzerland) was used to measure vertical jump height and power output. It utilizes an accelerometer to measure jump height, power, force, velocity, and flight time. For males, the Myotest was shown to have an intra-session reliability ICC value of 0.95 and an intersession reliability ICC value of 0.88. For females, the Myotest was shown to have an intra-session reliability ICC value of 0.91 and an intersession reliability ICC value of 0.92.¹⁸ The Myotest has been shown to have excellent validity with a Pearson's product correlation coefficient of $r = 0.89$ when compared to the gold standard force plate.¹⁹ In addition, validity was found to be high in studies utilizing a countermovement jump.²⁰

In order to measure dynamic balance, the Limits of Stability (LOS) test was used as part of the clinical assessment battery from the NeuroCom Balance Manager system (SMART EquiTest, Natus Medical Incorporated, Pleasanton, CA). The LOS test measures five variables associated with the participant's displacement of their center of gravity (COG) including reaction time (RT), movement velocity (MVL), end point excursion (EPE), maximum endpoint excursion (MXE), and directional control (DCL). The test consists of eight timed trials in which the participant attempts to move their COG towards one of eight targets located at different points along their theoretical LOS. The LOS test has been found to have good reliability with ICC values of 0.80, 0.88, and 0.69 for MVL, EPE, and DCL respectively.²¹

For the agility test, a modified T-test, which forms a vertical and horizontal 5 meter "T," was used. This test involved a participant sprinting 5 meters forward followed by a side shuffle to the left 2.5 meters, a side shuffle to the right 5 meters, a side shuffle back to the left 2.5 meters to return to the center, and then a back pedal to the starting line. The test has been proven to have high reliability with an ICC value of 0.92 for women and an ICC value of 0.95 for men.²² The timing system used in the study was the Zybek Power Agility Timer. This electronic timing system consisted of two reflectors mounted on tripods and a sensor connected to a timing unit that could take measurements up to $1/1000^{\text{th}}$ of a second. Time started when participants moved across sensors at the starting line and ended when individuals finished back at the starting line. These types of electronic timing systems have been found to be valid and reliable with ICC values of between 0.91-0.99 in the timing of sprint athletes.²³

Procedure

A two-way mixed method ANOVA study design was utilized to compare males and females for each of the dependent variables measured: vertical jump height, power, balance, and agility.

Prior to participation in the study, the participants were given an explanation of the study, but were not informed of the hypotheses on whether or not there would be a change in each of the conditions. Participants were required to attend three different testing sessions at the university research laboratory, separated by a minimum of 48 hours between sessions to minimize fatigue and any potential cumulating effects of the WBV. Each session was dedicated to the measurement of one of the dependent variables: vertical jump height, power, balance, or agility; vertical jump height and power were measured at the same time using the Myotest. The order in which subjects performed each of these tests was randomized using a counterbalanced design (random order with rotation) Figure 1.

During each session, participants began with a five-minute warm-up on a treadmill, which was set to the participant's preferred walking speed. Immediately following the warm-up, a practice test of the dependent variable being measured was recorded to

Figure 1. Study flow diagram.

account for any learning effects. Participants then had a two-minute rest period before a second baseline measurement was collected. After a two-minute rest period, subjects underwent the WBV intervention at 30 Hz, 2 mm for 60 seconds in a semi-squat position at approximately 60 degrees of knee flexion. A final measurement of the dependent variable was collected immediately after the intervention. For the vertical jump pre- and post-tests, participants jumped three times and an average was taken. The pre- and post-tests for balance were performed once to minimize the possibility of the acute WBV effect wearing off as time proceeds. The pre- and post-tests for agility tests were only performed once to minimize the effects of fatigue. The four examiners were second year physical therapy students who underwent training for each testing intervention by a physical therapist who is a Board Certified specialist in sports physical therapy. Three steps were taken to ensure consistency: the same tester was used throughout the duration of the experiment for an individual condition; each condition was assessed by a different investigator to reduce threats to internal validity; prior to commencing the study, all four examiners met during two separate one-hour sessions to discuss and practice techniques.

Statistical Analyses

A 2 (group: male, female) $\times$ 2 (time: pretest, post-test) mixed method ANOVA was used to determine changes for each of the dependent variables. An alpha level was set at 0.05 and power was set at 0.8 for each variable. Post hoc analysis was performed with pairwise comparisons if significant interactions were found. Statistical analysis was performed using the SPSS, 23.0 statistical software package (IBM Corp. Released 2013. IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp.).

RESULTS

A significant interaction was observed between time and gender for vertical jump as shown in Table 2. Follow-up (simple main effects) independent t-tests revealed a difference between groups for pre-testing, $t_{1,34} = 8.48$, $p < 0.0005$ and post testing, $t_{1,34} = 8.68$, $p < 0.0005$ with males jumping higher than females during pre and post time periods. Using paired t-tests, females had a significant decrease in the vertical jump height post WBV, $t_{15} = 2.137$, $p \leq 0.05$.

Significant outcome measures via a mixed method ANOVA for the main effect of time are shown in Table 3. Differences were observed for males and

Table 2. Significant outcome measures via mixed ANOVA with repeated measures for vertical jump.

	Pre and Post mean values of males and females				F	p value
Measures	Males		Females			
	Pre	Post	Pre	Post		
Vertical Jump Height (cm)	47.86	48.56	29.75	29.23	5.93	0.020*
* p ≤ 0.05						

Table 3. Significant outcome measures via mixed ANOVA with repeated measures for the main effect of time.

Measures	Pre Mean Males/Females (SEM) 95% CI	Post Mean Males/Females (SEM) 95% CI	p value
Agility (sec)	7.41 (.159) 7.09-7.74	7.29 (.168) 6.95-7.64	0.022*
End Point Excursion Left (%)	78.11 (1.99) 74.07-82.16	81.62 (1.82) 77.91-85.32	0.007*
Maximum Endpoint Excursion Left (%)	86.97 (1.35) 84.22-89.72	89.00 (1.53) 85.89-92.11	0.039*
* $p \leq 0.05$			

Table 4. Significant outcome measures via mixed ANOVA with repeated measures for the main effect of gender.

Measures	Mean Values (SEM) 95% CI		p value
	Males	Females	
Agility (sec)	6.31 (.215) 5.87-6.74	8.40 (.241) 7.91-8.89	<0.0005*
End Point Excursion Right (%)	73.60 (2.31) 68.91-78.29	81.20 (2.58) 75.94-86.44	0.035*
End Point Excursion Left (%)	75.20 (2.41) 70.30-80.10	84.53 (2.69) 79.06-90.01	0.014*
Maximum Endpoint Excursion Right (%)	84.63 (1.85) 80.87-88.38	91.16 (2.07) 86.96-95.35	0.024*
Maximum Endpoint Excursion Left (%)	83.88 (1.82) 80.18-87.58	92.09 (2.04) 87.96-96.23	0.005*
Power (W/kg)	47.33 (2.56) 42.13-52.52	28.61 (2.86) 22.80-34.42	<0.0005*
* $p \leq 0.05$			

females in the following areas: Agility: $F_{1,34} = 5.77$; EPE Left: $F_{1,34} = 8.12$; and MXE Left: $F_{1,34} = 4.60$.

When looking at the main effect of gender, females performed better overall when compared to males in the following balance components as shown in Table 4: EPE Right: $F_{1,34} = 4.80$; EPE Left: $F_{1,34} = 6.67$; MXE Right: $F_{1,34} = 5.55$; and MXE Left: $F_{1,34} = 9.06$. Males performed better overall than their female counterparts in the following performance variables: Agility: $F_{1,34} = 42.16$ and Power: $F_{1,34} = 23.82$.

DISCUSSION

The purpose of this study was to investigate the acute effects of WBV on vertical jump, power, balance, and

agility for males and females in an untrained adult population. It was hypothesized that there would be an effect on each condition following an acute bout of WBV. Previous research is non-definitive on the possible benefits of WBV in a group of untrained adults or for gender differences.

Vertical Jump

Regarding the effects of WBV on vertical jump for males and females, WBV produced no significant effect for males, but caused a decrease in vertical jump height for females. These findings did not coincide with the results of any of the literature reviewed as much of the research literature reveals an increase in jump height as a result of vibration

training.²⁴ Cochrane et al. examined the effects of WBV on vertical jump in 24 sports science students (16 males and 8 females) and found no significant differences between the WBV group and the control group.⁷ However, Torvinen et al. produced conflicting results, investigating 56 nonathletic volunteers (21 men, 35 women, ages 19-38 years old) and finding a significant increase in countermovement vertical jump height in the WBV group compared to the control group.²⁵ When examining the effects of WBV on 9 males aged 19-23 years old, Cormie et al. found that countermovement jump height increased following the use of WBV.¹⁷ This is in agreement with Wyon et al. who, when investigating the effects of WBV on 18 undergraduate female dancers, found that vertical jump height improved with the use of WBV.⁶

Although it is difficult to explain why a decrease in jump height for females occurred, it may be due to the untrained nature of the participants. It is also possible that the results seen with the present study could be due to the vibration parameters (frequency, amplitude, duration) used which is variable among studies. Additionally, the change could be due to measurement error; but this is inconclusive, as the SEM for a countermovement vertical jump using the Myotest has not been shown.

Main Effect of Time

Much research has shown that WBV appears to have immediate effects on postural control and static balance,²⁶ but other research in this area is inconclusive, particularly as it relates to dynamic standing balance. Our results demonstrated improvements in a few components of dynamic standing balance, specifically EPE Left and MXE Left. These findings are consistent with Ritzmann et al. who examined the effects of WBV on 40 subjects (17 female, 23 male, age 25 ± 4 years) and found that balance improved more with the WBV group compared to the control group.⁵ However, the results of this study conflicted with a study performed by Pollock et al.²⁷ who found that, using 18 adults (15 females, 3 males aged 24.3 ± 1.5 years), WBV had no effect on balance. They suggested that healthy young adults may have little margin for improved balance during simple tasks as one possible explanation. Additionally, Ebben et al.

found that WBV may actually impair dynamic stability and balance in collegiate Division One female basketball players.² They proposed that the duration of the WBV stimulus in their study (two minutes) may have been too long, leading to overstimulation and fatigue of muscle spindles and a consequent decline in performance. Given the paucity of research in this area, it is difficult to ascertain specifically why improvement in dynamic balance occurred. We can speculate that perhaps effects of WBV caused underlying neural mechanisms to improve coordination, but this speculation is beyond the scope of this research.²⁸

Regarding the effects of WBV on agility for males and females, agility times improved after an acute bout of WBV. This agrees with a study by Ghazalian et al., who found an improvement in agility following WBV in a group of 26 healthy male students and Pagaduan et al. who studied the effects of acute WBV on college football players.^{4,29} However, these findings did not coincide with studies performed by Cochrane et al. or Torvinen et al.^{7,30} Both researchers found no significant differences between the WBV and control groups for agility or shuttle run times, respectively. However, it should be noted in the Cochrane study that the performance tests were performed two days after the last WBV training. Although several theories persist in the literature regarding reasons for positive effects of WBV,²⁶ the findings observed in this study may simply be due to a warm-up effect resulting from intramuscular temperature increases during WBV exercise as noted by Cochrane et al.³¹ As such, an acute bout of WBV may have beneficial effects on any activities requiring quick lateral movements.

Main Effect of Gender

As noted, females revealed better dynamic standing balance ability than males for several of the components of dynamic standing balance. These findings reveal that WBV could help to broaden the base of support (BOS) of females. However, these results are in contrast to Ebben et al., who found that WBV has no effect on and may impair dynamic stability in NCAA Division One women basketball players.² The WBV component of this study differs from Ebben et al. in amplitude (2 mm vs 4 mm),

frequency (a constant 30 Hz vs a variable 30, 40, and 50 Hz) and duration (1 minute vs 2 minutes). Additionally, our test subjects in this study maintained a constant position of slight knee flexion during WBV while Ebben's subjects performed 10-12 body weight squats for 60 seconds of their total WBV treatment time. We may theorize that muscle fatigue from the squats may have contributed to the decline in performance after WBV. Although many of the studies between genders have focused on children and adolescents or the elderly, researchers have reported significant gender differences in balance skills with younger females tending to have higher balance scores than younger males.^{32,33} This changes with elderly males and females as females tend to display greater changes in postural sway with age than males, but evidence is lacking regarding dynamic standing balance ability between young adult and middle-aged males and females.^{34,35}

Differences between males and females were found for agility, power, EPE Right, EPE Left, MXE Right, MXE Left. Overall, males demonstrated faster agility performance times and greater power than females. Although this study examined only agility performance times and not other factors relating to agility such as change of direction (COD) or other agility maneuvers, several researchers have observed that males produce a faster COD as well as overall agility performance than females.^{36,37} Regarding power, these findings are consistent with previous research supporting gender differences for overall anaerobic power output and maximal strength.^{38,39} Much of the literature reveals that power output can be acutely increased by a bout of WBV exercise whether it be from neuromuscular facilitation or a warming-up effect.^{31,40} As such, it appears that WBV did not have any major distinguishing effects on these components for gender.

Limitations

This study has some limitations. The internal motivation of the participants is a potential limitation, as there was no particular incentive for performing at maximal effort. The positioning of the participants during WBV is another limitation. Maintaining the recommended semi-squat position for 60 seconds may have led to muscle fatigue and, therefore,

decreased performance.¹⁴ The set of parameters used for amplitude, frequency, and duration of WBV is another limitation. Currently, the evidence is inconclusive regarding the settings for optimal results.¹⁴ Further studies may help determine ideal parameters for WBV. Finally, the results of this study may not be generalizable to populations differing from the study group. This study did not investigate the effects of WBV on improving agility in trained individuals or balance in impaired individuals, but it does raise those questions for future research. However, these findings do suggest that WBV reduces the performance of vertical jump in untrained females.

CONCLUSIONS

The results of this study indicate that a bout of acute WBV is effective for improving agility time and some components of dynamic balance including EPE and MXE in untrained adults. In regard to gender, males demonstrated increased performance in power and agility times. Females performed better in several aspects of dynamic standing balance, which included EPE Left and Right and MXE Left and Right. A significant interaction was found for vertical jump between males and females with females actually decreasing vertical jump performance. Overall, the use of WBV may be beneficial in improving some aspects of athletic performance including balance and agility. Practical application for the combination of improvements in balance and agility may include playing offense and defense in sports such as basketball, soccer, hockey, and football as well as cutting maneuvers in all sports.

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