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Original Article

Acute Effects of Whole-Body Vibration on the Anterior Trunk Flexion in Sedentary Female University Students

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Abstract

Objectives: This study assessed the impact of whole-body vibration (WBV) exercise with a low frequency (30 Hz) on anterior trunk flexion flexibility among sedentary female university students. **Methods:** A pre-test and post-test experimental study design was carried out with 60 sedentary females in the age range of 20 to 30 years, who were divided evenly into an experimental group and a control group. Participants in the experimental group underwent three sessions of WBV exercise on a Power Plate platform (2 minutes each session, frequency 30 Hz, and amplitude 2 mm), followed by 1 minute of rest in between sessions. The participants in the control group stood on the Power Plate platform with the mechanical vibration turned off. The anterior trunk flexion test was used to assess the degree of flexibility. **Results:** The WBV technique significantly improved the anterior trunk flexion (mean difference 2.60; 95% confidence interval (CI): 2.2384–2.9617, $p<0.05$). The experimental group showed greater improvement (mean difference 2.20; 95% CI: 1.037–3.363, $p<0.05$) compared to the control group, as well as a larger effect size. **Conclusion:** Acute WBV immediately improved the anterior trunk flexion flexibility in female sedentary university students.

Keywords: Anterior Trunk Flexion, Flexibility, Sedentary Behavior, Vibration

Introduction

Whole body vibration (WBV) is a training method in which the entire body is exposed to mechanical vibrations while standing upright or in various positions on the base of a vibrating platform. Healthcare professionals use this procedure to improve particular motor and sensory outcomes in many groups, including the elderly and young adults, regardless of their physical activity level[1]. WBV has gained wide attention in scientific research over the past decade, and a guideline has been published[2].

WBV is a novel neuromuscular training technique that can affect muscle strength and power, electromyographic activity[3-5], neuromuscular reflexes[6], and postural control[7]. Vibrations are transmitted from a platform on which a person stands while holding the device with the upper extremity or sits passively on a chair with bare feet on the platform[8]. These devices generate vibrations with an amplitude of 0.7 to 14 mm and oscillation frequency between 0.5 and 80 Hz[9]. Several mechanisms have been identified through which mechanical vibration can improve flexibility, particularly as an immediate effect, including a reduction in pain perception,

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improved blood flow, and reduced muscle stiffness[10-12].

University students are young adults who tend to spend more time sitting and doing activities such as studying, watching television, or playing video games, which may jeopardize their future health and make them particularly vulnerable to health risks[13]. Reduced physical activity is known to pose health risks, it can significantly impact musculoskeletal health, and it can lead to postural changes in young adults[14]. Studies on sedentary behavior show that most adults are inactive for more than 8 hours a day. Globally, women are significantly more physically inactive (31.7%) than men (23.4%)[15]. According to a meta-analysis, university students say they spend an average of 7.29 hours a day sitting. University students exhibit more sedentary behavior overall compared to other young adults, and this trend has increased over the past decade[16].

Among healthy adult females, prolonged sedentary behavior has been demonstrated to have detrimental effects on the flexibility of the lower limbs and back[17]. Sedentary behavior can lead to a reduction in flexibility, indicating a decrease in the elastic properties of musculoskeletal tissues and connective tissues of joints[18]. Prolonged sedentary behavior can also cause a shift the type of muscle fibers from oxidative to glycolytic, resulting in a reduction in muscle mass and strength[19]. As such, excessive and prolonged sedentary behavior can have negative effects on overall physical fitness[17].

Research also suggests that prolonged sitting can cause mechanical stress on the hamstrings and that maintaining a sedentary lifestyle can reduce flexibility, particularly in the hamstrings[20]. Tightness in the thigh muscles impairs freedom of movement and leads to changes in posture, which can lead to postural disorders as a consequence of a sedentary lifestyle[21]. Other consequences of a sedentary lifestyle and prolonged sitting include functional imbalance of muscle chains, restricted chest expansion, and limited joint mobility[22].

Muscular imbalance can increase the likelihood of functional musculoskeletal disorders, discomfort, and reduced cardiorespiratory exercise capacity among young people[23]. Studies suggest that lumbar muscle stiffness measured by an indentometer increases after 4.5 hours of sedentary activity. Increased sedentary behaviors can promote musculoskeletal problems in the lower back by increasing muscle tension and maintaining a shortened state in the lumbar region[24]. Enhanced flexibility can improve movement efficiency and potentially reduce the likelihood of musculoskeletal problems[25].

Studies have reported that WBV exercises can help improve trunk flexibility for individuals with metabolic syndrome[26] and that varying vibration loads of WBV exercises affect the flexibility of springboard divers[27]. These studies concluded that WBV may be a strategy to improve flexibility. On the other hand, in other studies, WBV did not appear to have a significant effect on back and lower-limb flexibility among healthy women[28,29]. However, a recent study showed that three weeks of WBV training had positive effects on trunk flexor muscle endurance and dynamic balance among healthy young people[30].

WBV has been reported to improve muscle strength, agility, and vertical jump height in athletes, but its effects on flexibility are still unclear, particularly in the back and lower limbs[31]. Numerous studies have examined its immediate effects on flexibility, strength, and cardiovascular function, but there is a paucity of literature examining the immediate effects of WBV training on the back and lower limb flexibility of inactive female participants. Therefore, this study evaluated the immediate effects of low-frequency (30 Hz) WBV exercise on anterior trunk flexibility in healthy inactive women.

Materials and Methods

Study Design and Participants

This study uses a pre-test and post-test experimental design with an intervention group and a control group. The participants were 60 healthy female university students, who were divided randomly into two groups: 30 healthy female students in an experimental group (mean age = 20.9 ± 1.6 years, mean height = 157.8 ± 3.8 cm, mean body mass = 52.5 ± 8.8 kg, and mean body mass index (BMI) = 21 ± 3.4 kg/cm^2) and 30 matched healthy female students in a control group (mean age = 19.9 ± 1.5 years, mean height = 157.3 ± 3.2 cm, mean body mass = 59 ± 10.1 kg, and mean body mass index (BMI) = 23.8 ± 3.7 kg/cm^2). The following criteria were used to screen participants for inclusion in the study. All participants had to be healthy adult women aged 20 to 30 years, and the two groups of women had to have sedentary lifestyles and not participate in any specific physical activity.

Furthermore, the participants had to have no knowledge about treatment using WBV. Participants were excluded if they were pregnant; had a history of surgery or musculoskeletal abnormalities (e.g., leg length discrepancy); or had optic, vestibular, balance, and equilibrium disorders that could affect lower-extremity performance. Participants were also excluded if they had taken any medications that affect muscle tone or flexibility in the last 24 hours before the examination.

Study Settings

The experiment was carried out in a physical therapy laboratory.

Procedure

Before all participants underwent the selected therapeutic interventions, they were randomized into two groups of 30 each using a simple random sampling approach. Each individual was instructed to randomly select an envelope from a hidden box, which contained either a red or green card. Those who drew a red card were assigned to the experimental group, while those who drew a green card were assigned to the control group, as shown in Figure 1. The person in charge of managing the randomization process and handling the concealed box was not involved in the study. Moreover, the

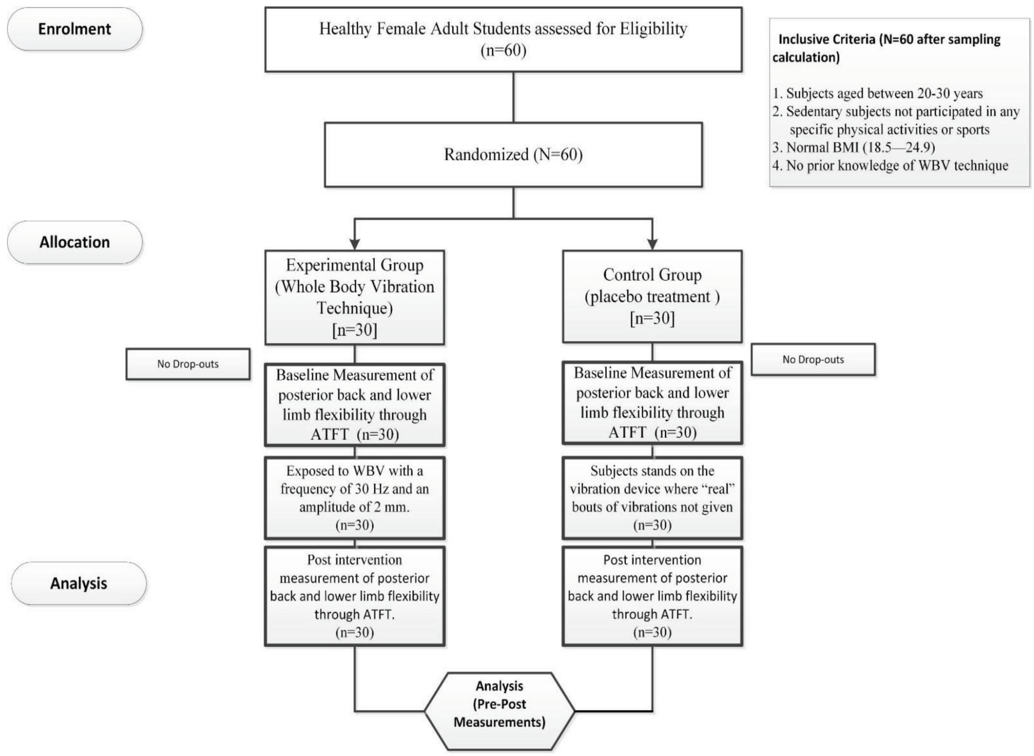

Figure 1. Flow of study participants in the experimental and placebo groups.

Table 1. Demographic characteristics of the participants in both control and experimental groups.

Groups	Age (years) *Mean ± SD*	Height (m) *Mean ± SD*	Body mass (kg) *Mean ± SD*	BMI (kg/cm²) *Mean ± SD*
Control group	19.9 ± 1.5	157.3 ±3.2	59.1 ± 10.2	23.8± 3.7
Experimental group	20.9 ± 1.6	157.8 ±3.8	52.5 ± 8.8	21.1± 3.4
T-value	-1.60	-0.347	1.70	1.91
p-value	0.125	0.732	0.104	0.069
**Significance at the alpha level (p< 0.05).*				

participants were unaware of what intervention they were receiving; however, they were told that they would receive one of the two interventions.

It was not possible to blind the therapist who was delivering the intervention to the participants because of the nature of the interventions. All 60 participants had similar pre-treatment characteristics, including age, body mass, height, and BMI, as indicated by a non-significant p-value (p>0.05; Table 1). The participants in the experimental group received three sessions of WBV intervention in a standing position with slight knee flexion, which was done using the Power Plate® Pro7HCTM (Figure 2), and the control group received a placebo treatment (standing on the vibrating device's platform with vibrations turned off). The WBV was provided using mechanical vibrations with a frequency of 30 Hz. The surface plate dimensions were 96 cm × 114 cm (38 in × 45 in) and a voltage of 100–240 V (https://powerplate.com). The laboratory temperature and timing of measurements were the same for all participants before and after the WBV procedure.

The participants in the experimental group stood upright without shoes on the base of the vibrating platform of the Power Plate® Pro7HCTM device with slight knee flexion, which delivers WBV with a frequency of 30 Hz and an amplitude of 2 mm (low vibration, which is safe). The WBV training was applied for 2 minutes, followed by 1 minute of rest before the

Table 2. Analysis of anterior trunk flexion flexibility of subjects in both control and experimental groups (Pre-test analysis).

Groups	N	*Mean*	*SD*	*T-value (p-value)*	95% Confidence interval of the difference		Effect Size (r)
					Lower	Upper	
Control Group	30	25.67	2.97	0.566 (*p*=0.40)	-2.118	1.185	0.075 (No Effect)
Experimental Group	30	26.13	3.40				

**Significance at the alpha level (p< 0.05).*

Figure 2. Anterior trunk flexion test (the distance between the middle finger tip and the floor is detected with a red arrow).

Figure 3. Standing on Power Plate ® Pro7HCTM with slight knee flexion.

next session. Three sessions were conducted[32]. The control group followed the same procedure as the experimental group except that the participants were not given "real" sessions of mechanical vibrations. To ensure that the placebo treatment was as faithful as possible, the participants were informed by the examiner that they could not physically feel the vibration waves because the vibration waves were too small to be detected. After vibration and placebo interventions, the flexibility of the anterior trunk flexion was assessed again using the anterior trunk flexion test (ATFT), as shown in Figure 2.

Measurement of Outcomes

The study participants' height and body mass were measured using a reliable scale (Detecto 349 Height Rod Handpost Weighbeam Physician's Scale, USA). The BMI of each participant was determined using an equation provided by the National Heart, Lung, and Blood Institution (US Department

Table 3. Analysis of the flexibility of the anterior trunk flexion of subjects in both the control and experimental groups after exposure to the therapeutic interventions (pre-test and post-test analysis).

Group	Stage of Intervention	*Mean*	*SD*	*Mean Difference*	*T-value (p-value)*	95% Confidence interval of the difference		Effect Size (r)
						Lower	Upper	
Control Group	Pre-Intervention	25.33	1.42	0.066	0.338 (p=0.738)	-0.3369	0.4702	0.063 (No Effect)
	Post-Intervention	25.27	1.53					
Experimental Group	Pre-Intervention	25.67	2.97	2.60	14.70* (p=0.00)	2.2384	2.9617	0.939 (Large effect)
	Post-Intervention	23.07	2.79					

**Significance at the alpha level (p< 0.05).*

Table 4. Analysis of anterior trunk flexion flexibility of subjects in both control and experimental groups after exposure to the therapeutic interventions (Post-test analysis).

Groups	*Mean*	*SD*	*Mean Difference*	*T-value (p-value)*	95% Confidence interval of the difference		Effect Size (r)
					Lower	Upper	
Control Group	25.27	1.53	2.20	3.79* (p<0.05)	1.037	3.363	1.438 (Large effect)
Experimental Group	23.07	2.79					

**Significance at the alpha level (p< 0.05).*

of Health and Human Services). All demographic data were recorded before randomly assigning the participants to one of two groups.

The measurement of the anterior trunk flexion flexibility was performed by the ATFT. This test is also known as the fingertip-to-floor distance test[24]. This assessment consisted of assessing the distance between the tip of the middle finger and the floor after anterior trunk flexion while keeping the feet closer together and not bending the knees. Each participant held their greatest stretch for 2 s, and the test was repeated three times with rest periods of 10 s in between[24]. To increase measurement accuracy, the participant stood over a stepper, of which the height was fixed for all participants at 26 cm (Figure 3).

A tape measure was used to measure the distance between the tip of the middle finger and the ground. The ATFT was carried out by a researcher under the same circumstances. Three trials were recorded for each participant in both the experimental and control groups before and after the WBV intervention during the same examination session. The average of the three examinations was calculated and analyzed.

Statistical Analysis

Data analysis was done using SPSS (Statistical Package for Social Sciences) for Windows version 23.0. A paired t test was used to find out whether there was a significant difference between the pre- and post-treatment results of each group. Additionally, the effectiveness of WBV and placebo treatment in the experimental and control groups was evaluated using an unpaired t test. The effect size (r) (Cohen's d) was calculated to determine the degree of change in the mean of an outcome measure over time[33]. The Shapiro–Wilk test was conducted to check the normality of the demographic data for both groups.

A descriptive analysis of all demographic data was performed, which gave the mean and standard deviation of age, body mass, height, and BMI. The findings indicated that there were no significant differences (p > 0.05) in the mean values of age, body mass, height, and body mass index (BMI) between the two groups. Additionally, Levene's test for equality of variances was used to check for significant differences between both groups (p > 0.05).

Results

The independent t-test used to analyze the demographic data showed no significant differences between both groups (Table 1). Table 2 shows that there was no significant difference in the average values of the flexibility of the anterior trunk flexion of participants in both the control group and the experimental group before the application of the selected therapeutic interventions in the pre-intervention phase.

We examined the in the anterior trunk flexion flexibility of participants between the pre-treatment period and immediately following exposure to the therapeutic intervention was compared. There was a significant improvement in the experimental group (mean difference of 2.60; 95% confidence interval (CI): 2.2384–2.9617, $p<0.05$), but the control group showed no improvement ($p=0.738$), as shown in Table 3. Furthermore, the improvement in anterior trunk flexion flexibility showed a large effect size.

In addition, when examining the effect of chosen therapeutic interventions, a significant difference was observed between the control and experimental groups ($p<0.05$). In particular, the experimental group showed greater anterior trunk flexion flexibility (mean difference of 2.20; 95% CI: 1.037–3.363, $p<0.05$) than the control group. The results are shown in Table 4.

Discussion

The current study evaluated how WBV acutely influences sedentary female university students' anterior trunk flexion flexibility. The study used a modified fingertip-to-floor approach to measure the anterior trunk flexion flexibility before and after the total body vibration intervention. Compared to the control group, the findings demonstrated a statistically significant improvement in the experimental group's anterior trunk flexion flexibility before and after the vibration intervention, as well as after the intervention. The results may suggest that a WBV frequency of 30 Hz with an amplitude of 2 mm could improve the anterior trunk flexion flexibility of sedentary female students. The current study's findings were consistent with those of Faes et al.[34], who demonstrated an acute effect of WBV in promoting several outcomes, including improved flexibility, increased balance, and a higher level of musculoskeletal wellbeing. However, unlike our study, the earlier study used low vibration frequencies of 6 and 8.5 Hz.

The possible mechanism behind the improved outcome of WBV is that the vibration promotes blood circulation and increases heat production, which both promote flexibility. WBV also causes muscles to contract and relax, which can increase a person's pain tolerance and allow them to stretch further with less discomfort[35]. WBV similarly improves muscular function and flexibility in healthy adult athletes and non-athletes[36]. Numerous studies have validated these findings[37-39]. The fundamental mechanism of vibration increasing muscle flexibility is presynaptic inhibition of group Ia afferent fibers, or the "busy line" phenomenon resulting from vibration stimulation and stretching acting on the same Ia pathways. Furthermore, by activating the Golgi tendon organ through Ib pathways, combining a severe stretch stimulus with vibration may prevent the autogenic response of the vibrating muscle[40].

Additionally, several studies have shown how acute WBV affects the flexibility of particular muscles, such as the lower back and limbs[41,42]. Specifically, Saldıran et al.[41] examined how different intensities of sinusoidal vertical WBV affected the properties of the lower leg muscles during the sit and reach test. They found a statistically significant increase in flexibility in both lower limbs in college-aged recreationally active people who had never experienced a lower leg injury. They observed no significant differences between the moderate-intensity vibration group and the vigorous-intensity vibration group during a session with an amplitude of 2 to 4 mm and a frequency of 25 Hz for the former and 40 Hz for the latter.

Azizi et al. recent measured hamstring flexibility using modified sit and reach tests. Stiffness was evaluated using the Biodex System 3. The study concluded that a single session of WBV with a frequency of 30 Hz and a 2-mm amplitude improved hamstring muscle flexibility and reduced stiffness. Extensive research has been carried out regarding the effects of vibration frequencies on flexibility. Although the effects of different vibration frequencies on flexibility remain debated, various frequencies such as 6 Hz and 12 Hz have shown a positive impact on flexibility in patients with stroke[28,32].

Besides vibration frequencies, it is important to understand that the performance of WBV platforms can vary based on factors such as amplitude and waveform shape, which also significantly influence muscle responses[44]. Utilizing WBV with appropriate acceleration levels can improve flexibility in individuals with limited mobility or disabilities. However, this study did not cover the impact of different vibration types or acceleration levels. Hence, further research is necessary to uncover the different vibration effects of WBV on flexibility.

Vibratory training is an effective alternative to traditional exercise methods as it offers numerous benefits such as improved muscle and bone health, enhanced neuromuscular function, increased bone mineral density, muscle mass, and strength, and pain relief[30]. Research suggests that applying vibratory stimuli to joints can improve sensorimotor control, increase muscle activity, and reduce injury risks during training[31]. According to Bonanni et al.[45], vibratory training is a legitimate substitute for traditional exercise methods that reduces the risk of injury while enhancing the physical performance of healthy athletes in terms of muscle strength, agility, flexibility, and vertical jump height. In accordance with earlier studies, the results of the current study also demonstrated the effects of acute WBV on the anterior trunk flexion flexibility, which tended to improve the functional performance of sedentary female students and may have reduced their risk of injury from a variety of unexpected activities.

The current study has several limitations that need to be addressed. Firstly, it was conducted on only female university students without taking gender variations into account. Secondly, the participants were between the ages of 20 and 30 years, which means that the study's conclusions can only be broadly applied to this age group. Furthermore, given that the experiment was carried out in a lab setting with specific controlled environmental conditions, it is possible that additional factors influenced the study's findings. It should also be noted that the current investigation has limitations when it comes to the selected vibration frequency of 30 Hz.

The study only examined the effects of acute WBV while standing, but different positions may have varying effects on the anterior trunk flexion flexibility. The results of the study may be affected by the limited number of participants in the sample. More research is needed to study the long-term effects. Additionally, it should be noted that the participants in our study were mostly young, whereas falls, slips, trips, and exposure to injury risk are more common among the elderly population. Therefore, further research is required to evaluate the effects of WBV in this age group.

Conclusion

The findings suggest that in sedentary female university students, acute WBV has an instantaneous effect on enhancing the flexibility of the anterior trunk flexion. The results could have practical applications in the incorporation of WBV exercise into young sedentary girls' physical activities to enhance functional performance and lower the risk of injury. While WBV exercise appears to be a viable approach to improving flexibility, larger studies with sufficient sample size and determination of the long-term effects are needed to definitively determine the value of acute WBV in the treatment of inactive individuals. This study could provide physical therapists with a better understanding of the use of WBV to improve anterior trunk flexion flexibility in sedentary female university students.

Ethical approval

This study was approved by the the Ethics Committee of Faculty of Physical Therapy, Cairo University (Approval number: P.T.REC./012/003299) and conducted in accordance with the 1964 Declaration of Helsinki and its later amendments.

Consent to Participate

Written informed consent was obtained from all participants.

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Authors contributions

Conceptualization, M.A., A.A.; data curation, M.A., A.A., and A.V. S.; writing—original draft preparation, M.A., A.A., A.V. S., V.P., H.S., and M.K.; writing—review and editing, M.A., A.A., H.S. and A.V. S.; supervision, M.A., and A.V.S. All authors read and approved the final version of the manuscript.

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