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The Impact of Acute Whole-Body Vibration and Anthropometric Data on Single-Leg Standing Balance in Sedentary Females

Running Title: Vibration and Anthropometry Impact on Balance

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Abstract Training with whole-body vibration (WBV) exposes the full body to mechanical vibrations. This study aimed to determine such an effect among sedentary young women and to identify the association between anthropometric data and single-leg standing time. Sixty young, sedentary women (ages 19–23) who scored ≥26 on the Rapid Assessment Disuse Index questionnaire study and with body mass index (BMI) of 25.0–29.9 kg/m^2 were enrolled in a quasi-experimental design study. From June 2022 to December 2022, the study was carried out at Jouf University's Laboratory of Physical Therapy. WBVs (5-min exposure and 3-min rest) at a 30-Hz frequency and 2-mm amplitude were administered to the experimental group, whereas the control group was given a placebo effect (the vibration plate was turned off). To examine balance, the single-leg standing balance test was employed. Paired sample t-test and Unpaired sample t-test were used to determine the mean differences of the single-leg stance (SLS) time within and between the groups. Correlation analyses were conducted to determine the relation between anthropometric measures and SLS time after the WBV intervention. The results showed no statistically significant difference in the pre-intervention between groups ($p = 0.383$, $t= -0.880$) while there was a statistically significant difference in the post-intervention between groups ($p = 0.001$, $t= -3.619$) in favor of the experimental group. The Unpaired sample t-test showed a statistically significant difference in the SLS time pre- and post-vibration interventions in the experimental group only ($p = 0.001$, $t= -5.443$). Non-significant weak positive and negative correlations were detected among all anthropometric variables and SLS time post-vibration intervention in both control and experimental groups except the body weight and BMI in the experimental group which showed statistically significant moderate negative correlations with the SLS time post-vibration intervention ($r = -0.495$, $p <$

0.01; r = -0.451, p < 0.01). Acute exposure to WBV may improve single-leg standing balance. Furthermore, body weight and BMI may act as hindering factors to improve the single-leg standing balance time after vibration intervention.

Keywords Vibration, Balance, Standing Position, Sedentary Behavior, Young Adult, Anthropometry

1. Introduction

Body balance and muscle strength training are considered to be the most important intervention methods to protect the body against falling, injuries, and associated disabilities. During dynamic or static activities, body balance and equilibrium require continuous evaluation and maintenance of deep joint proprioception and muscle strength. In physical therapy, many training methods tend to improve body balance and muscle strength, including functional activities such as resistance exercises as well as balance training on an unstable surface [1]. In addition to improving dynamic stability, muscle strength, and muscle performance, balance training on uneven surfaces may help reduce the risk of falling and ensuing injuries. However, it is one of the conventional physical therapy techniques with few proprioceptive training benefits [2-3].

Whole-body vibration (WBV) is a new and developing unstable surface training technique that can be used in place of or in addition to balance and resistance training. Vibration training was previously considered an effective method for warming up or cooling down or muscle activation as a prerequisite for the main exercise training techniques [4-5]. It is hypothesized that by increasing gravity stress, mechanical muscle stimulation might enhance muscle strength and power. Furthermore, vibration stimulation, which provides mechanical load on the muscle, tends to cause muscle lengthening and contraction, subconsciously firing more muscle fibers [6]. WBV also tends to increase myoelectrical activity [7], enable motor unit synchronization [8], and improve muscle strength, flexibility, and balance [9]. However, studies that confirm the effect of WBV in certain balance positions, such as single-leg standing, are lacking. Acute WBV, despite the lack of evidence of its efficacy, is gaining popularity across a range of fields owing to its potential to facilitate physical rehabilitation and athletic conditioning as well as the improvement of impaired health [10].

Upright single-leg stance (SLS) is one of the most challenging aspects of human movement and locomotion, not only because the entire body weight is supported by just one leg but also because maintaining the center of mass within the confines of the support requires skill. The single-leg standing balance test is considered reliable for predicting fall incidence and body balance [11]. It is also called one-legged stance [12], SLS time [13], or unipedal balance test [14]. This simple test is conducted in seconds in terms of time using a stopwatch while the person standing on one leg tries to maintain balance [11].

Some anthropometric data, such as gender and somatotypes, may affect single-leg standing balance. Lee and Lin [15] investigated the effect of gender and somatotypes on single-leg stability in children. They demonstrated that increased body weight may adversely affect balance, both with eyes open and closed. Girls exhibited a significantly smaller mean radius of the center of pressure (COP) distribution than boys as the displacement velocity of the latter was higher, which might be associated with their larger body mass. However, this study was conducted only on children. Studies involving young adults are lacking. Alonso et al. [16] reported that increased age and weight may worsen balance. To the best of the authors' knowledge, there are no reference studies investigating the influences of anthropometric data (age, height, weight, and BMI) on single-leg standing balance among young sedentary women.

Some previous studies have proven that older and middle-aged women have poorer balance and response to balance exercise training than men. Furthermore, fractures from falls account for the majority of injury-related deaths, with older women experiencing twice as many fractures as males [17,18,19]. However, most of these studies included older women rather than young women to determine the balance score and response to exercise training. Therefore, the present study aimed to fill this gap by focusing on young women. Life quality is inversely correlated with sedentary behavior. Furthermore, it has been associated with an increased incidence of obesity and balance problems. Most previous studies [20,21] focused on sedentary older adults without considering those of young adults, despite an inactive lifestyle being a common problem in young adults nowadays [22]. Thus, the dangers of an inactive lifestyle to one's health are poorly understood. The sympathetic nervous system is activated by sedentary behaviors, which decrease cardiac output and systemic blood flow. This decreases insulin sensitivity and increases the risk of DMT2 in young adults [22]; thus, the present study focused on this population. Footwear has a direct positive impact on body balance [19]. When older adult respondents were observed indoors wearing socks or going barefoot as opposed to wearing footwear, there was a higher incidence of falls [23]. This study aimed to examine the effect of WBV on the maximum SLS time to assess the possible application of WBV in balance training programs for sedentary young women. This will help increase stability as well as decrease the time of fatigue and risk of injury. The study also sought to demonstrate how anthropometric data affected the SLS time.

2. Materials and Methods

2.1. Participants

Students who applied Medical Sciences at ages of 19 to

23 participated in this study. **Table 1** displays the anthropometric statistics for them. The experimental group (n = 30) and control group (n = 30) were randomly assigned to the subjects. By the Declaration of Helsinki's guidelines for the security of human participants, they were given a thorough description of the study procedure and allowed to offer informed authority. Additionally, the study was given the go-ahead by Jouf University's ethical committee (Approval No. 3-07-43). Flyers in the area were used to deliver study invitations with research-related information. Convenience sampling was used to enroll the participants after the inclusion criteria were applied.

2.2. Inclusion/Exclusion Criteria

The study included women between the ages of 19 and 23 who led an inactive lifestyle, defined as any resting action (such as sitting, reclining, or lying down) that required more than 1.5 metabolic equivalents of task energy expenditure, except those who regularly cleaned their homes and went for walks. The study recruited sedentary women who scored at least 26 on the Rapid Assessment Disuse Index and had a body mass index (BMI) of 25.0–29.9 kg/m^2. In the meantime, the following subjects were not included in the research: Participants with uncontrolled hypertension, diabetes, or a history of abnormal cardiac events; ii) Those who were pregnant or had given birth within the previous six months; iii) Those who exercised regularly (at least twice a week); iv) Those who responded "yes" to any of the questions on the Physical Activity Readiness Questionnaire; v) Those who had experienced acute or chronic injuries within the previous two years; vi) Participants with any history of cardiovascular or other chronic diseases; viii) Participants with any type of surgery within the last six months; or ix) Those who were on any type of medication for balance or neuromuscular coordination.

2.3. Study Design

A quasi-experimental investigation was carried out to identify the variations in the maximal SLS duration among the cohorts. A total of 256 sedentary healthy female students were invited to the study, but only 92 were enrolled and subjected to screening. Finally, 60 subjects were identified to be eligible for the study. The required number of samples was calculated using G-power software 3.1.9.4 with a significance level of 0.05 and an assumption of 95% power (a total sample size of at least 50 participants was required). As such, 60 subjects would be equally distributed between the groups, as presented in **Figure 1**. The subjects were selected according to the inclusion and exclusion criteria (convenient sample). The sealed envelope approach was used to randomly assign the subjects to the groups, in which each subject selected a random envelope and handed it to the investigator.

2.4. Instrumentation

The Rapid Assessment Disuse Index questionnaire was used by participants and included in the study. The good reliability and moderate validity of this questionnaire were proven in a previous study [24]. Height and body mass were measured using a weighing scale (Detecto 349 Height Rod Handpost Weigh Beam Physician’s Scale, USA) and measuring tape, respectively. Then, using a method published by the National Heart, Lung, and Blood Institute (US Department of Health & Human Services), the BMI was computed by dividing mass (kg) by height squared (m^2). WBV was provided by Power Plate ® Pro7 HCTM (Chicago, Germany) with a frequency of 30 Hz, surface plate dimension of 96 × 114 cm (38” × 45”), and power supply of 100–240 V, universal voltage (https://powerplate.com). Furthermore, the maximum SLS time between the pre- and post-treatment intervention was measured using a stopwatch. The reliability and validity of the SLS test were acceptable, as proven by different previous studies [25,26].

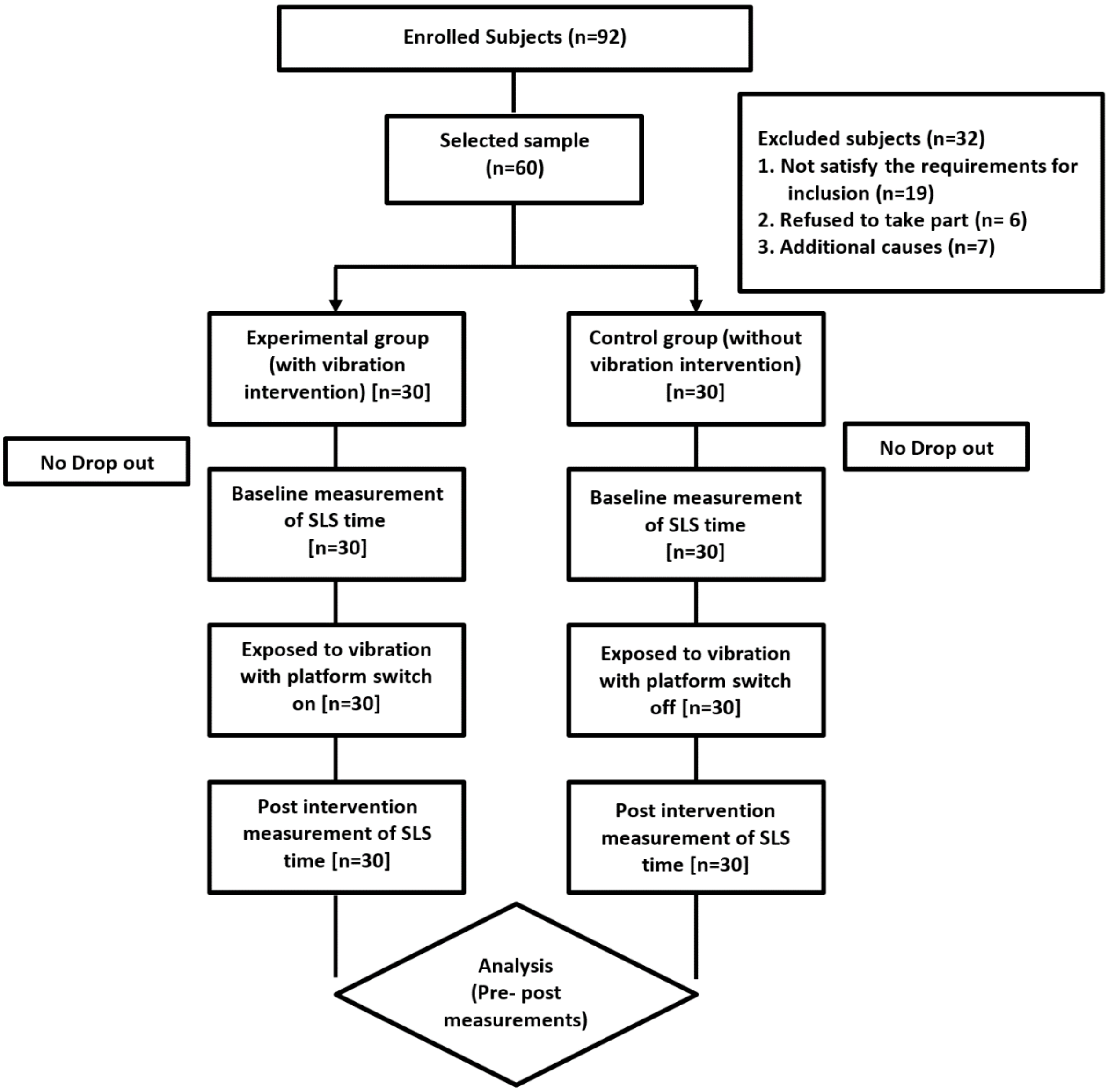

Figure 1. Flow Chart of Participants.

2.5. Procedure

The participants underwent a single lab session of acute vibration and a single-leg balance test under the supervision of a trained physiotherapist. They were advised to remove their shoes and close their eyes during the session. Whether to remove the socks or not was left to the discretion of the participants. Furthermore, to reduce the impact of environmental factors on balance, each session was conducted using the same room temperature and lighting with only one examiner pre- and post-vibration intervention to confirm the reliability of the measurements.

Each participant completed the entire session, which consisted of 5 continuous minutes of WBV for the experimental group and no vibration for the control group, a 3-minute rest after the intervention, and then a single-leg standing balance test. The experimental group's participants were instructed to stand upright in the center of the vibration plate with a small bend in their knees and their feet shoulder-width apart for five continuous minutes (**Figure 2**). The vibration amplitude was 2 mm, and the frequency was set at 30 Hz. The protocol that was previously employed by de Ruiter et al. [27] was comparable to this one. The experimental group received the identical treatment as the control group; however, the vibration platform did not vibrate in a placebo manner.

Figure 2. The subject's position on the platform of the vibration device

Performance evaluations were performed 3 min after the WBV session was completed, and the maximum SLS time was documented. The test was conducted three times consequentially with a 1-minute rest period between each trial. In the test, the participants stood on the dominant leg (preferred kicking leg) with the other leg lifted off the floor, arms crossed in front of the chest, and eyes closed (**Figure 3**).

Figure 3. The proper subject's position during the SLS test

It was told to every participant not to move their arms or to touch or support their raised leg. The participant's leg rise and arms crossed signaled the start of the maximum SLS time measurement. When the participant's elevated leg hit the floor, when their arms moved away from their chest to show they lost their balance while standing, or when they stopped, the timer was set off. For each of the three trials, the subject's maximal SLS time, a measure of how long they can sustain a static standing balance, was recorded in seconds. For both groups, the mean of the three trials was computed before and after the vibration intervention. To ensure the safety of the participants, a therapist was assigned to the performance area.

2.6. Data Analysis

The gathering and exploration of the maximum SLS time were performed by one examiner under the same circumstances using the SLS test. Three trials were conducted for each participant in each group at the similar examination sitting pre- and post-intervention. The average of the three examinations was determined and investigated. Data were examined using SPSS version 20 (IBM, New York, USA). Preliminary exploration checks were accomplished to confirm that there was no kind of violation of the homogeneity, normality, and equality of variance in anthropometric data and main variables of interest using the Shapiro–Wilk and Leven's tests. Furthermore, any outliers were detected and excluded.

A descriptive data representation was achieved to determine the mean and standard deviation (SD) for all variables. Moreover, an independent t-test was applied to detect variations in the anthropometric data and dependent variable (maximum SLS time) between the groups. Contrarily, a paired sample t-test was conducted to examine variations in the dependent variable (maximum SLS time) between pre- and post-vibration intervention in each group (within-group comparison). The Unpaired sample t-test was used to detect the mean differences between groups. Pearson's correlation analysis was also conducted to detect the relationship between the anthropometric data and SLS time post-vibration intervention.

3. Results

3.1. Descriptive Analysis

The results of the Shapiro-Wilk test indicated that the age, weight, height, and BMI data were normally distributed ($p > 0.05$). Additionally, there were no significant differences between the groups according to the results of Levene's test for equality of variances ($p > 0.05$). The mean and SD of age, mass, height, and body mass index (BMI) are shown in Table 1.

3.2. Paired Sample T-test

No statistically significant difference was observed in the mean values of the maximum SLS time between pre- and post-vibration intervention in the control group ($p = 0.208$, $d = 0.20$) with mean difference -1.78 and confidence intervals -4.61, 1.05. Contrarily, there was a statistically significant increase in the mean values of the maximum. There was SLS time between pre- and post-vibration intervention in the experimental group ($p = 0.000$; $d = 0.93$) with mean difference -12.50 and confidence intervals -7.80, -17.20. The improvement rates in the experimental and control groups were 64.37% and 9.27% correspondingly (Table 2).

3.3. Unpaired Sample T-test

The results discovered a statistically significant rise in the mean of the maximum time single-leg leg standing test between the experimental and control groups after vibration intervention, in favor of the experimental group ($p= 0.001$) with a high effect size. Furthermore, there was no statistically significant difference in the mean of the maximum time of the single-leg standing test between the experimental and control groups in the pre-vibration intervention ($p= 0.383$) with a small effect size, as shown in Table 3.

3.4. Person's Correlation Analysis of Anthropometric Data and sls Time Post-Intervention

Non-significant weak positive and negative correlations were detected among all anthropometric variables and SLS time post-vibration intervention in both control and experimental groups except the body weight and BMI in the experimental group which showed significant moderate negative correlations with the SLS time post-vibration intervention ($r = -0.495$, $p < 0.01$; $r = -0.451$, $p < 0.01$) as shown in Table 4.

Table 1. Independent t-test of anthropometric data

Anthropometric variables	Control group (mean ± SD)	Experimental group (mean ± SD)	t-value	p-value	df
Age, years	20.50 ± 1.17	20.57 ± 0.94	-0.244	0.808	58
Body Height, cm	157.47 ± 7.13	157.57 ± 4.70	-0.064	0.949	58
Bodyweight, kg	58.01 ± 9.74	53.22 ± 10.17	1.86	0.067	58
BMI, kg/cm^2	23.34 ± 3.37	21.48 ± 3.88	1.98	0.053	58

* Significance if P-value of less than 0.05. Abbreviation: SD, Standard deviation; BMI, Body Mass Index.

Table 2. Paired sample t-test showing variations in the maximum time of SLS test within each group (Pre-test versus Post-test analysis)

Variable	Group	Pre-intervention	Post-intervention	Mean Difference (95% CI)	*t*-statistics(df)	*P*-value	Effect Size (Cohen's *d*)
SLS test time (sec)	Experimental group (n=30)	19.42 ± 8.25	31.92 ± 17.09	-12.50 (-7.80, -17.20)	-5.443 (29)	0.001*	0.93 (High)
	Control group (n=30)	17.42 ± 9.30	19.20 ± 8.84	-1.78 (-4.61, 1.05)	-1.287 (29)	0.208	0.20 (Small)

*Significance if P-value of less than 0.05; Abbreviations: SLS; Single Leg Test.

Table 3. Unpaired sample t-test showing variation in the maximum time of SLS between groups

Variable	Intervention stage	Experimental group (n=30)	Control group (n=30)	Mean Difference (95% CI)	*t*-statistics (df)	*P*-value	Effect Size (Cohen's *d*)
SLS test time (sec)	Pre-intervention	19.42 ± 8.25	17.42 ± 9.30	-1.99 (-6.54, -2.55)	-0.880 (58)	0.383	0.23 (Small)
	Post-intervention	31.92 ± 17.09	19.20 ± 8.84	-12.72 (-19.80, -5.63)	-3.619 (44)	0.001*	0.94 (High)

*Significance if P-value of less than 0.05; Abbreviations: SLS; Single Leg Test, df; Degree of Freedom.

Table 4. Pearson correlation between the anthropometric data and maximum time of SLS test

	Control Group (n= 30)				**Experimental Group (n= 30)**			
Variable	Age	Body Height	Body weight	BMI	Age	Body Height	Body weight	BMI
SLS time post-intervention(sec)	0.217^{c} 0.249^{b}	-0.083^{c} 0.663^{b}	0.154^{c} 0.417^{b}	0.240^{c} 0.201^{b}	0.210^{c} 0.265^{b}	-0.177^{c} 0.351^{b}	-0.495^{c} 0.005^{b**}	-0.451^{c} 0.012^{b*}

* Significance if P-value of less than 0.05

** Significance if P-value of less than 0.01

^{b}P-values, ^{c}correlation coefficient (r).; SLS: Single Leg Test

4. Discussion

To assess the possible application of WBV in balance training programs for sedentary young women to increase stability, lower the incidence of tiredness, and lower the frequency of falls and injuries, the current study looked into the effect of WBV on single-leg standing balance. The current study's results show that WBV intervention leads to a statistically significant improvement in static balance through a single-leg standing test when compared to the control group (no vibration). The post-vibration intervention shows statistically significant improvement in the experimental group in comparison to the control group, in favor to the experimental group, according to the unpaired sample t-test. The experimental group exhibited a statistically significant difference between pre-and post-WBV intervention with a large effect size (r = 0.93), according to the paired sample t-test. In addition, body weight and BMI exhibited statistically significant moderate negative correlations with the SLS time post-vibration intervention, according to Pearson's correlation between the anthropometric data and the maximum SLS time.

The usage of unstable surfaces, like the WBV platform, enhances muscle force output to provide stability and balance, according to a study by Aguilera-Castells et al. [28]. Fitness enthusiasts, athletes, and coaches are always looking for new challenges to up the difficulty of the workouts and increase training. Examples of these challenges include changing the degree of instability or the intensity of the exercise [29].

Increasing muscle activity through superior motor unit recruitment by vibration training tends to increase exercise effort and improve joint proprioception [30]. Destabilizing surroundings therefore provides more effective and varied training stimuli that improve neuromuscular adaptations [31]. Numerous earlier investigations have documented a transient increase in the upper and lower extremity EMG activity following WBV treatment at different frequencies [32,33], which reported the improvement of muscle and proprioceptive control due to the WBV intervention that reflects its effect on improved balance control.

The findings of the study that is being given are in line with the research conducted by Torvinen et al. [34], which established that young, healthy persons of both sexes experienced positive improvements in their balance and jumping ability following an acute episode of WBV. Following six performance tests (the stability platform, grip strength, isometric extension strength of the lower limbs, tandem walk, vertical jump, and shuttle run), the participants received both WBV and placebo treatments for four minutes. Starting at 15 Hz, the frequency of the WBV intervention was raised by 5 Hz every minute until it reached 30 Hz. Measurements of balance time were made at baseline, two, and sixty minutes after the vibration intervention. A noteworthy 16% improvement in balance was noted following a 4-minute WBV intervention. As a result, it was suggested that prolonged contraction of the muscles, known as the tonic vibration reflex, produced by WBV training, tended to activate muscle receptors.

The length of the muscle-tendon complex may alter as a result of vibration's activation of Golgi tendon organs [5]. Therefore, neural signals sent to afferent nerve fibers activate muscle spindles that are sensitive to stretch, stimulating the reflex arc and causing muscles to contract or relax [35]. Additionally, Pollock et al.'s study [35] found that acceleration above 15 Hz vibration frequencies is typically linked to increased muscular activity, presumably as a result of posture control and muscle-tuning systems.

In addition, a study by Cloak et al. [36] validated the findings of our investigation and established that after only a short training period, WBVT can improve single-leg static balance in dancers with ankle instability. Another study demonstrated that vibration training might successfully reduce body sway and enhance muscular activity to improve single-leg standing balance control in individuals with weakened plantar feelings [37].

According to the correlation between the anthropometric data and SLS time post-vibration intervention, Peterson et al. [38] showed that there had been reports of poor connections between the composite equilibrium score and BMI, weight, and height. These results were consistent with ours, except for the body weight and BMI in the experimental group post-vibration intervention, which exhibited a significant moderate negative correlation with SLS time post-vibration intervention. This could lengthen the SLS period in the experimental group following the vibration intervention, resulting in a clearer picture of the association between body weight, BMI, and the SLS period. Participants with smaller body weights and BMI can benefit more from vibration training than those with greater body weight and BMI. A study by Pataky et al. [39]

reported that obesity tends to affect the functional capacity of the subjects and their capability to adapt to any type of exercise training, such as balance control

Several studies that explored how gender affected balance performance found that women performed better than men [40,41]. The possible explanation for the gender differences may be the variations in anthropometric features between the subjects [42]. Another study that investigated the effect of somatotypes on children's single-legged standing stability found that boys had significantly higher BMI values and body weight than girls. The findings of this study indicated that individuals with greater body fat percentage have a significantly higher mean radius of COP excursion than thin individuals [16]. However, since this study focused on children, it may differ from the recent study that provided results for adults. Contrarily, other studies [43,44] reported that ectomorphs were not as stable in their posture as endomorphs, indicating that as body weight increases, stability also tends to increase, but the authors point to increased muscle component in endomorphs as the reason behind this, not the body fat percentage.

Our research had several limitations. The limited sample size may affect the generalization of the study results. Individual differences that exist in how the environment, age factor, and health state are perceived, which can have an impact on performance. Visual, vestibular, and somatosensory signals can all have an impact on balance. Performance can be impacted by any distraction, including temperature, illumination, and noise [1]. However, these distractions were controlled in the present study by instructing the participants to close their eyes during the test, avoiding any surrounding noise as much as possible, and keeping the room at a constant temperature and humidity to minimize any environmental factors that could affect the participant's performance. The WBV training is recommended for elderly individuals those with neurological disorders or athletes to see the influence of vibration stimulation on balance performance in these populations that need more attention and consideration than healthy subjects. Another limitation is that the study was conducted without considering sex differences.

5. Conclusions

This study aimed to investigate the effect of acute WBV on single-leg standing balance in healthy female subjects. WBV may be a useful supplement to training and rehabilitation plans designed to help healthy sedentary women become more balanced during the single-leg stance phase of walking. The improvement of the SLS time post-vibration intervention may be impacted by body weight and BMI. However, additional research is warranted to detect the effectiveness of WBV and the impact of anthropometric data after a more extended period of exposure. Because nontraditional balance training programs have higher compliance than conventional training routines, unbalanced surface training (WBV) can be used as an addition or replacement to traditional training routines to improve standing balance in healthy sedentary women and reduce the risk of falling and injury.

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Ethics of Study

This research was ethically approved by the ethical committee of Jouf University, Saudi Arabia (Approval No. 3-07-43). All participants volunteered to take part in the study and gave their approval.

Conflict of Interest

No conflict of interest can be decelerated.

Fund

None.

Authors' Contributions

Conception and design: MAA, AMA.

Analysis and interpretation of the data: MAA, AMA, AAK, AHS, GEA, MHR, MSM, SBA, WSH.

Drafting of the article: MAA, FA, AHS, GEA, MHR, MSM, SBA, WSH

Critical revision of the article for important intellectual content: MAA, AMA, AAK.

Final approval of the article: MAA, AMA, AAK, FA, AHS, GEA, MHR, MSM, SBA, WSH.

Statistical expertise: MAA, AAK.

Collection and assembly of data: MAA, AMA, AAK, FA, AHS, GEA, MHR, MSM, SBA, WSH.

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