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Whole Body Vibration: The Effect of Position and Frequency on Perceived Exertion in Healthy, Active Adults

Annette Karim[1], Elizabeth Lemos[2], Huynh Nguyen[2], Katy Mitchell[2], Toni Roddey[2] and Sharon Olson[2]

1. Department of Physical Therapy, School of Behavioral and Applied Sciences, Azusa Pacific University, Azusa 91702, USA

2. School of Physical Therapy, Texas Woman's University, Houston 77030, USA

Abstract: Whole Body Vibration (WBV) is a new exercise trend in fitness and performance enhancement. WBV platforms oscillate over a range of frequencies and amplitudes; however no study to date has examined the experience of perceived exertion with differences in vibration frequency and static or dynamic body position, nor examined the difference between sexes based on position and frequency during WBV. The purpose of this study was to assess the effects of position and frequency on perceived exertion during WBV in healthy, active adults. A convenience sample of 39 healthy young adults who participated in moderated exercise was blinded and randomly allocated to six WBV conditions composed of different frequency and position combinations. The participants received instruction, provided informed consent, participated in a warm-up session, and then reported rating of perceived exertion for each WBV condition. A 2×3 within-subjects multivariate approach ANOVA was conducted against an alpha of 0.05. A statistically significant main effect of position ($p = 0.004$) and significant main effect of frequency ($p = 0.025$) were found. Significant marginal means were found between the frequencies of 0 Hz and 50 Hz ($p = 0.007$). Statistically significant differences were found between sexes for all combinations.

Key words: Whole-body vibration, Borg, plié, perceived exertion.

1. Introduction

Whole Body Vibration (WBV) is used by people in a wide range of the population in age, neuromuscular diseases, and musculoskeletal impairments with the intention of enhancing physical performance. Vibration platforms are found in physical therapy clinics, fitness clubs, and private homes across the United States. WBV is used to elicit physiological changes, such as increased bone mineral density [1] or neuromotor responses, such as improved balance or increased jump height [2]. The WBV plate is a mechanical stimulus, with the intensity of the vibration stimulus determined by a frequency and an amplitude, generating an oscillating perturbation ranging from 3.5-15 gravitational accelerations [2]. A person using the WBV plate can change position and add movement to alter the vibration transmitted to the body's tissues.

There are a variety of studies on the performance effects of WBV in healthy populations, such as the examination of WBV effects on strength and jump height in sample populations of basketball players [3, 4], volleyball players [2, 5] and ballet dancers [6]. However, there is no consensus to date for the most optimal position, frequency, and duration for each population [7]. Although beneficial gains have been documented, such as improved muscle electromyographic activity and knee extensor muscle power with larger vibration frequency levels [6, 8, 9], detrimental effects such as faintness, nausea, skin erythema, edema, and pain have been found in persons with long-term WBV exposure [10].

Corresponding author: Annette Karim, Ph.D., research fields: dance medicine movement analysis, performance, and screening.

In one study of collegiate dancers, vertical jump height increased significantly after a 6-week intervention of WBV at 35 Hz for 5 total minutes twice a week in five different positions [11]. In another study on basketball players, exposure to WBV resulted in a statistically significant increase in voluntary isometric strength of the knee extensors and squat jump height [12]. The participants held two different positions 3 times a week for 20 minutes of WBV training for a total of 4 weeks.

The effect of a short duration of intervention has been examined in only a few studies. One study found that durations of 30 and 60 seconds resulted in increased jump ability as well as power output, but the 90-second intervention resulted in decreased jump height [13]. Another study found a 75-second 30 Hz-frequency 2-mm amplitude WBV intervention resulted in increased CMJ height among competitive rhythmic gymnasts [14]. While early studies have yielded significant results, demonstrating beneficial effects of the use of whole body vibration for human performance enhancement, there is room for consideration of the variance introduced by the number of positions and the interaction between position, frequency, and duration.

To date, no study has examined the experience of perceived exertion with differences in vibration frequency and static or dynamic body position. Studies on perceived exertion between sexes are limited. Perceived exertion was not significantly different between sexes during 1-repetition-max exertion knee extension trials [15], nor during cycling or treadmill exercise [16], but it was significantly higher for women during arm ergometry ($p < 0.05$) [17], as compared to men. Perceived exertion as a function of WBV acceleration was lower for women during the lower 0.2 m/s^2 WBV vertical acceleration ($p < 0.001$) and significantly higher during the higher 0.8 m/s^2 accelerations ($p < 0.001$) as compared to men. To date, no study has examined the difference between sexes based on position and frequency during WBV. Last, perceived exertion during the use of the first position plié during WBV in the adult non-dancer or beginner dancer has not been examined.

1.1 Purpose

The purpose of this study was to assess the effects of position and frequency on perceived exertion during WBV in healthy, active adults.

1.2 Research Aims

The research aims were: (1) to compare the effect of a moving, dynamic 1st position plié (a ballet semi-squat with the lower limbs in lateral rotation) to a static 1st position plié on perceived exertion; (2) to compare the effect of 3 different frequencies (0 Hz, 35 Hz, 50 Hz) on perceived exertion; (3) to compare the effect of the combination of position (static plié, dynamic plié) and frequency (0 Hz, 35 Hz, 50 Hz) on perceived exertion; and (4) to examine the difference between sexes in perceived exertion during WBV.

1.3 Hypotheses

The hypotheses were there would be a significant increase in perceived exertion: (1) in the participants who performed moving, dynamic 1st position pliés as compared to those who performed a sustained, static 1st position plié ($p < 0.05$); (2) in the participants who received a 35-Hz WBV frequency or 50-Hz frequency as compared to those who received a 0-Hz WBV frequency ($p < 0.05$, respectively); and (3) in the participants in the dynamic plié-35-Hz WBV frequency condition and the dynamic plié-50-Hz WBV condition as compared to dancers who participated in all other position and frequency conditions ($p < 0.05$, respectively). The fourth hypothesis is that there would be a significant difference between sexes for dynamic plié-35-Hz WBV frequency condition or the dynamic plié-50-Hz WBV condition, as compared to participants in all other position and frequency conditions ($p < 0.05$, respectively).

2. Methods

2.1 Participants

A randomized crossover design was implemented for participation allocation using the Excel 12.3.6 random number generator function. Frequency setting and plié position were randomly ordered by allocation number and assigned sequentially to participants as they enrolled. Participants were blinded to the frequency setting, with the vibration unit settings covered. The 39 study participants signed approved consent forms following explanation of the study. Participants were excluded from the study if they reported presence of active cancer, chance of pregnancy, lower extremity fracture within the past year, surgery within past year, strain or sprain within the past 3 months, metal plates in the body, or history of migraines. They were invited to participate in the study if moderate physical activity participation was reported on the International Physical Activity Questionnaire Short Last 7 Days Telephone Format, a subjective measure of physical activity participation with good reliability and concurrent validity among healthy adults [18-20]. Table 1 depicts participant demographic information. This study was approved by the Texas Woman's University Institutional Review Board. A sample size of $n = 48$ was calculated by via G*Power 3.1 with the $\eta^2 = 34.7\%$ from Despina et al. [14].

2.2 Procedure

Subjects participated in one 30-minute session. After completing a demographic questionnaire the participants performed a 5-minute warm up similar to the protocol done by Wyon et al. [11] consisting of riding a lower extremity stationary bicycle at 40 to 60 revolutions per minute (rpm), while maintaining a heart rate between 120 and 140 beats per minute. Afterwards, the participants also completed 5 minutes of a preset routine of dynamic and static stretching of the gastrocnemius, soleus, hamstrings, and quadriceps muscles.

Participants then stood in bare feet on the Power Plate Pro5 *Air*Adaptive® WBV Platform in one of two different ballet semi-squat positions, static 1st position plié or dynamic 1st position plié. The Power Plate was set to one of three frequencies: 0 Hz (no vibration), 35 Hz (medium setting), or 50 Hz (high setting). In total, 6 trials on the Power Plate were completed, with each trial using a different frequency/position combination. Participants maintained the first randomly assigned combination for 30 seconds, rested 30 seconds, and then repeated the process for the other 5 position and frequency combinations. At the end of each combination application, the Borg RPE was assessed, with the participants pointing to a level on the rating chart that was equivalent to their perception of exertion during the trial.

2.3 Outcome Measure

The outcome measure used to assess perceived exertion was the Borg CR-10 Rate of Perceived Exertion (RPE) scale [21]. The Borg CR-10 scale is a category ratio scale, with a range from 0 to 10, with 0 as "Nothing at all" and 10 as "extremely strong (almost max)," but contains an anchor without a number, designated as the term "Maximal." The use of an anchor allows the rater to imagine a greater intensity of exertion, while at the same time scoring their highest exertion as a 10.

2.4 Data Analysis

A 2-factor, within-subjects ANOVA using a multivariate approach, examining 2 levels of position and 3 levels of frequency, was conducted through PASW 18.0 for Mac against an alpha of 0.05. An independent measures *t*-test was use to examine the difference in perceived exertion between sexes. A Levene's Test for Equality of Error Variance was conducted and Homogeneity of Variance was tenable, with $p > 0.05$.

3. Results

Means and standard deviations for perceived exertion are found in Table 2. There was no significant interaction of position and frequency. A statistically significant main effect of position and significant main effect of frequency were found, as shown in Table 3. Significant marginal means were found between the frequencies of 0 Hz and 50 Hz, found in Table 4. Statistically significant differences were found between sexes for all combinations, as shown in Table 5 and 6.

Table 1 Participant[a] demographics.

Characteristics	Men M (SD)[b]	Women M (SD)
Age	25.44 (3.28)	24.71 (2.53)
Weight in kilograms	78.28 (12.03)	64.09 (8.84)
Height in centimeters	176.18 (7.64)	166.14 (8.09)
BMI[c]	25.23 (3.85)	23.20 (2.71)

[a] There was a convenience sample of 18 men and 21 women non-dancer participants.

[b] M (SD) = Mean (Standard Deviation).

[c] BMI = Body Mass Index.

Table 2 Perceived exertion during each position and frequency.

Position	Frequency M (SD)[a]		
	0 Hz[b]	35 Hz	50 Hz
Static Plié[c]	2.03 (1.33)	2.28 (1.17)	2.41 (1.21)
Dynamic Plié[d]	1.67 (1.03)	2.00 (1.08)	2.08 (0.81)

[a] M (SD) = Mean (Standard Deviation).

[b] Hz = Hertz.

[c] ballet semi-squat position with lower limbs in lateral rotation, held isometrically.

[d] ballet semi-squat squat movement with lower limbs in lateral rotation, at a rate of 2-seconds up-2-seconds down.

Table 3 The effect of position & frequency on perceived exertion.

	F	df[a]	*p*
Main effect of position[b]	9.917	1.38	0.004
Main effect of frequency[b]	4.686	2.37	0.025
Interaction of position X frequency	4.447	2.37	0.938

[a] Df = degrees of freedom.

[b] significant main effect, held against an alpha of 0.05, in a 2-factor within-subjects ANOVA with a multivariate approach.

Table 4 Frequency estimated marginal means.

	Mean difference	Standard error	*p*
0 vs. 35	0.295	0.151	0.058
0 vs. 50[a]	0.397	0.140	0.007
35 vs. 50	0.103	0.090	0.263

[a] significant marginal means, held against an alpha of 0.0167.

Table 5 Perceived exertion differences between sexes.

Position	Frequency M (SD)[a]		
	0 Hz[d]	35 Hz	50 Hz
Static Plié[b] women	1.62 (1.20)	1.81 (0.98)	1.95 (1.07)
Static Plié men	2.5 (1.33)	2.83 (1.15)	2.94 (1.16)
Dynamic Plié[c] women	1.19 (0.75)	1.57 (1.03)	1.81 (0.81)
Dynamic Plié men	2.22 (1.06)	2.50 (0.92)	2.39 (0.70)

[a] M (SD) = Mean (Standard Deviation).

[b] ballet semi-squat position with lower limbs in lateral rotation, held isometrically.

[c] ballet semi-squat squat position with lower limbs in lateral rotation, at a rate of 2-seconds up-2-seconds down.

[d] Hz = Hertz.

Table 6 Perceived exertion between sexes.

Position	Frequency								
	0 Hz			35 Hz[a]			50 Hz		
	t	*df*[b]	*p*[c]	*t*	*df*[b]	*p*[c]	*t*	*df*[b]	*p*[c]
Static Plié[d]	2.16	37	0.037	3.00	37	0.005	2.77	37	0.009
Dynamic Plié[e]	3.55	37	0.001	2.95	37	0.006	2.37	37	0.023

[a] Hz = Hertz.

[b] df = degrees of freedom.

[c] $p < 0.05$ is significant, held against an alpha of 0.05, in an independent measures *t*-test.

[d] ballet semi-squat position with lower limbs in lateral rotation, held isometrically.

[e] ballet semi-squat squat position with lower limbs in lateral rotation, at a rate of 2-seconds up-2-seconds down.

4. Discussion

Results demonstrated that RPE values increased as vibration frequencies increased in both positions of static plié and dynamic plié; however, no combination of frequency/condition resulted in an RPE greater than 3.5 in individual data, indicating moderate exertion levels. The means did not result in a rating higher than 3, with most of the perceived exertion between very weak and moderate for all categories. The 3.5 RPE value is a reasonable rating for young, healthy adults unaccustomed to the application of WBV. While Cesarelli et al. [22] found no significant changes in the perceived exertion rate between static and dynamic squat exercises with and without vibration, the current study demonstrates a linear relationship with increased frequency and RPE values. In this study, the main effect of position indicates better tolerance to dynamic plié vs. static plié in regards to RPE values, but since both types of positions were rated between weak and moderate, either position could be used in healthy young adults.

Across the board, all frequency/condition combinations resulted in statistically significant differences between men and women, demonstrating increased perceived exertion values reported by men, in contrast to the results reported by O'Connor et al. [17]. It is possible that in the study sample of healthy young adults who were primarily physical therapy students, there was a competitive nature between sexes. Regardless of the reason behind the difference between sexes, the current study suggests sex should be separated for WBV intervention analyses.

Perceived exertion did not increase as number of trials increased, suggesting there was no cumulative effect of intervention on fatigue, though future studies should consider tolerable interventions. Ideally, the most effective, best-tolerated dosage with the least time involvement would be worth investigating in future studies.

Limitations to this study include generalizing to populations outside of young healthy adults and to other positions. This study cannot be generalized for protocols of increased repetitions, longer durations of vibration, other positions, or higher frequencies. Further assessment is needed for persons with chronic conditions, neurological impairments, balance deficits, and debilitating diseases, and for protocols of greater dosages than in the current study. Strengths of this study include randomization of the participants, blinded intervention, and use of a validated outcome measure.

5. Conclusion

Regardless of position or frequency, WBV was well tolerated by healthy, active adults for the 6 sets of 30-second intervals. Higher frequencies resulted in increased RPE values reported by both men and women. Dynamic plié was better tolerated than static plié. Sex differences in perceived exertion should be considered in future studies using whole-body vibration. Clinical Significance: This study demonstrates that both 35-Hz and 50-Hz WBV frequencies result in increased RPE values, versus no vibration, with good tolerance. Whole body vibration can be utilized by healthy, active adults with frequencies ranging from 35-50 Hz without perceived detrimental effects.

There are no conflicts of interests for any of the authors of this paper. We acknowledge Caleb Ashmore and Sara Burris for their efforts in participant recruitment and study feedback.

Ethical approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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