APST

Asia-Pacific Journal of Science and Technology

https//:www.tci-thaijo.org/index.php/APST/index

Published by the Research and Graduate Studies,
Khon Kaen University, Thailand

Acute effects of whole body vibration and weighted vest on muscle strength and balance in elderly

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Received 2 February 2021
Revised 25 March 2021
Accepted 31 March 2021

Abstract

This study aimed to investigate the physiological consequence of an acute bout of whole body vibration (WBV) combined with wearing a weighted vest (WBV+ WV) compared to WBV or WV alone. Fifty-two elderly volunteers (65.2 ± 3.7 years, mean ± standard deviation (SD)) were randomly allocated into 3 groups: WBV (n= 17, 10 sets of 1 minutes squat exercises interspersed with 60 s rest on a vibration platform with a frequency of 30 Hz and amplitude 2 mm), WV (n= 16, the same squat exercises with an additional 10% of bodyweight loaded into a weighted vest) and WBV+WV (n= 19, combination of both regimes). Heart rate was monitored at baseline, during and 15 minutes post-exercise, while muscle strength, balance, and functional mobility were measured before and 15 minutes post-exercise. Heart rate increased significantly with acute exercise but was not different between groups throughout the experiment. Compared to pre-exercise, WBV improved muscle strength (11% ± 5.6%, mean ± 95% CI, p-Value < 0.01), single leg stance test (43.5% ± 22.1%, p-Value < 0.01), and timed up and go test (5.3% ± 2.7%, p-Value < 0.01) 15 minutes post-exercise, while the WV exercise showed improvement only in timed up and go test (3.9% ± 1.3%, p-Value < 0.01). Compared to pre-exercise, combining WBV+WV increased single leg stance test (40.8% ± 37.7%, p-Value = 0.01) and timed up and go test (3.9% ±1.3%, p-Value < 0.01) post-exercise. Since WBV had an acute improvement on all outcomes, it may be useful as a warm-up activity for older adults.

Keywords: Functional mobility, Older adults, Strength, Vest, Vibration

1. Introduction

Whole body vibration training is an oscillatory movement that is generated from a platform through the participant's feet and transmitted up through the whole body. The vibration wave stimulates tonic vibration reflexes which stimulate muscle contraction [1]. Vibration training has been suggested as a safe and effective alternative to traditional exercise methods for the elderly [2] to improve muscle strength, balance, physical function, reduce risk of falls and increase quality of life [3-6]. Meta-analysis on the long-term effect of whole body vibration (WBV) training found significant positive effects on leg muscle strength and body balance in the older adults [5,7]. A single acute session of WBV exercise has been shown to provide a potentiation effect by increasing the muscle's ability to produce force and enhancing balance in the elderly, leading some to suggest it may be useful if used in a warm-up routine [8,9].

Weighted vests are sleeveless garments worn on the upper body to add extra weight and thereby increase exercise intensity. Using weighted vests during exercise can increase muscle contraction [10], metabolic cost, and loading of the skeletal muscle system [11]. Weighted vests have been used in exercise programs with elderly people and found to improve muscle strength and balance over a 9-month training period [12]. A single acute 10 minutes session using a wearing a weighted vest (WV) resulted in potentiation of performance in young adults [10,13,14], but similar research has not been completed on elderly subjects.

Adding load to WBV exercise increases muscle activation [15,16], and workload [17,18], which results in training-related improvements in muscle power, speed and agility [19]. However, adding extra load to WBV exercise as a means of enhancing the potentiation of the warm-up effect in elderly subjects is unknown. Therefore, the aim of this study was to examine the acute effects of adding extra load by using a weighted vest, to whole body vibration exercise in elderly subjects.

2. Materials and methods

2.1 Population and sampling

In this randomized controlled trial participants were the healthy elderly people (aged 60-80 years) living in the community. Participants were excluded if they had 1) any uncontrolled serious medical condition such as diabetes, hypertension or heart disease, 2) any serious musculoskeletal problems such as prior musculoskeletal surgery, hip pain, knee and ankle pain or 3) uncontrolled psychological disorders.

Sixty participants were subsequently randomly allocated (by block of 6) into WBV, WV and WBV+WV group (n= 20/group). Before starting the experiment, 8 participants withdrew from the experiment because of time constraints. Therefore, a total of 52 healthy elderly volunteers aged 65.2 ± 3.7 years (mean ± standard deviation (SD)), 11 male/ 41female, Body Mass Index (BMI) 26.0 ± 3.8 kg .m^{-2} completed the study: n = 17 for WBV group (high squat position with vibration training), n = 16 for WV group (additional 10% of bodyweight added while exercising in a high squat position), and n = 19 for WBV+WV group (high squat position with additional 10% of bodyweight with vibration training) (Figure 1).

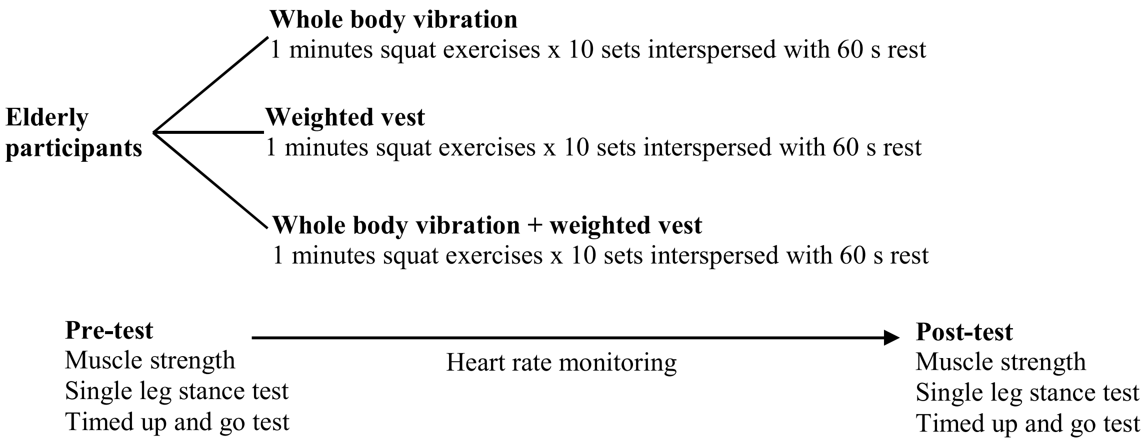

Figure 1 Diagram of three intervention groups.

2.2 Intervention

The WBV group participants were exercised on a whole body vibration machine (Power Plate® Pro5, Performance Health Systems UK Ltd, London, UK) at a frequency 30 Hz, and amplitude of 2 mm, for 10 sets of 1 min, interspersed with 60 s upright standing rest. The participants stood on the platform without shoes, holding a knee flexion of 200. In WBV exercise with added weight group (WBV + WV), the participants completed the same exercise on the vibration machine but with an extra 10% of bodyweight loaded into a vest (Domyos, Decathlon, Villeneuve d'Ascq France) worn on the upper body. The vest allows small bags of sand to be added to increase the weight and to keep the weight equally distributed. In WV group who also wore vests loaded with an extra 10% of their bodyweight, the participants completed the same squat exercise with a knee flexion of 20o on a solid and stable surface for 10 sets of 1 minutes, interspersed with 60 s rest periods.

During the exercise, the participants heart rate was monitored by a wireless body sensor (Polar Team Pro Sensor, Polar Electro, Kempele, Finland). The sensor attached with chest strap was placed on the mid anterior chest wall at the xiphoid process level. The heart rate was recorded before, during and after exercise and was analyzed using the Polar Team Pro application software.

2.3 Performance measures

The outcomes measure in this study were muscular strength (maximal isometric force), balance (single leg stance test) and functional mobility (timed up and go test), that were completed before and 15 minutes post-exercise. The test assessor was blinded from the group allocation. Prior to the intervention, participants were given a warm-up consisting of gentle stretching exercise of the large muscles of the upper and lower extremities for 3 minutes. Participants performed a familiarization test which included all testing and exercise protocols 1 week before commencing the experiment.

Isometric muscular strength was evaluated using a back and leg dynamometer (TKK 5002, Takei Scientific Instruments, Niigata, Japan) that has high test-retest reliability and correlates highly with knee flexion and extension strength [20]. The dynamometer measures isometric muscle strength of the trunk and legs muscles. Participants stood on the base of the dynamometer with their arms straight and hands pronated. The apparatus was adjusted so that participants produced knee flexion of 110o, with hips in slight flexion, back slightly forward and head in the upright position. Participants were asked to pull the handle in a vertical direction without bending the back and only using the leg muscles as much as possible. Participants were asked to gradually increase the leg flexion over a 2 s period until a maximum peak was produced at 3 s. The best of three trials with a 30 s rest period between trials was recorded.

Static body balance was evaluated by a single leg stance test that has excellent test-retest reliability and discriminant validity in the elderly subjects [21]. When the single leg stance test was performed, the participants were instructed to stand on their dominant leg as long as possible. The single leg stance test was timed when one foot was lifted from the floor until the same foot touched the ground or the other leg; no hand-held support was allowed during the test. The test was repeated 3 times, with a 5-minutes rest between each test, and the best time over the 3 trials taken for analysis.

Functional mobility was assessed by the timed up and go test that also has excellent reliability and validity [21]. The participants sat in a chair with arms on the chair arm rests. The participants were instructed to rise from the chair, walk 3.0 m at a comfortable pace to a mark placed on the floor, turn around at the 3.0 m mark, walk back to the starting point, and return to sitting in the chair. The time was recorded from starting to get up and ended when sitting back on the chair. The best of 3 trials was recorded after 5 minutes recovery was given between each trial. The performance measures started with the leg dynamometer, followed by the single leg stance test followed by the timed up and go test, with 5 minutes rest between each series of tests.

2.4 Statistical analyses

Statistical analysis was performed using SPSS version 26 analysis package. The descriptive data is presented as mean, standard deviation and 95% confident interval. Non-normal distribution of the data was determined by a Kolmogorov-Smirnov test. A Kruskal-Wallis test for non-parametric data such as muscle strength, single-leg-stance and functional mobility was performed for differences between the three groups. Changes within groups were analyzed by a Wilcoxon Signed-Rank test. Normally distributed data of heart rate changes within groups and the difference between groups was analyzed by one-way ANOVA test. Results were considered significant p-Value < 0.05. Values are expressed as mean ± SD.

3. Results and discussion

The demographic data including age, gender, height, weight, BMI, and heart rate of WBV, WV, WBV+WV groups are presented in Table 1. There was no significant difference between the groups at baseline.

Table 1 Participants' characteristics in the three exercise intervention groups.

Characteristics	WBV (n=17)	WV (n=16)	WBV+WV (n=19)
Male/Female	2/15	3/13	6/13
Age (y)	64.2 ± 3.4	67.2 ± 4.7	64.4 ± 3.0
Height (cm)	154.2 ± 6.4	152.1 ±7.4	154.3 ± 8.2
Weight (kg)	61.7 ±10.2	58.5 ± 10.2	63.4 ± 9.4
Body mass index (kg.m^{-2})	26.0 ± 4.3	25.2 ± 3.0	26.6 ± 4.1
Resting heart rate (bpm)	72.7 ± 8.2	75.3 ± 11.1	75.7 ± 11.7

Data are mean ± SD, WBV, whole body vibration group, WV, weighted vest group, WBV+WV, whole body vibration and weighted vest group.

Fifteen minutes after an acute bout of static leg flexion on the vibration platform (WBV group), isometric muscle strength, single leg balance and functional mobility (timed up and go test) all significantly improved (Table 2). However, the same leg flexion exercise without vibration but with participants carrying 10% extra bodyweight (WV group) only increased performance in the timed up and go test. On the other hand, adding 10% body weight to participants exercising on a vibration platform (WBV + WV group) increased single leg stance and timed up and go performance compared to baseline, but did not change muscle strength significantly.

Acute isometric strength was significantly higher post-exercise in the WBV group compared to all other groups (Table 2). Interestingly, the single leg stance acute post-exercise response in the WBV groups (both WBV and WBV + WV) showed a significant improvement (18.5 ± 9.5 s and 21.4 ± 19.8 s in the WBV and WBV + WV groups respectively) compared to the WV group that showed a mean decrease in balance time (-10.9 ± 35.4 s). There was little difference in the timed up and go test between all groups (Table 2).

In all groups heart rate increased significantly from baseline to exercise and remained significantly elevated compared to baseline at 15 minutes post-exercise. There was no significant difference between groups for heart rate change during the study (Table 3).

Table 2 Acute effects on isometric muscle strength, balance and functional mobility in the three exercise intervention groups. (WBV, WV. and WBV+WV).

Outcomes	WBV (n = 17)			WV (n = 16)			WBV + WV (n = 19)		
	Pre	Post	Mean difference ± 95%CI	Pre	Post	Mean difference ± 95%CI	Pre	Post	Mean difference ± 95%CI
Muscle strength (kg)	80.1 ± 24.6	88.9 ± 26.7	8.8± 4.5[*,a,b]	79.1 ± 28.1	81.7 ± 34.0	2.6 ± 6.1[a]	87.0 ± 34.3	91.1 ± 34.1	4.1 ± 4.9[b]
Single leg stance (s)	42.5 ± 22.9	60.9 ± 36.5	18.5 ± 9.4[*,a]	82.4 ± 76.2	71.4 ± 68.4	-10.9 ± 35.4[a,c]	52.5 ± 46.2	73.9 ± 61.8	21.4 ± 19.8[*,c]
Timed up and go (s)	7.5 ± 0.8	7.1 ± 0.9	-0.4 ± 0.2[*]	7.7 ± 1.3	7.4 ± 1.2	-0.3 ± 0.1[*]	7.7 ± 1.2	7.4 ± 1.1	-0.3 ± 0.1[*]

Data are mean ± SD, mean difference = post – pre exercise mean ± 95% confidence interval, WBV, whole body vibration group, WV, weighted vest group, WBV+WV, whole body vibration and weighted vest group, [*]significant difference within group, [a] significant difference between WBV and WV, [b] significant difference between WBV and WBV+WV, [c] significant difference between WV and WBV+WV, *p*-Value < 0.05.

Table 3 Acute effects of heart rate at baseline, during and post-exercise of three groups (WBV, WV. and WBV+WV).

Outcomes	WBV (n = 17)			WV (n = 16)			WBV + WV (n = 19)		
	Baseline	During	Post	Baseline	During	Post	Baseline	During	Post
Heart rate	72.7± 8.2[*]	90.4± 9.0[*]	77.1± 8.8[*]	75.3± 11.1[*]	95.2± 13.4[*]	81.2± 9.2[*]	75.7± 11.7[*]	96.8± 14.2[*]	80.7± 11.7[*]

Data are mean ± SD, WBV, whole body vibration group, WV, weighted vest group, WBV+WV, whole body vibration and weighted vest group, [*]significant difference within group, *p*-Value < 0.05.

Acute whole body vibration exercise facilitated an augmenting effect on isometric muscular strength and single leg stance, but adding weight to whole body vibration exercise had little effect on isometric muscle strength and no significant additional effect of whole body vibration on single leg stance performance. Functional mobility (timed up and go test performance) improved from baseline to post-testing in all groups equally.

Similar to the current study, previous research has reported that WBV acutely improved muscle strength and balance in healthy normal and athletic subjects. For example, Bosco et al. (2000) [22] showed whole body vibration applied 10 times for 1 minutes (26 Hz, 4 mm) improved vertical jumping ability. Torvinen et al. (2002) [23] showed that 4 minutes of WBV immediately improved isometric leg extension force, explosive power and balance in healthy young adults. In elite gymnasts, 2 minutes of WBV improved flexibility and explosive strength compared to controls [24]. These beneficial acute effects of WBV on strength and balance have also been found in the elderly. Ramos et al. (2018) [9] revealed a single WBV training session with a frequency of 40 Hz and amplitude 2-4 mm, 30 seconds per set x 3 sets per position (half-squatting stretch and hamstrings stretch positions) increased quadriceps muscle strength, functional mobility and Berg balance score in the elderly. These results corroborate previous research on elderly subjects [8] and agree with the results of the current study that indicate an acute potentiation of performance after WBV exercise.

Mechanisms behind an acute strength improvement after WBV exercise include the vibratory tonic reflex, whereby vibration stimulates type Ia muscle fibers consequently enhancing the α-motor neuron excitability possibly resulting in an improvement muscle strength [25]. In addition, WBV may increase tissue blood flow via the vasodilatation process by increasing endothelium derived vasodilators [26,27]. Increasing vascular blood flow may also effectively eliminate waste products and promote oxygen uptake resulting in facilitated recovery processes of the phosphocreatine energy system [28] thereby enhancing ATP availability and possibly muscular performance. As the current study did not measure possible mechanisms, the reasons for the enhanced performance in the WBV participant's remains speculative.

Performing the knee flexion exercises with a weighted vest did little to improve muscular strength or single leg stance in the elderly participants of this study. Previous research has observed increased jumping performance in female [10,13] and male athletes [14] after performing a warm-up with a weighted vest. Researchers believe that by adding resistance via the weighted vest, subjects would be required to increase motor unit activation which would remain after the vest was removed thereby enhancing neuromuscular facilitation and performance [10]. However, it appears that in elderly subjects this potentiation of the neuromuscular system may not occur when wearing weighted vests. On the other hand, perhaps the weight was too heavy for elderly participants who were not familiar with wearing weighted vests.

Adding a weighted vest to the whole body vibration exercise increased the workload on the elderly participants (witnessed by the highest exercise heart rates), and somewhat dampened the potentiation effect of the whole body vibration exercise on acute muscle strength improvement (significantly lower strength improvement in WBV + WV compared to WBV group). We speculate that adding 10% bodyweight to the vibration exercise has caused changes that altered the beneficial effects of whole body vibration alone. We suspect that by adding resistance (weighted vest) during WBV, the participants were required to recruit a greater number of motor units [10,29] thereby, leaving them fatigued at the post-test period. However, this theory remains speculative until it can be substantiated by data from the neuromuscular system.

This study found all groups improved their functional mobility from baseline (as shown by the significantly decreased timed up and go results). Because there was no significant difference in the timed up and go test between the three groups, the improvement from baseline, therefore, may be due to learning effect when the test was repeated. In hindsight, perhaps more practice trials before the main intervention would be useful when using techniques that are novel for the participants.

A limitation of the study was that we used active healthy elderly subjects. Therefore, the generalizability is limited to this group and further research should be conducted into more typical groups including elderly with health problems. We used low frequency and low amplitude vibration which may not suit elderly subjects and further research exploring other vibration parameters should also be conducted.

4. Conclusion

WBV alone had a greater positive acute effect on isometric muscle strength, and single leg balance compared to WV or WBV + WV. Combined WBV + WV did not significantly enhance acute effects any more than using WBV alone. Having elderly participants exercise for a short period on a vibration platform enhances their acute ability to produce force, maintain balance and functional mobility. WBV may therefore be a useful tool to help warm-up elderly people prior to exercise.

5. Ethical approval

The participants completed a medical condition health questionnaire and gave their informed consent before enrolling in the study. The study was approved by the University Human Ethical Committee (IRD no HE611192).

6. Acknowledgments

This work was supported by the Research Center in Back, Neck, Other Joint Pain and Human Performance, Khon Kaen University: Grant Number 0092.

7. Conflict of interest

No potential conflict of interest was reported by the authors.

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