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Whole-body vibration augments resistance training effects on body composition in postmenopausal women

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ABSTRACT

Age-related changes in body composition are well-documented with a decrease in lean body mass and a redistribution of body fat generally observed. Resistance training alone has been shown to have positive effects on body composition, however, these benefits may be enhanced by the addition of a vibration stimulus.

Objective: The purpose of this study was to determine the effects of 8 months of resistance training with and without whole-body vibration (WBV) on body composition in sedentary postmenopausal women.

Methods: Fifty-five women were assigned to resistance only (RG, $n = 22$), vibration plus resistance (VR, $n = 21$) or non-exercising control (CG, $n = 12$) groups. Resistance training (3 sets 10 repetitions 80% strength) was performed using isotonic weight training equipment and whole-body vibration was done with the use of the power plate (Northbrooke, IL) vibration platform for three times per week for 8 months. Total and regional body composition was assessed from the total body DXA scans at baseline (pre) and after 8 months (post) of training.

Results: In the VR group, total % body fat decreased from pre- to post-time points ($p < 0.05$), whereas, the CG group had a significant increase in total % body fat ($p < 0.05$). Both training groups exhibited significant increases in bone free lean tissue mass for the total body, arm and trunk regions from pre to post ($p < 0.05$). CG did not show any changes in lean tissue.

Conclusion: In older women, resistance training alone and with whole-body vibration resulted in positive body composition changes by increasing lean tissue. However, only the combination of resistance training and whole-body vibration was effective for decreasing percent body fat.

1. Introduction

Age-related changes in body composition are well-documented with increases in fat mass, decreases in lean body mass, and a redistribution of body fat patterns generally observed [1–3]. In addition to the effects of aging, postmenopausal women experience hormone changes which are associated with an accumulation of central body fat, leading to the development of insulin resistance and the metabolic syndrome [4,5]. Sarcopenia, the age-related decrease in skeletal muscle mass, also negatively impacts health as it leads to reduced mobility and functional disability [3]. These body composition changes associated with aging and menopause have important implications for women's health as they contribute to increased risk for chronic diseases, such as type 2 diabetes and cardiovascular disease [6].

Resistance training has been shown to be an effective intervention for sarcopenia by increasing strength and muscle mass older men and women [7]. Several training studies [8–10] have found that high intensity resistance training increased lean tissue in postmenopausal women, whereas, decreased percent body with resistance training was documented in only one of those studies [8]. Since high intensity resistance training may not be feasible for certain clinical populations (i.e., osteoarthritis patients), alternative interventions are being developed for improving body composition and health-related outcomes.

Whole-body vibration (WBV) training has been receiving attention in recent years in the area of musculoskeletal research. The potential advantage of a vibration stimulus is that it may potentiate muscle activity while avoiding the safety and compliance issues associated with high intensity resistance training programs. Theoretically, a vibration stimulus also may have an osteogenic effect since a subject is exposed to a number of ground reaction forces in a very short time period while standing on a vibration platform moving at a high frequency (30–40 cycles per second) and displacing at a low amplitude (2–5 mm). Human research should take a conservative approach to ensure subject safety and to avoid side effects associated with chronic vibration exposure, such as dizziness, and low back pain [11]. However, the majority of vibration

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studies reported that this type of training was well-tolerated by older individuals with relatively minor side effects such as erthyma, edema, and itching of the legs [11]. For example, Verschueren et al. [12] demonstrated that postmenopausal women can safely handle up to 30 min of high amplitude, high frequency vibration training 3 days per week.

The beneficial effects of whole-body vibration in older populations include increases in muscle mass [13] and muscle strength [12–14], as well as improvements in balance [15]. The skeletal responses to WBV training are less clear as Rubin et al. [16] found that bone mineral density (BMD) did not increase after a 12-month WBV intervention, whereas Verschueren et al. [12] and Gusi et al. [17] reported that hip BMD improved significantly after WBV training programs in postmenopausal women. Body composition is another aspect of physiological function which may be affected by WBV training. In animal studies, brief exposure to high frequency, low magnitude whole-body vibration suppressed adipogenesis in young adult mice [18] and reduced fat accumulation in rats [19]. The effects of WBV on percent body fat and fat mass has not been well-documented in the literature, particularly in older women. Verschueren et al. [12] found that both WBV and resistance training treatments altered by body composition by decreasing fat mass assessed by dual energy X-ray absorptiometry (DXA). However, lean body mass did not change significantly for either treatment in this 6-month study [12].

Although previous studies have examined the influence of resistance training on body composition in older women [8–10] and the effects of WBV in older women [12,14–17], little is known about whether resistance training in combination with WBV has a greater affect on changes in body composition than resistance training alone. The purpose of this study was to determine the effects of a combined whole-body vibration and traditional high intensity resistance training intervention on body composition in sedentary, postmenopausal women. We hypothesized that women who underwent resistance training with whole-body vibration training would have greater improvements in total and regional bone free lean tissue mass and decreases in fat mass compared to the resistance training only group.

2. Methods

2.1. Subjects

Estrogen-deficient postmenopausal women between the ages of 60–75 years of age were the target population for this study. The inclusion criteria were: (1) subjects had to be normal healthy women volunteers, 60–75 years of age; (2) subjects had to provide information on menopausal status, menstrual history, and hormone replacement therapy (HRT) status obtained by a menstrual history questionnaire; (3) subjects had to be at least 5 years postmenopausal; (4) subjects who had a history of hormone use had to have been off HRT for at least 1 year; (5) subjects could not have participated in a weight training program for at least 1 year prior to the study; and (6) recruited subjects had to be medically stable, ambulatory, and capable of undergoing physical strength testing and training. The exclusion criteria were: (1) women diagnosed with osteoporosis; (2) any persons with physical disabilities preventing them from being strength tested and trained, including orthopedic or arthritic problems; (3) those with heart problems such as congestive heart failure and arrhythmias, or chronic high blood pressure; (4) subjects who were currently smoking or past smokers within the last 15 years; (5) women with a current diagnosis or a history of renal disease, chronic digestive or eating disorders, rheumatoid arthritis, or thyroid disease; and (6) those who were currently taking medications that affect body composition or bone, such as steroid hormones, calcitonin, or corticosteroids. All participants obtained medical clearance from their physician and signed a written informed consent form prior to testing. The Institutional Review Board at the University of Oklahoma approved all procedures in this study.

A total of 82 subjects responded to recruitment advertisements, however, 15 subjects were excluded due low BMD ($n = 3$), medical problems/illnesses or inability to obtain medical clearance ($n = 9$), steroid medication use ($n = 1$), inability to make time commit for the training program ($n = 2$), and five women did not show up for the first meeting. Sixty-two women began the study, however, 7 subjects were unable to continue for medical or personal reasons, thus, 55 subjects completed the entire 32 weeks of the study. The compliance for both training programs was excellent with an average attendance of 92% for the vibration plus resistance training group and 90% for the resistance training only group.

2.2. Research design

This study employed a mixed factorial research design with one between subjects factor (group) and one repeated measures factor (time). Women were non-randomly assigned to either a resistance training group (RG, $n = 22$), vibration plus resistance training group (VR, $n = 21$) or a non-exercising control group (CG, $n = 12$). During the first visit to the laboratory, subjects completed questionnaires to assess physical activity levels, menstrual history, calcium intake, and health status and performed a total body scan. A menstrual history questionnaire was used to determine menopausal status, and their physical activity levels were estimated by the physical activity scale for the elderly (PASE) questionnaire [20]. VR and RG subjects underwent a supervised 8 months progressive resistance training program in the Neuromuscular Laboratory. Total and regional body composition was assessed again immediately post-training.

2.3. Body composition

Total and regional body composition was measured by dual energy X-ray absorptiometry (DXA) (GE Lunar Prodigy, GE Medical Systems, Madison, WI). Height was measured with a wall stadiometer and body weight was measured using a Tanita BWB-800 digital scale (Tanita Corporation of America, Inc., Arlington Heights, IL). The subject removed any metal or plastic materials she was wearing, then she was positioned supine on the DXA table for the scan. The legs were secured in place using velcro straps and the arms were placed close to the sides. Scan modes for the total body scans were selected based on the subject's trunkal thickness as follows: thick > 25 cm; standard, 13–25 cm; and thin < 13 cm. One qualified technician performed all the scan analyses using the Prodigy enCORE 2002 software version 8.80. The total body scan analysis provides % fat, fat mass, bone free lean tissue mass (BFLTM) and bone mineral content (BMC) for the total body and for the arms, trunk, and leg regions. Quality assurance and spine phantom calibration procedures were performed daily prior to each scanning session to ensure no machine drift occurred during the intervention period. In our laboratory, the coefficients of variation (%) for the body composition variables are as follows: 2.5% for % fat; 2.74% for fat mass; and 1.39% for BFLTM. The least significant change at the 95% confidence level for the outcome variables was calculated as: LSC = 2.77 $\times$ precision error expressed as root mean square standard deviation.

2.4. Resistance training intervention

Resistance training and strength testing were performed by the use of Cybex® isotonic weight training equipment (Cybex International, Inc., Medway, MA). Prior to training, the subjects had an acclimation period of 2 weeks to get familiar with the equipment

Table 1
Description of vibration positions and resistance exercises performed.

Vibration position	Resistance exercise
Seated	
While performing a shoulder press using rigid straps fixed to the platform	Shoulder press, hip abduction, hip adduction, abdominal flexion
Wrist curls	
Using rigid straps fixed to platform	Wrist curls, lat pull down, low row
Squat	
Standing performing a dynamic squat movement	Leg press, hip flexion, hip extension

Table 2
Physical characteristics at baseline for each group.

Variables	Group		
	RG ($n = 22$)	VR ($n = 21$)	CG ($n = 12$)
Age (years)	63.9 ± 0.9	62.8 ± 1.1	63.1 ± 1.4
Height (cm)	160.6 ± 1.7	163.9 ± 1.5	162.8 ± 1.5
Weight (kg)	76.6 ± 3.2	73.6 ± 2.8	77.9 ± 5.2
BMI (kg/m^2)	29.6 ± 1.1	27.3 ± 0.9	29.4 ± 1.4
Years PM	17 ± 2	16 ± 2	19 ± 5

Values are means ± SE; no significant group differences; BMI, body mass index; PM, postmenopausal; RG, resistance training group; VR, vibration plus resistance training group; CG, control group.

as well as resistance training procedures. The familiarization was followed by one repetition maximum (1-RM) testing for the following eight resistance exercises: supine leg press; hip flexion; hip extension; hip abduction; hip adduction; seated military press; latissimus pull down; and seated row. The hip exercises were performed on a multi-hip machine. Subjects performed a warm up, consisting of a 5 min walking or cycling and a warm up at each exercise machine, prior to the 1-RM testing. The 1-RM was obtained by finding the maximum weight lifted through an entire range of motion in a single repetition. The 1-RM was found within five attempts, giving 1 min of rest between attempts. 1-RM testing was monitored and recorded by project staff.

The resistance exercise protocol consisted of training three times per week for 8 months, with each session lasting for approximately 1 h. The workload was 3 sets of 10 repetitions at 80% of 1-RM for each resistance exercise. The progressive overload principle was applied to the exercise program, as 1-RMs were re-assessed every 4 weeks and the loads were adjusted to maintain the 80% 1-RM intensity. The non-exercising control group was asked to maintain their normal daily activities and not to perform any resistance exercise.

2.5. Vibration intervention

The VR group performed the same resistance exercise protocol described above with the addition of vibration exposures during

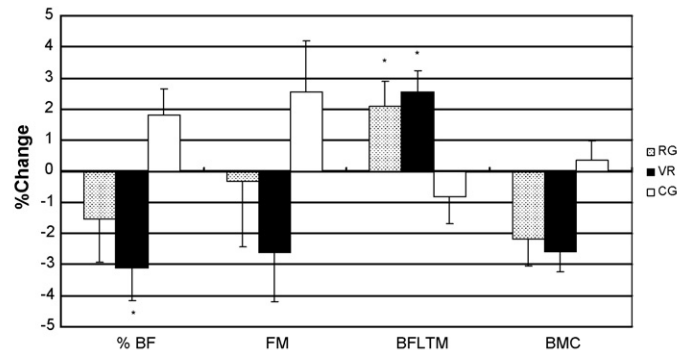

Fig. 1. Percent changes for total body composition variables after training. Data are reported as means ± SE; $^*p < 0.05$ significant compared to CG; RG, resistance training group; VR, vibration plus resistance training group; CG, control group; BFLTM, bone free lean tissue mass; FM, fat mass; %BF, percent body fat; BMC, bone mineral content.

workout sessions. The WBV training was conducted with the use of a Power Plate® vibration platform (Power Plate North America, Inc., Northbrook, IL) which vibrates in a vertical direction. The subjects were exposed to the vibration stimulus while they performed dynamic movements in three positions: (1) dynamic squats while standing on the vibration platform, (2) sitting on the vibration platform and performing shoulder extension/flexion movements with the use of straps attached to the platform and (3) performing wrist curls with the straps attached to the platform while standing on the floor. These vibration bouts preceded a specific grouping of resistance exercises (Table 1). The principle of progressive overload was applied with the vibration stimulus. Vibration exposures started at a low intensity with 15 s at 30 Hz on low amplitude (3 mm), then the frequency and duration were increased during the course of the study, and the final exposures consisted of 2–60 s sets at 40 Hz on low amplitude for each vibration position. There were 15 s rest intervals between every vibration bout.

2.6. Statistical analysis

All statistical procedures were performed using SPSS for Windows version 15.0 (SPSS Inc., Chicago, IL). Descriptive analyses for each group are reported as means ± standard error for the dependent variables. Two-way repeated measures ANOVA (group × time) was used to determine the effects of the interventions on the body composition variables. If a significant group × time interaction was detected, paired *t*-tests comparing pre- vs. post-training were computed separately for each group as a *post hoc* procedure. Percent changes from baseline in body composition variables calculated and one-way ANOVA, with the Bonferroni *post hoc* procedure, was used to determine group differences. The level of significance was set at $p \le 0.05$.

Table 3
Total body composition variables pre- and post-training.

Variables	Group					
	RG ($n = 22$)		VR ($n = 21$)		CG ($n = 12$)	
	Pre	Post	Pre	Post	Pre	Post
% Fat	42.4 ± 1.2	41.8 ± 1.4	40.6 ± 1.6	39.3 ± 1.7**	44.2 ± 1.8	44.9 ± 1.8
Fat mass (kg)	32.6 ± 2.1	32.7 ± 2.3	30.2 ± 2.1	29.5 ± 2.2	34.7 ± 3.3	35.7 ± 3.6
BFLTM (kg)	40.6 ± 1.3	41.9 ± 1.3*	40.1 ± 1.1	41.1 ± 1.1**	39.8 ± 1.5	39.5 ± 1.4
BMC (g)	2458.5 ± 99.1	2402.9 ± 97.4*	2439.0 ± 67.3	2376.8 ± 68.8**	2417.8 ± 72.8	2425.8 ± 71.8

Values are means ± SE; BFLTM, bone free lean tissue mass; BMC, bone mineral content; RG, resistance training group; VR, vibration plus resistance training group; CG, control group.

* $p < 0.05$ pre vs. post.

** $p < 0.01$ pre vs. post.

Table 4
Regional body composition pre- and post-training.

	Group					
	RG (n = 22)		VR (n = 21)		CG (n = 12)	
	Pre	Post	Pre	Post	Pre	Post
Arm (kg)						
FM	2.74 ± 0.18	2.81 ± 0.21	2.45 ± 0.15	2.66 ± 0.22	2.82 ± 0.21	2.99 ± 0.19
BFLTM	4.03 ± 0.14	4.29 ± 0.15**	3.92 ± 0.09	4.33 ± 0.13**	3.80 ± 0.20	3.89 ± 0.16
Trunk (kg)						
FM	16.99 ± 1.11	16.83 ± 1.11	15.49 ± 1.27	14.76 ± 1.23	18.50 ± 1.77	18.69 ± 1.88
BFLTM	20.54 ± 0.63	21.22 ± 0.67**	20.38 ± 0.62	20.89 ± 0.60*	20.56 ± 0.90	20.06 ± 0.85*
Leg (kg)						
FM	12.04 ± 0.98	12.21 ± 1.11	11.39 ± 0.89	11.25 ± 0.90	12.57 ± 1.49	13.09 ± 1.66
BFLTM	13.16 ± 0.54	12.97 ± 0.50	12.82 ± 0.40	12.86 ± 0.36	12.65 ± 0.55	12.69 ± 0.56

Values are means ± SE; FM, fat mass; BFLTM, bone free lean tissue mass; RG, resistance training group; VR, vibration plus resistance training group; CG, control group.
* $p < 0.05$ pre vs. post.
** $p < 0.01$ pre vs. post.

3. Results

3.1. Subject characteristics

Subject characteristics for the three groups are shown in Table 2. There were no significant ($p > 0.05$) group differences in baseline physical characteristics or number of years postmenopausal. The group mean BMI values were within the overweight (25–29.9) and obese (≥30) classifications. Body weight did not significantly change ($p > 0.05$) after the training period for any group (post-test body weights—RG 77.4 ± 3.4 kg; VR 73.8 ± 2.9 kg; CG 78.4 ± 4.6 kg). There were no significant ($p > 0.05$) group differences in percent changes in body weight from pre- to post-testing (RG 0.9% ± 0.9; VR 0.4% ± 0.7; CG 0.6% ± 1.0).

3.2. Body composition variables

Table 3 shows the body composition variables for the total body for pre- and post-training for each group. There were significant time × group interaction effects ($p < 0.05$) for total % fat and total bone free lean tissue mass (BFLTM) variables. Total % body fat decreased in the vibration plus resistance (VR) group from pre- to post-time points ($p < 0.01$), whereas there was a trend ($p = 0.06$) for an increase in the control group (CG). Both the resistance training only (RG) and the vibration plus resistance (VR) training groups exhibited significant increases ($p < 0.05$) in total bone free lean tissue mass (BFLTM) from pre- to post-training. An unexpected finding was that total body BMC significantly decreased in both RG ($p < 0.05$) and VR ($p < 0.01$) after training. The control group (CG) did not show significant changes ($p > 0.05$) for either total body bone free lean tissue mass (BFLTM) or total body BMC.

Fig. 1 shows the group comparisons of the percent changes in the body composition variables for the total body. There were significant ($p < 0.05$) group differences in the % body fat changes as vibration plus resistance group (VR) exhibited a decrease after the training program, whereas the control group (CG) increased % body fat. There also was a significant ($p < 0.05$) group effect for % changes in total bone free lean tissue mass (BFLTM) with the relative increases shown by both training groups being significantly different from the relative decrease in the non-exercising controls. There was a trend ($p = 0.052$) for group differences for the relative change in total body BMC. In contrast to the control group (CG), the two training groups (RG and VR) exhibited decreases in total body BMC.

The regional body composition analyses determined significant time ($p < 0.05$) and time × group interaction effects for arm bone free lean tissue mass (BFLTM) ($p < 0.05$) and trunk bone free lean tissue mass (BFLTM) ($p < 0.05$) (Table 4). Both RG and VR training groups showed significant increases in arm bone free lean tissue mass (BFLTM) ($p < 0.01$) and in trunk bone free lean tissue mass (BFLTM) ($p < 0.05$), while the control group (CG) had a significant decrease in trunk bone free lean tissue mass (BFLTM) ($p < 0.05$) from pre- to post-training. Similar results were found for the percent changes in trunk bone free lean tissue mass (BFLTM) as both RG and VR training groups had significantly ($p < 0.01$) greater relative increases than the non-exercising controls (RG 3.3% ± 0.9; VR 2.7% ± 0.9; CG −1.7% ± 0.7). However, only the vibration plus resistance training group (VR) exhibited a significantly ($p < 0.05$) greater percent increase in arm bone free lean tissue mass (BFLTM) than the control group (CG)1 (VR 10.2% ± 2.1; CG −0.5% ± 5.7). There were no significant ($p > 0.05$) group or training effects for regional fat mass or leg bone free lean tissue mass (BFLTM) variables.

4. Discussion

The primary finding of our study was that the addition of a whole-body vibration stimulus to high intensity resistance training resulted in greater improvements in percent body fat compared to resistance training alone in estrogen-deficient postmenopausal women. In addition, the relative change of −3.1% in percent body fat in the vibration plus resistance training group is greater than the least significant change of 1.8% calculated from the precision error for this variable. We note, however, that the positive body composition effect in our sample was accomplished by increasing the lean soft tissue component of the body, not by reducing fat mass. In addition, the percent increases in arm bone free lean tissue mass in the vibration plus resistance training group were greater than the control group.

Our study is unique as the majority of previous studies [12,14,15] compared whole-body vibration alone to resistance training interventions for neuromuscular performance, whereas we specifically examined whether WBV and resistance training would have additive effects on body composition. The effects of vibration on body composition have been examined using young adult rodent models. Recently, Rubin et al. [18] and Maddalozzo et al. [19] reported that the vibration stimulus significantly reduced fat mass without affecting lean tissue mass. Additionally, Rubin et al. [18] demonstrated that the vibrated mice developed fewer fat cells, suggesting that the vibration signal suppressed adipogenesis. In contrast to those findings, fat mass in the older women in our study was not altered by the WBV resistance training protocol. It is possible that fat tissue is more responsive to the vibration stimulus in younger compared to older subjects.

Our finding of increased total body bone free lean tissue mass with resistance training agrees with previous studies which documented significant increases in lean tissue in older women undergoing moderate intensity [10] or high intensity resistance training programs ranging from 6 to 12 months in duration [8–10]. Typically, body weight does not change much with resistance training as losses in fat mass are accompanied by increases in fat-free mass [21]. The gain of lean tissue is an important health outcome for postmenopausal women by reversing sarcopenia and the risk for its associated problems, such as decreased mobility, falls, and decreased independence [21]. However, an unexpected negative effect associated with both training interventions was the significant decrease in total body BMC. It is difficult to compare our BMC findings to the literature, as most of the training studies [8–10,12] reported total body BMD, not BMC, results. Our total body BMD results (data not shown) are in agreement with previous studies which documented no significant changes in total body BMD with resistance training [8–10] or WBV only training [12] in this population.

There are several limitations to our study. First, we did not randomly assign subjects to the treatment groups, therefore, it is possible that the training subjects were more motivated than average postmenopausal women. Since our focus was to test the hypothesis that WBV would add to the effects of resistance training, we were not able to determine the effects of WBV alone on body composition. WBV alone has been reported to have positive effects on muscle mass in older men [13]. Verschueren et al. [12] found that fat mass in postmenopausal women decreased 2.3% after 6 months of WBV training, whereas, muscle mass was not affected by either WBV or resistance training. A possible mechanism for the effects of WBV on body composition is increased oxygen uptake and energy expenditure associated with the vibration stimulus [22]. Although we did not assess or control for changes in dietary intake during the 8-month intervention period, subjects were instructed to maintain their current dietary habits and the stable body weights observed suggests that the women complied with our dietary instructions.

In conclusion, we found that whole-body vibration enhanced the effects of high intensity resistance training on body composition, specifically the lean tissue components, in postmenopausal women. Positive body composition results can be achieved by increased lean mass without weight loss. Given the lack of human data in this area, larger randomized control trials are warranted to substantiate the potential benefits of adding whole-body vibration to traditional exercise interventions for body composition changes in older populations.

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