EFFICACY OF WHOLE BODY VIBRATION AS A MODALITY TO INDUCE CHANGES IN BODY COMPOSITION AND MUSCULAR STRENGTH IN POST-MENOPAUSAL WOMEN

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ABSTRACT

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by Lauren R. Tapp

Doctor of Philosophy

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The purpose of this study was to evaluate the effectiveness of whole body vibration training (WBVT) as a modality for inducing changes in body composition and muscular strength in sedentary, overweight/obese post-menopausal women. The WBVT program was compared to other training regimens commonly used as weight loss strategies or to increase muscular strength. These training regimens were aerobic training (AT) and circuit resistance training (CT).

The postmenopausal women (48 to 60 years of age) were randomly assigned to one of the following exercise training regimens: WBVT, CT or AT. Participants performed their training regimens three times per week for 8 weeks. The training regimens were progressive in nature with increases in training intensity and duration occurring throughout the 8-week period.

Body composition and bone mineral density data were obtained by DEXA analyses. Upper and lower body strengths were determined by one repetition maximum (1-RM) chest press and leg press, respectively. A treadmill VO_2peak test was performed to assess aerobic capacity.

The following statistical analyses were performed: a 3 x 2 repeated measures ANOVA, with three levels of exercise modalities (WBVT, AT, and CT) and two levels of time (pre and post); one-way ANOVA on change scores; and, because sample size was small, non-parametric analyses.

There were no significant effects of any of the training modalities for percent body fat, lean body mass, bone mineral density, or VO_2peak. The 1-RM for lower body strength increased for all three training modalities. The 1-RM for upper body strength increased for the CT modality.

The results indicate that 8 weeks of WBVT is as effective as CT and AT training regimens for increasing lower body strength in post-menopausal women. None of the 8-week training modalities influenced changes in body composition, bone mineral density, or VO_2peak.

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Upon my acceptance into the PhD program back in 2004, I remember looking through the graduate handbook and reading that there was a 7-year time limit on completing the Doctoral program requirements. I thought to myself, “who really takes that long to finish?” And now, almost 7 years later I am answering my own question: me!

Throughout this process I have learned so much about myself, the world of academic research, and of course, whole body vibration. I faced many obstacles and was able to overcome them and work through them with the support of many colleagues, friends, and family members. For those who chose to stand beside me and behind me throughout this process, I am truly grateful.

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PART 1

EFFICACY OF WHOLE BODY VIBRATION AS A MODALITY TO INDUCE CHANGES IN BODY COMPOSITION AND MUSCULAR STRENGTH IN POST-MENOPAUSAL WOMEN

Introduction

Approximately 60 million adults in the U.S. are considered obese with another 127 million considered overweight (American Obesity Association, 2007). The number of individuals becoming overweight and obese continues to escalate, with obesity noted as a primary comorbid factor associated with cardiovascular and metabolic diseases. Reports indicate that obesity is the second leading cause of preventable deaths in the U.S. (Mokdad, Marks, Stroup, & Gerberding, 2004). Although commercial weight loss products and programs are readily available, the incidence of obesity continues to rise.

It is widely accepted that maintaining a healthy weight is necessary for optimal health, and weight loss may be achieved through a combination of exercise and a healthy diet (Shinkai, Watanabe, & Kurokawa, 1994; Stefanic, Mackey, & Sheehan, 1998; Svendsen, Hassanger, &

Christiansen, 1993). However, one problem for many overweight and obese individuals is an inability to perform exercise for a sufficient duration and intensity for the purpose of inducing weight loss or increasing muscular strength. Weight-related issues such as orthopedic limitations or reduced physical capacity make it difficult for many overweight and obese individuals to perform many of the traditional terrestrial exercise activities. These limitations, in conjunction with time constraints, lack of enjoyment in performing regular exercise, and work or family issues, create reasons to avoid regular exercise paradigms. Because of these factors, many individuals begin exercise programs but have difficulty with adherence, and thus eventually stop exercising.

Post-menopausal females are at a higher risk than younger females and males of any age for increases in body fat and decreases in muscle mass and bone mineral density (Bjorkelund, Lissner, Andersson, & Lapidus, Bengtsson, 1996; Poehlman, Toth, & Gardner, 1995; Toth, Tchernof, Sites, & Poehlman, 2000; Tremollieres, Pouilles, & Ribot, 1996). These risks may be due to contributions from several factors, including decreased physical activity and lower estrogen levels in post-menopausal women (Totosy de

Zepetnek, Giangregorio, & Craven, 2009). Increased body fat further places post-menopausal women at increased risk for development of cardiovascular disease, diabetes, and cancer (Dennis, 2007).

Issues surrounding exercise paradigms and adherence of overweight or obese post-menopausal women provoke interest in other modalities of exercise. New exercise modalities need to be studied to determine their effects on the body composition and muscular strength of post-menopausal women. Whole body vibration (WBV) may be an exercise stimulus or training (WBVT) modality that may result in positive changes in body composition (Asikainen et al., 2002a & 2002b; Brentano et al., 2008; Brooke-Wavell, Jones, & Hardman, 1997; Shinkai et al., 1994) and muscular strength (Bosco et al., 1999; Russo et al., 2003) of post-menopausal women. To determine if WBVT programs are beneficial, the outcomes of WBVT need to be compared with exercise programs often used in conjunction with diet to improve body composition or muscular strength. Two of these traditional programs are circuit resistance training (CT) and aerobic training (AT). Both of these traditional training strategies have been shown to have positive effects on body composition in post-menopausal women (Asikainen et al., 2002a & 2002b; Brentano et al., 2008; Brooke-Wavell, Jones, & Hardman, 1997; Shinkai et al., 1994), although the long-term adherence rates may not be favorable. WBVT programs may provide a viable, alternate modality of exercise that is time efficient and causes less joint strain, thus more effectively promoting physical activity.

The concept of WBVT was originally introduced as a performance-enhancing modality by Russian physiologists in the early 1940s, but the first official documentation of its application in sport did not occur until 1985 (Nazarov & Spivak, 1985). Acute episodes of WBV stimuli and chronic WBVT programs have been shown to provoke changes in neuromuscular responses such as increased strength and power output (Bosco et al., 1999; Roelants, Delecluse, Goris, & Verschueren, 2004a; Roelants, Delecluse, Sabine, & Verschueren, 2004b; Russo et al., 2003; Torvinen et al., 2002a).

The effects of WBV stimuli and WBVT on neuromuscular patterns, muscle performance, and flexibility have been studied to a greater extent than the effects of WBVT on body composition and aerobic performance. A few studies have reported the relationship between vibration exercise and oxygen consumption and/or energy expenditure

(Rittweiger, Beller, & Felsenberg, 2000; Rittweiger, Schiessel, & Felsenberg, 2001; Roelants et al., 2004a). Rittweiger et al. (2000) concluded that WBVT increases oxygen consumption at a similar rate as moderate walking (Rittweiger et al., 2000).

To date only one study examining the effects of WBVT on body composition has been reported (Roelants et al., 2004a). Although Roelants et al. found that 24 weeks of WBVT did not induce any significant changes in body composition in young, untrained females, research needs to be undertaken to determine if WBVT could be used as a weight loss modality or to improve lean body mass of post-menopausal women as opposed to young, normal weight females. In designing a study using WBVT by post-menopausal women, a good predictive evaluation of body composition (i.e., DEXA scans) can be used instead of either underwater weighing or skinfold fat caliper methods of estimating body composition. Also, a more progressive WBVT protocol than the protocol used by Roelants et al. (2004a) may result in body compositional changes of lean body and fat masses.

A key element lacking in the study by Roelants et al. (2004a) was external load. Pilot data acquired for this study indicated that external load significantly increased oxygen consumption during WBVT (Serravite, Roos, Mow, & Signorile, 2009), thereby suggesting a greater intensity of effort and a greater chance of providing a suitable stimulus to influence body composition.

Statement of the Problem

The purpose of this study was to determine if a progressive WBVT program influences changes in body composition and muscular strength of post-menopausal women. The outcomes of the WBVT program were compared to traditional circuit weight training (CT) and aerobic training (AT) programs.

Research Questions

The following research questions were addressed in this study:

1. Does having an external load of 10 to 30% of lean body mass for WBVT provide sufficient loading to induce reductions in body fat of overweight adults?

2. Does having an external load of 10 to 30% of lean body mass for WBVT provide sufficient loading to increase lean body mass of overweight adults?

3. Will changes in body mass (i.e., percent body fat and lean body mass) induced by WBVT be similar to changes in body mass of participants in a CT or AT program?

4. Does WBVT provide similar changes in aerobic capacity as AT at similar heart rate intensities?

5. Does WBVT maintain or increase lower body strength similar to AT and CT?

6. Does WBVT maintain or increase upper body strength similar to AT and CT?

Hypotheses

The following null hypotheses were tested in this study.

1. There will be no significant difference in the percent body fat among overweight/obese post-menopausal women participating in an 8-week progressive WBVT, AT, or CT modalities.

2. There will be no significant difference in the lean body mass among overweight/obese post-menopausal women participating in a progressive 8-week WBVT, AT, or CT modalities.

3. There will be no significant difference in aerobic capacity and time to peak exhaustion among overweight/obese

post-menopausal women participating in a progressive 8-week WBV, AT, or CT modalities.

4. There will be no significant difference in upper and lower body strengths among overweight/obese post-menopausal women participating in a progressive 8-week WBV, AT, or CT modalities.

Methods

Participants

All participant recruitment strategies were reviewed and approved by the Institutional Review Board of the University of Miami. Recruitment consisted primarily of IRB-approved flyers distributed throughout the University of Miami Medical Campus, and by advertisements placed in campus and community print and electronic media. The initial contact occurred by either telephone or electronic mail to assess participant eligibility, introduce the study parameters, and to determine if the potential participant remained interested in enrolling into the study. The following script was utilized for the initial contact with the potential participant:

Telephone Script

"Thank you for your interest in our study. My name is Lauren Tapp and I am a graduate student in the Department of Kinesiology at Temple University in Philadelphia. I am here at the University of Miami working on my doctoral degree. I am currently working under Dr. Joseph Signorile, a research scientist and professor here at the University of Miami.”

“We obtained your information from __________ and are looking for post-menopausal women who would like to participate in an exercise intervention study. I would like to ask you a few questions to see if you would be eligible to participate.”

The following questions were asked:

1. “Are you currently participating in any exercise program?”

2. If yes, “What type of activity, and how many hours per week?”

3. “Do you have any medical issues or injuries that would prevent you from exercising regularly?”

4. “Are you currently post-menopausal?”

5. “Did your last menstrual cycle occur within the past 12 months?”

6. “Would you be willing and able to participate in an exercise program three times per week for 8 weeks?”

Upon completing the telephone script, one of the scripts below followed:

“Thank you. Judging from your answers, I would like to meet you in person to further confirm that you are an appropriate candidate for our study. I would like you to come to the laboratory for an orientation/assessment session. Can we set up an appointment?”

or

“Thank you for your time. Based on your answers, I’m sorry to say we would need participants who fit a different profile, so you may not be eligible. However, I would like to keep your name on file and after our full review of candidates, you may be able to participate in this study or we can keep your information on file for future studies. Would that be acceptable to you?”

In order to qualify for the study, participants had to meet the following criteria:

1. Have not had a menstrual period during the last 12 months
2. Were between 48 and 65 years of age
3. Have a Body Mass Index (BMI) $\geq$ 24.
4. Were not on any Hormone Replacement Therapy (HRT).
5. Were currently sedentary (i.e, not having participated in a regular exercise program or moderate physical activity more than 2 hours per week.
6. Were non-smokers

Participants who met the initial eligibility requirements were given details of the study, including what their participation would entail as well as frequency and duration of each appointment. Participants were informed that they would not receive any monetary compensation, but they would receive two DEXA scans, two complete fitness evaluations, and 8 weeks of exercise training with a fitness professional. Additionally, they were informed that their participation in the study would be purely voluntary and that they were free to discontinue their involvement at any time.

Medical Clearance

If participants met the initial criteria, they were invited for an interview session to determine their eligibility for the study. All participants were required to complete a medical clearance form and were either included or excluded from the study based on their medical history. Exclusion criteria included women who had a current condition or history of:

- acute thrombosis or serious cardiovascular disease
- pacemakers or implantable cardioverter defibrillators (ICD)
- recent surgery
- joint implants
- acute hernia, discopathy or spondylolysis
- severe diabetes, especially resulting in neuropathy
- epilepsy
- retinal conditions
- recently placed metal pins or plates
- recent infections
- severe migraines
- tumors
- pulmonary embolism
- gallstones, kidney or bladder stones

- neoplastic disease of the spine
- poor somatosensory receptor
- sensitivity on the plantar surfaces of the feet

Of the 28 enrolled participants, 19 completed all of the program requirements (n=19). Six of the enrolled participants dropped out due to various reasons, including work conflicts (3), aggravation of previous injuries (2) and transportation problems (1). Three participants did not show up for their first training session, despite completing all baseline testing.

Experimental Design

Once participants completed the initial screening process, and were determined to meet the eligibility criteria, they were asked to report to the lab for baseline testing. A verbal and written explanation of all test procedures was given, and each participant was again given the opportunity to ask questions. Prior to being enrolled in the study, all participants completed a written eligibility questionnaire (Appendix A), a medical screening form (Appendix B) and informed consent forms (Appendix C).

Pre-testing

Upon enrolling into the study, participants arrived at the lab at the University of Miami for Day 1 screening and testing. These evaluations included standard height and weight measurements (Healthometer 402 EXP Doctor's Scale, Bridgeview, IL), resting heart rate and blood pressure, and the completion of the health-screening questionnaire. Following initial screening, baseline testing was performed.

Body Composition

Participants were scheduled to receive a DEXA scan at the University of Miami Clinical Research Lab within one week after reporting to the exercise laboratory for pre-exercise measurements. A trained and licensed technician performed all DEXA scans. DEXA reports included a detailed assessment of body composition, including percent body fat and lean body mass.

Aerobic capacity

Participants participated in a baseline peak aerobic capacity treadmill test (VO_2peak) with peak oxygen consumption measured as ml/kg/min. All metabolic equipment was calibrated prior to each treadmill test. Participants were fitted with a gas collection mask, which captured expired air for the determination of oxygen consumption during the exercise test. Gas exchange data were collected and analyzed with the Viasys metabolic cart (Oxycon Mobile, Viasys, Yorba Linda, CA). Participants were fitted with a heart rate monitor (model F51, Polar USA, Lake Success, NY), which transmitted a constant heart rate response to the metabolic cart computer. Once the participant was situated with the proper equipment, a warm-up period of 3 min was given in order to acquaint the participant with the treadmill (Quinton Treadmills, Bothell, WA). During the warm-up period, the test procedures were explained and the participants were informed that they would periodically be asked to provide their perceived level of exertion by selecting a number from a visible chart. The numbers ranged from 6 to 20, (Borg, 1970). Participants were instructed to request to stop when they reached maximum volitional fatigue. Due to the practical considerations of performing a maximal aerobic capacity test, a VO_2peak aerobic capacity was performed instead. The VO_2peak aerobic capacity test required the participant to walk on a treadmill at a pace consistent with the modified Bruce Protocol (Bruce, Blackman, Jones, & Strait, 1963), as described in Table 1.

Participants began the modified Bruce protocol by walking at 1.7 mph at a 0% grade. Exercise intensity increased every 3 min by increasing the grade and speed of

Table 1. Modified Bruce Protocol

Stage	Speed	Grade
1	1.7	0
2	1.7	5
3	1.7	10
4	2.5	12
5	3.4	14
6	4.2	16
7	5.0	18
8	5.5	20
9	6.0	22

walking until the participant requested to end the test. An active cool down period of 3 to 5 min was administered following the completion of the test.

1-RM Strength Testing

After a brief intermission following the aerobic capacity test, participants performed one-repetition maximum (1-RM) strength tests for the upper body and lower body using chest press and leg press selectorized exercise machines (Life Fitness Circuit Series, Schiller Park, IL), respectively. Participants were shown how to perform each exercise with proper form. Seat settings were adjusted appropriately for each participant to ensure optimal body and joint positioning. The leg press exercise position consisted of each participant seated in a reclined position with feet placed on the platform slightly wider than hip width, with knees angled at 90°. The chest press exercise required participants to sit with their back against the pad and feet flat on the floor. Hands were positioned such that they were adjacent to the chest. Seat settings were recorded in order to maintain consistency for the post-testing.

Testing of the 1-RM consisted of completing three warm-up sets of 10, 5, and 3 repetitions of a comfortable weight, increasing the weight for each set (Hoeger, Hopkins, Barette, & Hale, 1990; Stone & O'Bryant, 1987). Once the warm-up sets were completed, weight was progressively increased for repeated single repetition attempts until failure occurred. A rest period of 3 to 5 min was allowed between maximum attempts. The 1-RM score was recorded as the highest weight lifted successfully.

Group Assignment

Following all pre-testing and baseline measurements, participants were randomly selected to participate in one of the three training modalities: WBVT, AT, or CT. Participants remained in these respective groups for the entire duration of the study; thus each participant completed only one type of exercise training program.

Post-Testing

Within one week of the completion of the 8-week exercise-training program, all participants returned to the research lab for post-testing on the pre-test variables. Post-testing appointment times were scheduled as close to the pre-testing appointment time as possible.

Training Protocols

Once all initial testing was completed and all participants were assigned to their respective modes of training, the formal training program began. All participants were required to complete 3 exercise sessions per week for 8 weeks, for a total number of 24 sessions. Initially, exercise modality protocols required participants to perform 36 sessions over 12 weeks. However, in order to recruit participants, the protocol was changed to 24 sessions over 8 weeks.

WBVT Protocol

The WBVT mode of exercise consisted of the performance of multiple sets of a squat exercise on a Power Plate vibration platform (Power Plate Pro5, Power Plate North America, Northbrook, IL). Squats were performed in sets of 10, 15, or 20 repetitions (or 30, 45, or 60 s per set, respectively) at a rate of 1 squat every 3 s.

Participants were carefully monitored to ensure proper form. They were instructed to stand on the vibration platform with feet slightly wider than shoulder width apart. Participants were directed to squat down as far as they were able to up to a bent knee angle of 90°, making sure to maintain heel contact with the platform. Participants held on to the console for balance, but were instructed to use an open handgrip in order to prevent pulling themselves up. During latter stages of the protocol, relative external load was applied using a weighted belt.

A periodized strategy allowed for variation in the arrangement of sets and repetitions in order to introduce a new protocol to WBVT, as well as to add variety and prevent boredom. The vibration training protocol was progressively altered by applying external load, as a percent of lean body mass, and increasing exercise duration, Table 2. A work:rest ratio of 1:1 was maintained throughout the 8-week program. The introductory period of WBVT consisted of low volume and low vibration frequency. The original protocol design included one week of low-amplitude vibration, with the intention of increasing the vibration amplitude. As participants became acquainted with the vibration exercise

Table 2. Whole Body Vibration Training Protocol

Session	Frequency (Hz)	Load (%LBM)	Sets/Repetitions	Time/Set (s)
1-3*	30	0	4/10	30
4	35	5	6/10	30
5	35	5	4/15	45
6	35	5	3/20	60
7	35	10	7/10	30
8	35	10	5/15	45
9	35	10	4/20	60
10	35	15	8/10	30
11	35	15	6/15	45
12	35	15	5/20	60
13	40	20	9/10	30
14	40	20	7/15	45
15	40	20	6/20	60
16	40	20	10/10	30
17	40	25	8/15	45
18	40	25	7/20	60
19	40	25	11/10	30
20	40	25	9/15	45
21	40	30	8/20	60
22	40	30	12/10	30
23	40	30	10/15	45
24	40	30	9/20	60

Note. %LBM represents percent load of lean body mass.
*Sessions 1 to 3 were familiarization sessions.

the vibration amplitude was initially designed to increase significantly. However, some participants reported intolerable discomfort at the high amplitude vibration rate during the first session. Therefore, the protocol was re-designed to include only low amplitude vibration.

The periodized model was based on a weekly variation, and applied undulating durations of work periods while maintaining similar total volume. This strategy has not yet been documented as the optimal approach for performing WBV exercise. However, this approach added a degree of variety that was anecdotally less monotonous to the exercising participants.

Aerobic Training Protocol

Participants who were assigned to the aerobic training group performed an 8-week progressive treadmill-walking program in accordance with ACSM guidelines (ACSM Position Stand, 1998). Participants walked on a treadmill (Life Fitness, Schiller Park, IL) on three non-consecutive days per week for 8 weeks. The intensity and duration of the AT mode of exercise increased progressively throughout the 8-week study. Intensity was defined as a percent of age-predicted maximal heart rate.

All exercise sessions began with a 5-min warm-up at approximately 40% of age predicted maximal heart rate and ended with a 5-min cool-down at a declining intensity. Exercise intensity was monitored throughout the exercise sessions using a Polar heart rate monitor.

A trained and certified exercise professional was present at all sessions for safety and to ensure protocol adherence. In order to achieve and maintain appropriate exercise intensity, treadmill speed and grade were adjusted to keep the participant at her appropriate training heart rate. The AT protocol is outlined in Table 3.

Table 3. Aerobic Training Protocol

Session #	Intensity	Duration (min)
1 - 3*	50-60%	20
4	60-65%	20
5 - 6	60-65%	25
7 - 9	65-70%	30
10 -12	65-70%	35
13 -14	70-75%	30
15 -16	70-75%	35
17 -18	70-75%	40
19 -21	75-80%	35
22 -24	75-80%	40

Note. Intensity was determined by age-predicted maximal heart rate.
*Sessions 1 to 3 were familiarization sessions.

Circuit Resistance Training Protocol

The first CT exercise session consisted of participants completing additional 1-RM testing on all nine selectorized exercise machines to determine the exercise intensity that would be used for the 8-week training program. The nine exercises that were performed on standard selectorized resistance training machines (Lifefitness, Schiller Park, IL) included: leg press, chest press, leg extension, lat pulldown, seated leg curl, shoulder press, bicep curls, tricep extension, and abdominal crunch.

Exercise sessions were performed on three nonconsecutive days per week. The intensity of the exercise was initially set at 50% of the 1-RM, and increased to 55% 1-RM and 60% 1-RM at Weeks 4 and 6, respectively, as part of the progressive strategy. Total volume of exercise gradually increased over the 8-week period as rest/transition periods were decreased, Table 4. A trained and certified fitness professional was present at all training sessions for safety and to ensure protocol adherence.

Table 4. Circuit Training Protocol

Session	Sets/Repetitions	Intensity	Rest Period(s)
1*	---	100%	---
2-3	1/12	50%	60
4-9	2/12	50%	30
10-12	2/12	55%	45
13-15	3/12	55%	60
15-18	3/12	55%	30
19-24	3/12	60%	45

Note. Intensity was determined by a 1-RM test procedure.
*Session 1 was used to obtain 1-RM

Potential Risks

Minor risks to participating in this study included fatigue and/or cramping of the working muscles during exercise tests and regular exercise sessions. Delayed onset muscle soreness (DOMS) was an expected outcome on the day following testing protocol often lasts for several days. DOMS can potentially range from slight soreness of the muscle to the inability to move the affected area. Slight increases in blood pressure, shortness of breath, and/or dizziness may occur due to the intensity of the activities. Risks linked to vibration exercise include minor skin irritation and itching ears.

Overall, very little risk was associated with this study. Vibration exercise has been used in several studies with no adverse occurrences reported. Additionally, the vibration exercise platforms that were utilized in this study are commercially available for the general public and have not been associated with any adverse events. The selectorized resistance machines and treadmill have been used for decades in the commercial fitness industry.

Potential Benefits

Participants were involved in a supervised exercise training program at no monetary cost. Participants also received, at no cost to them, an evaluation of their aerobic capacity with sophisticated equipment and a trained professional, as well as two DEXA scans to analyze their body composition and bone mineral density. It was anticipated that participant health status and fitness level would improve by their participation in this study.

Statistical Analysis

Descriptive data (i.e., age, height, weight, and BMI, were analyzed using one-way analysis of variance (ANOVA). Separate 3 x 2 repeated measures ANOVA, with three levels of exercise mode (WBVT, AT, and CT), and two levels of time (pre and post) were initially used to analyze the main outcome variables: percent body fat, lean body mass, 1-RM, VO_2peak, and body mass index. The initial analyses of the data revealed significant differences among groups for several of the pre-training measurements. Therefore, a one-way ANOVA was performed using the differences between post-test and pre-test values (Δ). Because there was a small sample size, non-parametric analyses were also performed. All analyses were performed with PASW software (SPSS, Inc.), version 18.

Results

Participant Characteristics

Mean descriptive physical characteristics for participants (n=19) are presented in Table 5. No significant differences were initially observed among

Table 5. Physical Characteristics of Participants

Variable	WBVT (n=6)	AT (n=6)	CT (n=7)
Age, yrs	53.2 ± 2.1	55.2 ± 6.4	54.8 ± 7.0
Height, in	64.5 ± 2.4	63.1 ± 2.6	63.4 ± 3.5
Weight, lbs	193.0 ±52.1	198.0 ±18.0	177.3 ±17.2
Body Mass Index	32.6 ± 7.9	35.3 ± 5.6	31.1 ± 3.3

Note. WBVT, AT, and CT represent whole body vibration training, aerobic training and circuit resistive training, respectively.
Values are reported as mean ± standard deviation.

groups for age, height, weight, or body mass index. The one-way ANOVA summary for the pre-test physical characteristics is presented in Appendix F and raw data for each participant can be found in Appendix G.

Body Composition

Body composition data were obtained through DEXA analysis. Two specific parameters for body composition were assessed: percent body fat and lean body mass. Mean values, change scores, and percent difference are presented in Table 6. The 3 x 2 repeated measures ANOVA did not reveal any differences among groups for percent body fat or lean body mass for any of the three training modalities. However, a near significant main effect was observed in

Table 6. Mean Body Composition Values

Variable	N	Pre-Test	Post-Test	Δ	%Change
Body Mass (lb)					
WBVT	6	193.00 ± 52.11	193.75 ± 51.26	0.75	0.003
AT	6	198.00 ± 17.97	198.17 ± 18.20	0.17	0.001
CT	7	173.79 ± 18.19	176.00 ± 16.21	2.21	0.013
Percent of Body Fat					
WBVT	6	46.47 ± 5.16	47.12 ± 4.57	0.65	0.13
AT	6	52.63 ± 5.62	52.13 ± 5.88	-0.5	-0.01
CT	7	44.61 ± 5.49	44.37 ± 5.66	-0.24	-0.01
Lean Body Mass (lb)					
WBVT	6	101.6 ±20.26	100.77 ±19.07	-0.79	0.78
AT	6	93.2 ± 7.91	94.27 ± 8.38	1.07	1.15
CT	7	95.9 ±10.90	97.61 ±10.83	1.71	1.78

Note. WBVT, AT, and CT represent whole body vibration training, aerobic training and circuit resistive training, respectively.
*Pre and Post Values are reported as mean ± standard deviation.

percent body fat ($p=0.052$), and a near significant group*time interaction was observed for lean body mass ($p=0.093$). Neither the one-way ANOVA on change scores or the non-parametric analyses revealed any significant differences on percent body fat or lean body mass.

Aerobic Capacity

The variables used to assess changes in aerobic performance were VO_2peak and time to peak exhaustion, Table 7. The 3 x 2 repeated measures ANOVA did not reveal any significant differences for VO_2peak, however a significant main effect between the pre and post test for time to peak exhaustion was observed. The one-way ANOVA on the change scores did not reveal a statistically significant difference for VO_2peak or time to peak exhaustion. However, there were functionally large improvements in VO_2peak and time to peak exhaustion between 10.6 and 21.7% for the AT and CT exercise modalities. The percent change for VO_2peak and time to peak exhaustion were -3.4 and 3.2%, respectively, for the WBVT modality.

1-RM Strength

Upper body and lower body strengths were assessed via a 1-RM chest press and leg press maneuver, respectively, Table 8. The 3 x 2 repeated measures ANOVA revealed a significant interaction for upper body strength ($p=0.020$), and a main effect for time in lower body strength ($p=0.00$). The one-way ANOVA performed upper body 1-RM change scores indicated a significant difference between the WBVT and CT modalities ($p=0.005$). No significant difference between

Table 7. Mean Aerobic Performance Scores

Variable	N	Pre	Post	Δ	%Change
Peak Oxygen Uptake (ml/kg/min)					
WBVT	6	19.15 ±3.88	18.50 ±2.38	-0.65	3.39
AT	6	16.27 ±3.12	19.38 ±3.39	3.11	19.11
CT	7	16.41 ±6.10	19.24 ±5.99	2.83	17.25
Time to Peak Exhaustion (min)					
WBVT	6	12.32 ±2.62	12.71 ±2.20	0.39	3.17
AT	6	9.36 ±1.45	11.39 ±1.81	2.03	21.69
CT	7	11.94 ±2.49	13.21 ±2.25	1.27	10.64

Note. WBVT, AT, and CT represent whole body vibration training, aerobic training and circuit resistive training, respectively.
*Pre and Post Values are reported as mean ± standard deviation

the CT and AT modalities, or the WBVT and AT modalities were detected. The one-way ANOVA for 1-RM lower body strength change scores did not detect any significant differences among groups as all three exercise modalities increased their times to peak exhaustion. Non-parametric testing using the Wilcoxon Mann-Whitney method confirmed that the upper body strength scores for the CT modality increased significantly over the 8-week period with no significant increases detected in either the WBVT or AT

Table 8. 1-RM Scores

Variable	N	Pre	Post	Δ	%Change
1-RM Upper Body (lb)					
WBVT	6	72.50 ±19.68	64.17 ±15.63	-8.33	11.49*
AT	6	46.67 ±13.29	47.50 ±11.29	0.83	1.78
CT	7	67.85 ±15.77	75.00 ±14.43	7.15	10.54*
1-RM Lower Body (lb)**					
WBVT	6	222.50 ±99.89	265.83 ±84.05	43.33	19.47
AT	6	137.50 ±43.56	165.83 ±69.38	28.33	20.60
CT	7	176.43 ±43.85	207.14 ±35.92	30.71	17.41

Note. WBVT, AT, and CT represent whole body vibration training, aerobic training and circuit resistive training, respectively.
* Significance ($p<0.05$)
** Significance main effect for time ($p<0.05$)
Pre and Post Values are reported as mean ± standard deviation.

modalities. Lower body strength scores increased significantly over time for all of the three training modalities.

Discussion

The primary objectives of this study were to determine (a) if 8-weeks of WBTV had positive outcomes on improving body composition, muscular strength, and aerobic capacity, of obese post-menopausal women; and, (b) to compare WBVT to the outcomes of AT and CT on the same variables. The results indicated that WBVT had no effect on body composition; however there is some evidence that WBVT may have potential to positively impact aerobic performance and muscular strength. As expected, CT resulted in the greatest improvements in 1-RM scores of the assessment of upper body strength while both CT and AT induced measurable changes in lower body strength. Upper body strength was not impacted by AT, but was shown to decline for the WBVT group. Lower body strength indicated similar improvements as the CT and AT training groups. All three training modalities resulted in measurable improvements in time to peak exhaustion.

Body Composition

It is well documented that aerobic exercise and circuit training can be used as effective strategies for eliciting improvements in body composition over time (ACSM, 1998 & 2001; Gettman, Ayers, Pollock, & Jackson, 1978; Gettman & Pollock, 1981; Gettman, Ward, & Hagman, 1982; Mosher, Underwood, Ferguson, & Arnold, 1994; Pollock & Wilmore, 1990; Wilmore et al., 1978; Wilmore, 1974 & 1983). Because the AT and CT traditional modalities of training can elicit positive changes in body composition, WBVT was compared to these modalities of training.

It was hypothesized that WBVT would have similar effects on improvements in body composition as the traditional modalities of AT and CT. Because of the drop out rate of participants in this study, the number of the participants was insufficient to observe significant improvements in any of the training modalities. Unfortunately, access to equipment and training site no longer exists to add more participants to the study.

Expected non-significant improvements in lean body mass were observed with the AT and CT modalities with increases in lean body mass by about 1 and 2 lbs, respectively. The increases in lean body mass resulted in slight non-significant decreases in percent body fat. It is recognized that increases in lean body mass is often accompanied with loss of body fat with AT (Konopka et al., 2010; Sillanpaa et al., 2009) and CT (Campos et al., 2002; Ferreira et al., 2010, Gettman et al., 1978, 1981, 1982; Pollock & Wilmore, 1990; Wilmore, 1974). These are consistent with studies that have shown that that longer duration AT and CT programs can elicit positive changes in body composition.

When participants are not dieting, it has been proposed that reducing percent body fat with exercise training is most likely to be accomplished when participants experience negative energy balance. Both AT or CT programs can create a negative energy balance (Broeder, Burrhus, Svanevik, & Wilmore, 1992; Geliebeter et al., 1997) which is likely due to the caloric expenditure during both the performance of the exercise modality and post-exercise oxygen consumption (EPOC) (Bahr, Ingnes, Vaage, Sejersted, & Newsholme, 1987; Borsheim & Bahr, 2003; Braun, Hawthorne, & Markofski, 2005; Broeder et al., 1992; Burleson, O'Bryant, Stone, Collins, & Triplett-McBride, 1998; Crommett & Kinzey, 2004; Jamurtas et al., 2004; Laforgia, Withers, & Gore, 2006; Murphy & Schwarzkopf, 1992) and resting metabolic rate (Binzen, Swan, & Manore, 2001; Broeder et al., 1992; Haddock & Wilkin, 2006; Haltom et al., 1999; Osterberg & Melby, 2000; Williamson & Kirwan, 1997). It has been demonstrated that when AT and CT modalities are matched for calorie expenditure, EPOC may be greater after CT than AT (Braun et al., 2005; Burleson et al., 1998; Broeder et al., 1992; Murphy & Schwarzkopf, 1992). This suggests that CT would be a more effective method than AT for long-term effects on body composition.

Unfortunately, the increases in percent body fat in the WBVT group may indicate that WBVT has little, if any, effect on EPOC and resting metabolic rate.

WBVT does not appear to be an effective alternative to AT and CT exercise modalities for reducing the percent body fat of obese post-menopausal women. This observation is in agreement with the findings of Roelants et al. (2004a) who did not find any significant changes in percent body fat after 24 weeks of WBVT. Although several investigators have reported that when an acute WBVT stimulus was applied during dynamic exercise a greater increases in oxygen uptake was observed (DaSilva et al., 2007; Rittweiger et al., 2001; Vissers, 2008, the effect of WBVT on EPOC had not been studied. Two studies (Garatachea et al., 2007; Serravite et al., 2009) reported an increase in oxygen uptake following WBVT, but this increase may not have been sufficient for a long-term effect on EPOC or resting metabolic rate.

The current study and the study performed by Roelants et al. (2004a) may be the only two studies to date that have investigated the impact on WBVT on changes in percent body fat and lean body mass. Two research groups have investigated the effects of WBVT on visceral adipose tissue (Vissers et al., 2010) and in combination with resistance training (Fjeldstad et al., 2009; von Stengel et al., 2010a); however, these studies included either a calorie-restricted diet or did not isolate WBVT as a training modality.

Another issue with determining the effects of WBVT on body composition is the limited research to date which makes it difficult to determine the optimal training protocol to adequately compare WBVT with AT and CT. Attempts were made to appropriately create a significant WBVT stimulus with progressive increases in exercise intensity during the duration of the study. The periodized protocol used in the current study varied the sets and repetitions, progressively increasing the volume of exercise on a weekly schedule. This approach was different than most other studies using WBVT exercise protocols.

Adding an external load to WBVT exercise should increase the caloric expenditure (Rittweiger et al., 2000 & 2001; Serravite et al., 2009). It was expected that adding the external load of 10 to 30% of lean body mass in combination with the WBVT of the current study would increase the caloric expenditure and result in a reduction of body composition. The addition of the external load did not impact on percent body fat or lean body mass.

Several investigators have reported that lean body mass may be increased with WBVT programs (Bogaerts et al., 2007; Fjeldstad et al., 2009; Machado, Garcia-Lopez, Gonzalez-Gallego, & Garatachea, 2010). Verschueren et al. (2004) did not find any significant changes in lean body mass after 6 months of WBVT, which supports the lack of improvement in lean body mass in the current 8-week study.

A major appealing factor of WBVT programs is that the exercise duration is typically shorter than for most AT or CT programs. The findings of the current study and the findings by Roelants et al. (2004a) indicate that perhaps the duration of training continues to be an important factor in determining the effectiveness of exercise. Perhaps a longer training stimulus or the addition of a vibratory stimulus during dynamic exercise is needed in order to elicit improvements in body composition.

Aerobic Performance

Aerobic performance was evaluated using VO_2peak and time to peak exhaustion. Although the AT and CT training modalities indicated improvements in VO_2peak by 19.1% and 17.3% respectively, these improvements were not statistically significant, which is likely due to the constraints of the small sample size. The large percentage improvements are also a function of the low initial VO_2peak scores obtained in pre-testing. When comparing this result to the non-significant decline in VO_2Peak of 3.39% in the WBVT modality, one may conclude that WBVT is not an effective method for improving aerobic capacity.

However, when looking at the time to peak exhaustion scores, there was an improvement across all three training modalities, with no significant differences between groups. As anticipated, the improvement in the time to peak exhaustion scores in the AT modality was the most pronounced (2.03 min). These increases in the time to peak exhaustion have important functional benefits in the obese post-menopausal women in that they may be able to walk greater distances before they become fatigued. The literature strongly indicates that both AT and CT modalities of training can improve aerobic performance and delay fatigue (Campos et al., 2002; Gettman et al., 1978; Haltom et al., 1999; Tanaka & Swensen, 1998).

To date, there have been only a few investigations comparing the influences of WBVT and other modalities of training on cardiovascular responses (Bogaerts, Verschueren, Delecluse, Claessens, & Boonen, 2009; Hazell, Thomas, Deguire, & Lemon, 2008; Lythgo, Eser, deGroot, & Galea, 2009). Bogaerts et al. (2009) compared the effects of WBVT and a combined cardiovascular and resistance training program on cardiovascular fitness. They reported that both VO_2peak and time to peak exhaustion improved in the WBVT and combined cardiovascular and resistance training groups of participants, but differences between groups were not statistically significant. A functional improvement in the time to peak exhaustion occurred in the AT and CT modalities used in this study, but very little improvement was observed in the WBVT modality.

1-RM Strength

Upper body strength and lower body strength were assessed using a 1-RM test. As expected, the CT exercise modality elicited significant improvement in the upper body strength of the obese post-menopausal women. The WBVT had a significant negative effect on upper body strength which was unexpected and was mostly due to two participants that had post test scores that were 20 pounds lower than pre test scores. All three exercise modalities significantly increased lower body strength between 17.4 and 20.6%. The increase in upper body strength by the CT was attributed to the inclusion of upper body exercises in the CT protocol. All three training modalities required the use of lower body performance (i.e., CT participants performed specific lower body resistive training, AT participants performed walking activity, and the WBVT participants performed squats as a part of their training). These data suggest that all three modalities of training may have beneficial effects on lower body strength. It has been well established in the literature that CT improves lower body strength (Gettman et al., 1978, 1981, 1982; Mosher et al., 1994; Wilmore et al., 1975). Several investigators using WBVT have also reported that WBVT can be used to improve lower body strength (Bogaerts et al., 2007; Fernandez-Rio, Terrados, Fernandez-Garcia, & Suman, 2010; Machado et al., 2008).

WBVT: Modification of the Exercise Paradigm

The most important component lacking in existing WBVT research is a training protocol that provides the optimal stimulus to demonstrate significant improvements in anthropometric and physiological outcomes of WBVT. There is a lack of consistency in the utilization of the intensity of the vibration (frequency and amplitude), exercise session and training duration, and mode of application. Determination of the optimal settings for these variables has the potential to elicit a variety of positive outcomes to the WBVT.

The WBVT protocol used in the present study was designed from previous research and consisted of squatting exercise, which explains the improvement observed in lower body strength. It would be interesting to examine if WBVT combined with both upper and lower body exercises would elicit the same results as a CT protocol. In many CT strategies, including the protocol used in the current study, the exercise tasks alternate between the lower body and upper body allowing for one muscle group to rest while maximizing energy expenditure and time efficiency. By using a similar strategy for a WBVT protocol, the effects of WBVT on upper body strength may be investigated more precisely, and perhaps a protocol more conducive to maximizing energy expenditure may be developed.

Decisions on Hypotheses

Based on the results of this study, the following decisions on the hypotheses were made.

1. Because there were no significant differences in the percent body fat among overweight/obese post-menopausal

women participating in an 8-week progressive WBVT, AT, or CT exercise programs, Hypothesis 1 was not rejected.

2. Because there were no significant differences in the lean body mass among overweight/obese post-menopausal women participating in a progressive 8-week WBVT, AT, or CT exercise programs, Hypothesis 2 was not rejected.

3. Because there were no significant differences between improvements in VO_2peak and time to peak exhaustion among overweight/obese post-menopausal women participating in a progressive 8-week WBVT, AT, or CT exercise programs, Hypothesis 3 was not rejected

4. Because CT elicited a significant improvement in upper body strength in the overweight/obese post-menopausal women, and the WBVT, AT, and CT groups of overweight/obese women experienced significant improvements in lower body strength, Hypothesis 4 was rejected.

Conclusions

Based on the current data, the following conclusions were formulated. However, it should be noted that due to the small sample size used in the present study, these conclusions must be interpreted with caution.

1. Eight weeks of WBVT is not an effective training modality to reduce percent body fat.

2. Eight weeks of WBVT is not an effective training modality to increase lean body mass.

3. Eight-weeks of WBVT is not an effective training modality to improve VO_2peak.

4. Eight-weeks of WBVT is an effective training modality to improve time to peak exhaustion.

5. Eight weeks of WBVT, AT, and CT improve lower body strength. Eight weeks of CT improves upper body strength.

Recommendations

Based on results of this study, the decisions on the hypotheses, and the conclusions, the following recommendations for future study are made.

1. A WBVT protocol while performing both upper and lower body resistive exercises should be established to determine if WBVT influences upper body strength.

2. A WBVT protocol should be explored in order to establish a suitable exercise load to increase oxygen uptake to a level to induce an aerobic training effect.

Part 2

REVIEW OF THE LITERATURE

Whole-Body Vibration

Whole body vibration is a mechanical vibratory stimulus that has recently gained interest as a mode of training for the athlete, the fitness industry, and medical communities. Recent findings indicate benefits of WBV exercise training for improving a multitude of physiological parameters. Initially, WBV was used as a performance enhancing modality for Russian athletes (Nazarov & Spivak, 1985). More recently, WBV has become a commercially promoted alternative to traditional exercise training programs. Investigations in clinical applications of WBV includes promising evidence for treatment of ailments such as Parkinson's disease, fibromyalgia, osteoporosis, and multiple sclerosis (Alentorn-Geli, Padilla, Moras, Haro, & Fernandez-Sola, 2008; Arias, Chouza, Vivas, & Cudeiro, 2009; Chien, Wu, Hsu, Yang, & Lai, 2000; Ebersbach, Edler, Kaufhold, & Wissel, 2008; Wunderer, Schabrun, & Chipchase, 2010). Much of the existing research is focused on the acute effects of WBV, such as muscular power and flexibility. However, the effects of chronic WBVT programs are now being investigated. Interest lies primarily in the areas of muscular performance, balance and coordination, and changes in body composition.

Physical and Neural Mechanisms

The concept of WBV as a training method stems in part from Newton's Second Law of Motion, represented by the equation:

$$\text{Force} = \text{Mass} \times \text{Acceleration}$$

Traditional training methods are centered on producing greater force values by manipulating the first variable in the equation, mass. With the development of vibration training, acceleration can now be manipulated as well. Thus, WBV is often referred to as "acceleration training". By increasing acceleration, the force the body momentarily resists against during vibration is much greater than without vibration, creating a physical overload.

In addition to physical overload, neural mechanisms are also responsible for increasing the electrical activity of the muscles. Several EMG studies have demonstrated that heightened muscular activity occurs during a vibration stimulus as compared to similar exercise with no vibration (Abercromby et al., 2007; Eckhardt, Wollny, Muller, Bartach, & Friedman-Bette, 2010; Moras, Toue, Munoz, Paduilee, & Vallejo, 2006; Ritzmann, Kramer, Gruber, Gollhofer, & Taube, 2010). Complete muscle activation is difficult to achieve during a strictly voluntary contraction, but adding a vibratory stimulus may allow for greater muscle recruitment through enhancement of activation (James, Sacco, & Jones, 1995).

When performing a movement in a standing position on the vibrating platform, there may be greater stimulation of muscular sensory receptors. More specifically, the muscle spindles and Golgi tendon organs may be stimulated. These receptors send a signal to the spinal cord via Type Ia afferent nerves resulting in a response from the alpha motor neurons. The observed vibration-induced muscular activity has been referred to as the tonic vibration reflex (Bishop, 1974; Bongiovanna & Hagbarth, 1990; Burke, Hagbarth, Lofstedt, & Wallin, 1976; Claus, Mills, & Murray, 1988; Mester, Spitzenfeil, Schwarzer, & Seifriz, 1999). This reflex was originally documented by Eklund and Hagbarth (1966) who applied a high-frequency vibratory stimulus directly to the tendon, which caused a significant contractile response. Eklund and Hagbarth demonstrated that concurrent muscular contractions enhanced the tonic vibration reflex and elicited a contraction of both agonist and antagonist muscles.

During exposure to vibration, the tonic vibration reflex is induced, but the stretch reflex and the Hoffman reflex are both inhibited (Armstrong et al., 2008). This is known as the vibration paradox. The Hoffman Reflex is a well-documented measurement of motor neuron excitability and is comparable to the stretch reflex (Bulbulian & Darabos, 1986). One explanation is that this occurs because of the inhibition of Type Ia afferents of the muscle spindle, allowing the vibration excitation pathways but inhibiting the pathways that respond to stretch (Flieger, Karachalios, Khaldi, Raptou, & Lyritis, 1998). Armstrong et al. (2008) suggest that this vibration paradox occurs due to a collision of action potentials along the motor neuron, blocking the Hoffman Reflex. These proposed mechanisms do not necessarily explain the benefits that vibration exercise has been shown to elicit. More research is needed to determine the mechanisms that are responsible for inducing the changes noted in previous studies.

WBVT Protocols

Existing literature in the area of WBVT indicates inconsistent findings. This can be largely attributed to the various protocol designs. Due to the novelty of WBVT, there has yet to be a consensus on what the optimal protocol should be. Some progress has been made in determining optimal combinations for load and frequency for power output after acute WBV exposure (Adams et al., 2009; Bedient et al., 2009). However, the optimal settings for chronic WBV exercise intensities and frequencies remain unknown. There are several variables that may be influenced by WBV exercise such as muscular strength and power, flexibility, balance and coordination, and effects on metabolism and body composition. Unfortunately, an ideal training protocol has yet to be established to gain maximal benefits from WBVT.

As with any form of physical activity, vibration exercise sessions vary in intensity, duration, and frequency. Intensity is dependent on the vibration settings, which are a function of frequency (Hz) of the vibrations and the amplitude of the vibrations. The duration of the vibration application influences the volume of the exercise session. Other factors that could impact the effectiveness of the program are the mode of application of the vibration, the number of exercise sessions performed each week, and the external load.

Inconsistencies in the literature regarding terminology, the vibration parameters require further discussion.

Vibration Frequency

Vibration frequency is defined as the cycles per unit of time, or Hz. Vibration frequency has been reported to be the main determinant of WBV exercise on the body (Griffin, 1996). Vibration is generally most effective for acutely enhancing strength and power when the frequency is between 30 and 50 Hz (Lamont et al., 2010a; Luo, McNamara, & Moran, 2005). In partial agreement with these findings, Bedient et al. (2009) found that using frequencies of either 30 or 50 Hz were effective for acute increases in strength and power but that 35 or 45 Hz were not as effective. Ronnestadt (2009) found that only 50 Hz was enough to improve 1-RM strength after vibration exposure. High frequencies of up to 137 Hz have been studied, but were found to be less effective than the lower frequencies of 30 to 50 Hz (Jackson & Turner, 2003). Vibration frequencies of less than 20 Hz should be avoided due to possible injury as a result of resonance factors on the body (Mester, Kleinoder, & Yue, 2002).

Establishing optimal settings with certainty for vibration exercise would be an important contribution to this field of study. Individuals respond differently to a vibration stimulus, therefore optimal vibration frequencies may be determined for each person wishing to use WBV as a training aid (DiGimiani, Tihanyi, Safar, & Scrimaglio, 2009). Cook et al. (2009) suggested that the frequency used during the WBV exposure was dependent on the muscles the user intends to target. For example, higher vibration frequencies (40 Hz) should be used to train musculature surrounding the knee joint and lower frequencies (<30 Hz) should be used for the ankle joint. In order to activate hip and gluteal muscles, combining lower frequencies with a deep squatting movement are ideal (Cook et al., 2009).

Chronic WBVT studies are in agreement that the recommended frequency range of 30 to 50 Hz is an adequate stimulus for producing changes in strength and power over time (Annino et al., 2007; Delecluse, Roelants, Diels, Konickx, & Verschueren, 2005). To date, there are no reports on the frequency of stimulus to be used to impact oxygen consumption.

Vibration Amplitude

The amplitude of the vibration wave refers to the magnitude of the platform movement in a specific direction. It may also be called displacement. This variable is generally measured in centimeters (cm) or millimeters (mm). Displacement settings on most commercially available vibration exercise machines can either be set to “high” or “low” and can range from 1.5 mm to 10 mm. WBV exercise can also be referred to as “acceleration exercise”. This is because the amplitude of the vibration platform provides an accelerative force, measured in *g* or m/s^2. The combination of frequency and amplitude can result in acceleration forces that can reach up to 15 *g* (Rittweiger et al., 2000). Unfortunately, in many reports, the total acceleration was not disclosed, leading to uncertainty of the actual vibration intensity (Lorenzen, Maschette, Koh, & Wilson, 2009).

Typical amplitude or displacement settings range from 2 to 10 mm. High amplitude settings have been shown to induce greater muscle activation than lower amplitude, demonstrated by EMG readings (Hazell, Jakobi, & Kenno, 2007; Marin, Bunker, Rhea, & Ayllon, 2009; Torvinen et al., 2002a; Torvinen et al., 2002b). More specifically, amplitude of 4 mm produced significantly more muscular activity than a 1 mm amplitude (Torvinen et al., 2002b). Marin et al. (2009) found that a 4 mm amplitude was more effective than a 2 mm amplitude. Rittweiger et al. (2000)

used 6 mm amplitude with similar success. Performing WBV exercise under barefoot conditions intensified the neuromuscular response (Marin et al., 2009).

Oscillation Pattern

Vibrations can occur in one, two, or all three planes of motion. They may also occur in different patterns, depending on the manufacturer of the platform. Vibration wave patterns exist in several forms including square, triangular, sawtooth, and the most commonly used sinusoidal wave. Wave patterns used in vibration exercise represent a predictable pattern, which is important for using vibration as an exercise stimulus (Signorile, 2006). The predictable pattern of mechanical waves created by vibration platforms are different from the unpredictable vibrations caused by work and sport-related injuries (Signorile, 2006). It is this predictable pattern that allows for adaptation.

External Load

An externally applied load, through a weight belt, weighted vest, or backpack, has been shown to increase heart rate (Garatachea et al., 2007) and oxygen consumption during dynamic vibration exercise (DaSilva et al., 2007; Rittweiger et al., 2001; Serravite et al., 2009). External loads of up to approximately 74% of body weight were applied to dynamic squatting exercise with WBVT in young men and compared to dynamic squatting with no vibration (DaSilva et al., 2007). Superimposed vibration appeared to exacerbate the oxygen consumption measured during exercise. In a similar study, a load of 40% of body weight was used and comparable results were obtained (Rittweiger et al., 2000). Another study investigated the effects of HI (50 Hz, 5 to 6 mm), LO (35 Hz, 2 to 3 mm), and NV (no vibration) conditions of vibration with loads of 0, 20, or 40% of body weight (Serravite et al., 2009). While there were no significant differences between the HI and LO conditions, the 40% external load resulted in increased oxygen consumption both with vibration and without. WBV exercise with a moderate load of 20% of body weight produced similar VO_2 values as a 40% load with no vibration. This suggests that WBV can be used as a method of increasing intensity and subsequent metabolic effects without the potential discomfort of a high external load.

Exercise Mode

The majority of WBVT protocols described in the literature consist of performing dynamic full squats, half squats, static squats or standing upright on the vibration platform. A few studies have also employed the use of other exercises such as calf raises, seated upper body exercises, and push-ups with hands on the vibration platform (Fjeldstad et al., 2009; Vissers et al., 2010). The degree of muscle activation is greater when the whole body is involved in the vibration. The vibratory stimulation operates synergistically with the muscle mass activated during a squatting movement (Abercromby et al., 2007; Amonette et al., 2005; McBride et al., 2010; Roelants et al., 2006).

Duration and Volume

As previously described, WBV can be used to trigger effects in physical performance. Acute exposures can range from a total time of 30 s to 6 min. As with any mode of exercise training, the duration and total volume of the exercise sessions should be increased gradually in accordance with the principle of progressive overload. Due to the unique effects of WBV, a more conservative approach should be applied when designing a protocol.

WBV work periods, or sets, during an exercise session are generally administered in time increments of 30, 45, or 60 s. A few studies have applied constant exposure over an extended period of several minutes. The rest interval usually matches the work period, maintaining a work:rest ratio of 1:1. Most of the protocols outlined in the literature either use shorter work periods initially (i.e., 30-s sets) and gradually progress to longer work periods of 60-s sets, over a period of several weeks or months.

WBV and Muscular Performance

The majority of research findings support the use of WBV exercise as a method of increasing muscular strength and power. Several studies have concluded that an acute exposure to WBV results in a temporary increase in muscular power and/or strength (Adams et al., 2009; Bosco, Cardinale, & Tsarpela, 1998; Bosco et al., 1999; Bullock et al., 2008, Lamont et al., 2010a; Roelants et al., 2004b; Russo et al., 2003; Torvinen et al., 2002a). In a study by Bosco et al. (1999) a series of 10 sets of a 10-s vibration stimulus (26 Hz) was applied to a single leg in female volleyball players. This was found to induce a significant increase in average force and power when performing a subsequent leg press exercise. Because the athletes were accustomed to the leg press machine, they concluded that neural mechanisms must have enhanced the motor unit recruitment patterns. Four sets of 1-min bouts of vibration exposure have been shown to cause an increase in jump height and isometric knee extension force (Torvinen et al., 2002a). A 5% increase in vertical jump height was also documented in post-menopausal women (Russo et al., 2003). Despite the increases in strength after the vibration exposure, the effects were only temporary, and were non-existent within 60 min post-vibration.

More recent studies confirm the earlier findings of acute WBV stimuli and power output (Adams et al., 2009; Bedient et al, 2009; Bullock et al, 2008; Cormie, Deane, Triplett, & McBride, 2006; Lamont et al., 2010a). A study performed using elite skeleton athletes, who rely greatly on power development, initially found no significant improvement in a countermovement jump and a squat jump following the WBV exposure (Bullock et al., 2008). However, on a subsequent sprint test, the performance of the control group of skeleton athletes declined while that of the athletes who completed a brief bout of vibration exercise demonstrated much less of a decline. Guggenheimer, Dickin, Reyes, and Dolny (2009) observed the impact of acute vibration exposure, at 30, 40, or 50 Hz, prior to a sprint performance and found that there was a potential for enhancement. Although minimal, a decrease of 0.1 s in sprint time was noted after only 4 bouts of 5 s of high knee running with a vibratory stimulus of 30 Hz.

A study involving elite female hockey players demonstrated an 8% improvement in vertical jump height after WBV (Cochrane & Stannard, 2007). No improvement was observed in a control group. Rhea and Kenn (2009b) concluded that the peak power of squat performance, measured by acceleration of a 75% 1-RM, was significantly greater following acute WBV exposure when a frequency of 35 Hz was applied. These data suggest that WBV may be an effective preparatory device for single or repeated high-intensity exercise bouts (McBride et al., 2010).

Adams et al. (2009) and Bedient et al. (2009) examined a combination of different vibration variables that would potentially optimize power output. Their findings confirmed those of previous studies, which showed temporary increases in power, with benefits subsiding after 60 s (Bazett-Jones, Finch, & Dugan, 2008; Cormie et al., 2006). The optimal frequency used to increase power was suggested to be either 30Hz or 50Hz, and frequencies of 35 Hz and 40 Hz were not as beneficial (Bedient et al., 2009). Ronnestadt (2009) found that applying a frequency of 50 Hz was necessary in order to increase squat 1-RM after WBV exposure. Lamont et al. (2010a) attempted to determine the lowest possible dose of WBV that could be used to enhance power output. They concluded that a frequency of 50 Hz was advised. Adams et al. (2009) added that WBV bouts of as little as 30 s can result in optimal power output with the effects lasting up to 5 min post-treatment. Furthermore, a 1-min recovery period post-vibration was recommended for optimizing power output (DaSilva-Grigoletto et al., 2009).

There may be gender differences in the responses to WBV exercise. When comparing the effects for different accelerations on countermovement jump, males displayed no improvement after performing squats at four different vibration combinations (Bazett-Jones et al., 2008). However, the female participants underwent the same conditions and improved their performance by approximately 8 to 9% when exposed to either 40 Hz and 2 to 4 mm amplitude or 50 Hz and 4 to 6 mm amplitude. No significant changes were observed in the other combinations of frequency and amplitude.

Increased muscle temperature after WBV exercise may be one explanation for improvements in power output (Cochrane, Stannard, Firth, & Rittweiger, 2008). As muscle temperature increases, an increased muscular power has been demonstrated (DeRuiter & De Haan, 2000). Cochrane and associates (2010) revealed that WBV elicited a post-activation potentiation response. This was likely due to myogenic factors such as enhanced contractile component cross-bridge interaction and increased muscle spindle sensitivity (Cochrane, Stannard, Firth, & Rittweiger, 2010). This post-activation potentiation was also thought to be the mechanism responsible for the decrease in muscle fatigue and subsequent power increase measured after a short WBV session (Serravite, Edwards, Vitali-Gamen, & Signorile, 2010). However, not all reports are in agreement. A similar study using a short WBV session did not show any potentiation of the stretch reflex (Hopkins et al., 2009).

The positive effects of WBV on strength and power mentioned thus far may be due to the acute vibration exposure. However chronic exposure to WBVT has been shown to improve strength and power as well. Some findings indicate that WBVT can produce strength gains similar to those resulting from resistance training (Delecluse, Roelants, & Verschueren, 2003). Delecluse et al. (2003) found that 12 weeks of vibration training (35 to 40 Hz) induced similar strength gains as participants participating in a traditional resistance training program. Similarly, an 8-week vibration training program showed to be effective for improving knee extensor strength as well as jump height in competitive female athletes (Fagnani, Giombini, Di Cesare, Pigozzi, & Di Salvo, 2006; Mahieu et al., 2006). When comparing a WBVT program with a traditional resistance training program, there may be no additional benefit. In female basketball players, 14 weeks of training resulted in no significant differences between WBVT and resistance training (Fernandez-Rio et al., 2010). In male basketball players, 4 weeks of WBVT at a frequency of 40 Hz did not show any change in knee extensor explosiveness. However a significant increase was observed in strength (Colson, Pensini, Espinosa, Garrandes, & Legros, 2010). Colson et al. (2010) deduce that there was no enhancement of the stretch-shortening cycle. It should be noted that static squats, as opposed to dynamic squats, were used in this study and may have affected the response.

Lamont et al. (2008a & 2008b) examined the effects of a 6-week dynamic squatting protocol, with low frequency vibration and without vibration exposure, on jump height and peak power. A significant effect was observed in the WBVT group. The variance between these observations and those from the 4-week study of Colson et al. (2010) may suggest that there is a minimum training period to induce adaptation. Another explanation would be that the use of static squatting is not an effective application of WBV for improving power.

Lower body power, often measured by countermovement jump or jump height, can also be assessed with sprint performance. Administration of acute WBV protocols have demonstrated mixed results when applied to sprint performance. However, chronic WBVT may be more effective. Six weeks of WBVT (30 Hz) decreased sprint time by 2.1% and 2.7% in two subsequent studies (Paradisis, Tziortzis, & Zacharogiannis, 2005; Paradisis & Zacharogiannis, 2007). Maximum running velocity was also enhanced. No improvements in maximum strength of the leg flexors or extensors were observed.

A study involving female ballet students, found that 8 weeks of WBVT, three times per week at 30 Hz, significantly increased knee extensor explosiveness and countermovement jump (Annino et al., 2007). It is difficult to determine exactly if the WBVT caused this adaptation, or if squatting alone could have caused a similar change. A more recent study involving dancers concluded that 6 weeks of WBVT for as little as 10 min per week (two weekly sessions, 5 min each) could improve lower body power, measured by vertical jump height (Wyon, Guinan, & Hawkey, 2010). These findings are in agreement with the 6-week study of Petit et al. (2010) who demonstrated 6 weeks of WBVT elicited significant improvements in knee extensor strength and power. Improvements occurred regardless of the vibration settings, but the combination of a high amplitude and high frequency yielded the greatest improvement.

The aforementioned studies were primarily conducted on athletic or young, healthy populations. Less is known about the effects of chronic WBVT on older or more sedentary populations. There have been a few studies on WBV training on older adults (Bogaerts et al., 2007; Furness & Maschette, 2009; Machado et al., 2009; Rees, Murphy, & Watsford, 2008 & 2009). Two of these studies originate from the same laboratory exploring the effects of 8 weeks of WBVT at a low frequency (26 Hz) on an older population, with a mean age of 73 years of age (Rees et al., 2008 & 2009). The program consisted of 4 weeks of static squatting, followed by 4 weeks of dynamic squatting. No significant changes in knee flexor or extensor strength were observed when compared to a group who performed traditional resistance training exercises (Rees et al., 2008). This suggests that WBVT could be a realistic alternative to resistance training. A significant increase in ankle plantar flexors was observed in participants who participated in the WBVT as compared to the control group (Rees et al., 2009). This has implications for improvements in balance, which is especially important for the older population. Another study involving an older population (mean age = 72 years) assigned individuals to a WBVT program for 6 weeks, at either one, two, or three sessions per week using a progressive frequency overload schedule with a maximum vibration frequency of 26 Hz (Furness & Maschette, 2009). It was concluded that the participants who participated in three sessions per week displayed the most significant changes on tests that measured functional activity including the TUG (Timed Up and Go) Test and the Chair Stands Test. Machado et al. (2009) were interested in the effect of WBVT on similar activities performed by older women (Machado et al., 2009). A training period of 10 weeks with exposure to vibration frequencies of 20 to 40 Hz was utilized. In addition to significant improvements in functional tests performance, notable increases in strength were also observed. Data from a 1-year WBVT study also demonstrated significant improvements in muscular power (+10.9%) and strength

(+9.4%). However, a traditional resistance training program elicited a more significant change, a 12.5% increase in strength (Bogaerts et al., 2009).

Vibration exercise may be an effective alternative to traditional resistance training programs for improving muscle strength, and has been shown to be as beneficial as resistance training (Bogaerts et al., 2007). Interestingly, only a few investigations to date have studied the effects of vibration training combined with resistance training (Bemben, Palmer, Bemben, & Knehans, 2010; Carson, Popple, Verschueren, & Rick, 2009; Issurin, Liebermann, & Tenenbaum, 1994; Kvorning, Bagger, Caserotti, & Madsen, 2006; Lamont et al., 2010b). All of these studies applied WBV exercise, with the exception of the study of Issurin et al. (1994) who used a direct vibratory stimulus to the exercising limb. Issurin et al. concluded that a short-term program of only 3 weeks induced more significant strength gains than those resulting from traditional resistance training. Lamont et al. (2010b) investigated the effects of a 4-week training program using WBV in college-aged men. The protocol consisted of squatting exercise with or without the addition of WBV. The researchers concluded that adding WBV stimuli to a traditional resistance training program showed potential for improving explosive isometric strength, measured by rate of force development. Bemben et al. (2010) used a longer term study to explore the effects of WBV (30 to 40 Hz) in combination with resistance training in post-menopausal women. After 4 months of training, both the WBVT group and resistance training group displayed significant increases in strength. The increase in strength was more prominent in the group that participated in the combination of WBVT and resistance training. Carson et al. (2009) previously examined the effects of WBVT and resistance training in a younger population. They found that WBV superimposed with resistance training did not have any type of synergistic effect resulting in strength increases. Kvorning et al. (2006) also did not observe any additional benefit when WBV was combined with resistance training after 9 weeks of training. Data from the aforementioned investigations indicate that vibration exercise may enhance muscular strength and power; however, WBV likely provides little or no additional benefit in increasing strength (Rees et al., 2008; Rittweiger, 2010).

Data from several other studies suggest that WBV exercise offers little or no benefit with respect to strength or power (DeRuiter, Van der Linden, Van der Zijden, Hollander, & De Haan, 2003a; Paradisis et al., 2005; Torvinen et al., 2002b). These conclusions are consistent with Colson et al. (2009) who reported that WBV does not enhance muscle activity.

Acute exposures of varied vibration frequencies failed to show any significant improvement in lower body power (Bullock et al., 2008; Cochrane et al., 2004; DeRuiter, Van Raak, Schilperoort, Hollander, & De Haan, 2003b; Torvinen et al., 2002b) or force-generating capability, usually measured by isokinetic or isometric strength (DeRuiter et al., 2003b; Paradisis et al., 2005). However, weak methodology and inconsistency in protocols cause difficulty in making accurate comparisons as to the optimal vibration frequencies, duration of program, and mode of exercise (Merriman & Jackson, 2009). Acute WBV and short duration WBVT programs indicate that there is no significant change in strength, sprint performance, or agility (Cochrane, Legg, & Hooker, 2004; DeRuiter et al., 2003a). Generally, studies that indicate promising results from WBVT require durations of at least 4 weeks.

DiGimiani et al. (2009) concluded that individualizing the WBV frequency may elicit more consistent results than using a universally, seemingly optimal setting. They found that the degree to which explosive and reactive leg strength was improved was dependent on vibration frequency. By measuring EMG activity in the vastus lateralis during WBV bouts with different frequency settings, the researchers were able to determine optimal settings for each participant. Although this individualized approach may hold merit, it seems impractical to measure EMG response on everyone desiring to include WBVT in his or her exercise programs. Thus, it would be more useful if an alternate method of determining optimal individualized settings were employed.

Older sedentary and untrained individuals such as post-menopausal women may be more likely to demonstrate positive benefits from WBVT (Rehn, Lidstrom, & Lidstrom, 2007). Because of the lack of consistent methodology in protocol design, it is difficult to assess the true potential of WBVT as a method of improving strength and/or power. There also seems to be a lack of transferability between WBVT protocols and measurement tests, furthering the inconsistencies (Wilcock, Whatman, Harris, & Keogh, 2009).

It needs to be noted that WBVT therapy used for recovery from injury may exhibit differential effects. Muscle soreness following physical activity is a common discomfort affecting individuals of all training levels. Delayed-onset muscle soreness (DOMS) seems to occur more frequently in untrained individuals as well as after eccentric exercise (Newham, 1988). Cardinale, Jenkinson, Evans, Meikeljohn, and Mart (2006) reported that WBV exercise results in higher creatine kinase levels than non-vibratory exercise. These data indicate that WBVT may, at least initially, elicit greater muscle damage than non-vibratory exercise. However, high-frequency vibration exercise preceding eccentric exercise has shown to attenuate muscle soreness following an exercise bout in untrained individuals (Bakhtiary, Safavi-Farokhi, & Aminian-Far, 2007).

Flexibility exercises performed concurrently with a vibratory stimulus of 35 and 50 Hz resulted in decreased muscle soreness when compared to a flexibility session with no vibration (Rhea et al., 2009). With low frequency vibration (i.e., 12 Hz), there was no effect of WBVT on recovery after high-intensity interval training (Edge, Mundel, Weir, & Cochrane, 2009).

Effects of WBVT on Balance and Flexibility

In addition to its potential impact on strength and power, acute and chronic WBVT protocols have been associated with performance and health-related improvements in flexibility and balance (Bautmans, VanHees, Lemper, & Mets, 2005; Bogaerts, Verschueren, Delecluse, Claessens, & Boonen, 2006; Bruyere et al., 2005; Cheung et al., 2007; Jacobs & Burns, 2009; Van den Tilaar, 2006). This may be an important area of research when considering the potential functional benefits of vibration exercise training for all populations.

There is evidence that WBVT may be an effective treatment for improving balance in older individuals. When elderly participants participated in a 12-month progressive WBVT program, computerized posturography analyses revealed a significant decrease in the incidence of falls (Bogaerts et al., 2006). Bruyere et al. (2005) investigated the effects of a 6-week vibration exercise and physical therapy program on gait and body balance in nursing home residents and compared it with a formal physical therapy program. Participants in the vibration exercise program scored significantly higher on a panel of balance and gait tests than those who were not involved with the vibration exercise. The researchers concluded that improved balance and gait play an important role in decreasing the risk of falls in the elderly. Data obtained by Rees et al. (2009) suggest that vibration exercise increases ankle plantar flexor strength, which may contribute to improved balance. Cheung et al. (2007) found that a 3-min vibration exposure three times per week improved functional reach, reaction time, and balancing ability in elderly women. WBVT was also shown to improve walking ability (i.e., stride length and 10-m walking time) in elderly participants (Kawanabe, Kawashima, Takeda, Sato, & Iwamoto, 2007). Maximum time of standing on one leg was also markedly increased.

A 4-week WBVT program did not improve ankle joint stabilization and balance in young active individuals (Melnyk, Schloz, Schmitt, & Gollhofer, 2009). Participants exercised at a rate of 3 days per week, for 3-min per session at a vibration frequency of 30 Hz. It is likely that the younger adults possessed an adequate functional balancing ability, which resulted in the lack of improvement. Van Nes et al. (2006) examined the effects of WBVT 5 days per week for 6 weeks on balance and motor control during recovery from a stroke. No significant differences were observed between a WBVT and the exercise therapy groups in any of the tests of balance and motor control. These data do not necessarily translate into a lack of efficacy for WBVT as a balance training tool, but suggest that WBV exercise may be only as effective as traditional therapeutic strategies.

It is well known that flexibility is maximized following an adequate warm-up period. Several studies have considered WBV as a warm-up exercise in order to enhance flexibility and performance (Bunker, Rhea, Simons, & Marin, 2010; Cochrane & Stannard, 2007; Dabbs et al., 2010; Gerodimos et al., 2010; Jacobs & Burns, 2009). Jacobs and Burns (2009) compared a WBV warm-up with a standard cycling warm-up, both consisting of a 6-min period. It was determined that the WBV stimulus during warm-up resulted in an increase in the sit-and-reach flexibility score by 16.2%, as compared to a much smaller increase of 2.6% in the cycling group. Cochrane and Stannard (2007), using female hockey players, reported similar outcomes of WBV exercise with a smaller magnitude of change. An acute WBV stimulus was compared with cycling in order to determine the impact on flexibility. Results indicated that WBV exposure elicited an 8.2% increase in sit-and-reach scores compared to a 5.3% increase after cycling.

Female athletes had a significant improvement above controls in the sit and reach maneuver following an 8-week WBV exercise program of standing on a vibration platform 3 times per week (Fagnani et al., 2006). A vibration protocol of 35 Hz with a displacement of 4 mm was used. Similarly, a 4-week training period including WBV in combination with “contract-release” stretching exhibited a significant increase in hamstring flexibility when compared with control participants who only performed contract-release stretching (Van den Tilaar, 2006).

WBV during warm-up in male, recreational golfers resulted in significant improvements in the sit and reach scores and ball speed and carry distance (Bunker et al., 2010). Participants performed WBV stimulus with eight exercises performed for 30 s at 50 Hz. The improvements in ball speed and carry distance also indicated that a WBV warm-up did have an effect on power development in golfers; however, a study measuring power in female softball players, defined by bat speed, was not in agreement with these results (Dabbs et al., 2010). The warm-up protocol for the softball players consisted of either 30 s of WBV exposure at 25 Hz at a high amplitude of 13 mm while standing in a hitting position or standing on the WBV platform while performing bat swings. No significant changes were observed after either WBV condition.

Gerodimos et al. (2010) attempted to determine an optimal protocol using WBV to enhance flexibility. Although the results were unremarkable, they concluded that WBV application of varied frequency and amplitude resulted in increased flexibility for a post-WBV period of 15 min. A maximum amplitude of 8 mm at a frequency of 30 Hz was applied. Most WBV research studies reviewed thus far have used frequency levels of greater than 30 Hz suggesting that frequencies of 30 Hz or less may not be as effective.

Effects of WBV on Bone Mineral Density

Loss of bone mineral density (BMD) is an age-related change most commonly observed in post-menopausal females. Loss of bone mineral density may lead to increased injury, fractures, and diminished quality of life. It is well documented that weight-bearing exercise, such as resistance training may increase bone mineral density or attenuate bone loss (Bonaiuti et al., 2002; Gusi, Raimundo, & Leal, 2006; Heinonen et al., 1999; Taafe, Robinson, Snow, & Marcus, 1997; Totosy et al., 2010; Verschueren et al., 2004; Wallace & Cumming, 2000). Many of these more traditional exercise modes, however, may provide additional stress on joints, especially for obese or older individuals. Due to the accelerative nature and increased load WBV can place on an individual with minimal dynamic movement, WBV exercise may be beneficial for older populations and bone strength. Vibration exercise may offer a safer, more comfortable alternative for improving bone strength.

Research is inconclusive on the effectiveness of using WBV exercise to improve bone health. Data from several investigations using young adults (15 to 20 years of age) and children (9 to 13 years of age) indicate that WBV exercise may have beneficial effects on bone mineral density at lumbar, femoral, and tibial sites (Gilsanz et al., 2006; Ward et al., 2004). Furthermore, increases in trabecular (6.2%) and cortical bone (2.1%) were observed after 8 weeks of WBVT (Pitukcheewanont & Safani, 2006).

Two investigations involving young healthy adults (18 to 35 years of age) have conflicting outcomes on bone mineral density (Humphries et al., 2009; Torvinen et al., 2003). Torvinen et al. (2003) revealed that an 8-month WBVT program did not elicit any change in bone mineral density or bone formation markers after performing 3 to 5 vibration sessions per week at 25 to 45 Hz. Humphries et al. (2009) found that younger women may benefit from WBV training. Femoral bone mineral density increased 2 to 3% as a result of 16 weeks of performing 3 to 5 min of vibration exercise at 50 Hz twice a week.

Young, healthy individuals may not benefit from WBV to the extent that individuals with compromised bone health would. Post-menopausal women participated in either an 8-month vibration training program or a walking program (Gusi et al., 2006). Vibration training resulted in greater bone mineral density of the femoral neck by 4.3% than the walking group. A practical benefit of the study was that each walking session was 55 min while each vibration exercise session was only 12 min. Verschueren et al. (2004) found that a 24-week WBVT program significantly increased hip bone mineral density, while a traditional resistance training program induced no significant change. Corrie et al. (2007) provided additional evidence that WBVT increased bone formation markers after 12 weeks of a progressive WBVT protocol (Corrie et al., 2007).

Von Stengel, Kemmler, Engelke, and Kalendar (2010b) recently compared WBVT with traditional resistance training. They found that bone mineral density of the lumbar spine was increased in both training modalities after 18 months but no significant differences were observed between groups. The participants who were exposed to the vibration exercise experienced a reduction in falls. Other studies interested in the effects of WBV exercise on bone mineral density in post-menopausal women did not find any significant benefit resulting from 6 or 12 months of WBVT (Iwamoto, Takeda, Sato, & Uzawa, 2005; Rubin et al., 2004; Russo et al., 2003). Vibration frequency in these studies ranged from 20 to 30 Hz, which may have been inadequate as a stimulus for imparting changes in bone morphology.

Two review papers analyzing WBVT suggest that this modality has a potentially positive impact bone mineral density and bone morphology (Mikhael, Orr, & Singh, 2010; Slatkovska, Alibhai, Beyene, & Cheung, 2010). Johnell and Eisman (2004) suggest that vibration exercise may have a synergistic effect when used simultaneously with pharmacological therapy (Johnell & Eisman, 2004).

Effects of WBV on Cardiovascular Fitness

Many modes of cardiovascular exercise can be performed in order to evoke improvements in aerobic fitness, body composition, and overall health. The American College of Sports Medicine recommends participating in cardiovascular exercise 3 to 5 days per week for 45 to 60 min in a continuous large muscle group activity (Whaley & Brubaker, 2006). A question remains if WBV exercise alone or in combination with other exercise modalities can improve muscle performance and cardiovascular fitness. In an older population, WBVT and traditional fitness training performed 3 times per week for 1-year both lead to significant improvements in VO_2peak (Bogaerts et al., 2009). The time to peak exhaustion was more pronounced in the traditional fitness training group. Raimundo et al. (2009) compared WBVT to a traditional walking program in post-menopausal women. The post-menopausal women participated in a program three times per week for a period of 8 months. The WBVT group exercised for a total time of 12 min, including rest periods of a 1:1 work:rest ratio, while the walking group exercised for 60 min at an intensity of 70 to 75% of maximal heart rate. Both groups improved their walk test times with the walking group demonstrating greater significant improvement. The WBVT group exhibited a marked increase in power (vertical jump) than the walking group. This finding was consistent with the majority of findings related to WBVT as an effective tool for improving muscle performance.

Acute cardiovascular effects of WBV exercise have also not been studied. A few investigations have examined the effects of WBV on heart rate responses and local blood flow (Hazell et al., 2008; Kerschan-Shindl et al., 2001; Lohman, Petrofsky, Maloney-Hinds, Betts-Schwab, & Thorpe, 2007; Lythgo et al., 2009). Rittweiger et al. (2000) reported that loaded dynamic WBV increased heart rate while unloaded static exercise has been reported to have no influence on heart rate (Hazell et al., 2008; Kerschan-Shindl et al., 2001). Skin blood flow was shown to increase during dynamic movement (Kerschan-Shindl et al., 2001) and passive WBV exposure (Lohman et al., 2007), but not during static exercise (Hazell et al, 2008; Lohman et al., 2007).

Metabolic Effects of WBV, Energy Expenditure, and EPOC

Studies on the effectiveness of WBV to improve body composition and for weight management are lacking in the literature. There is also limited research examining the relationship between vibration exercise and oxygen consumption and/or energy expenditure (DaSilva et al., 2007; Garatachea et al., 2007; Rittweiger et al., 2000 & 2003; Roelants et al., 2004a). To date only one study has specifically examined the effects of a vibration exercise training program on changes in body composition (Roelants et al., 2004a). Combining vibration exercise and calorie restriction on visceral adiposity has also been undertaken (Vissers et al., 2010). Combining WBV exercise with traditional resistive training protocols have also examined the effects of the combined modes of exercise on body composition (Fjeldstad et al., 2009; von Stengel, Kemmler, Engelke, & Kalendar, 2010a).

Rittweiger et al. (2000) explored the acute metabolic effects of exhaustive WBV exercise with added external loads on oxygen uptake. Metabolic responses were found to be similar to low-intensity aerobic exercise with oxygen uptake being less than 50% of the maximal oxygen uptake. Blood flow during vibration exercise has also been shown to increase in a similar fashion as during aerobic exercise (Kerschan-Shindl et al., 2001). Doppler ultrasound imaging revealed a significant increase in mean blood flow, which the authors attributed to the vibration stimulus.

Rittweiger and associates (2001) compared squatting during vibration exercise with squatting alone and observed increases in oxygen uptake during squatting with vibration. The researchers proposed that the observed increase in oxygen consumption was due to the continuous concentric-eccentric contraction pattern that occurs when the muscles were subjected to vibration. DaSilva et al. (2007) found that RER and oxygen consumptions was greater when half-squats were performed on a vibrating platform. Total energy expenditure, which included the recovery period, was also higher for the vibration condition.

Although performing exercise tasks during a vibratory stimulus may in metabolic rate, there is little data to suggest that vibration exercise in conjunct with other exercise tasks enhances weight loss or fat mass. The only study to date which specifically examined WBV exercise and body composition indicated no significant training effects on body mass at 24-weeks of training (Roelants et al., 2004b). In overweight and obese participants, Vissers et al. (2010) found that a WBV exercise combined with a calorie-restricted diet for 6 months helped to reduce body mass by 5% which was similar to participants who aerobic trained. Interestingly, the participants who participated in WBVT showed the greatest decrease in visceral adipose tissue when compared to the AT group or controls. This suggests that WBVT may be as effective as aerobic training for weight management purposes, but that it could potentially be more effective at reducing visceral adiposity.

When combined with traditional resistance training, it appears that WBV provides no additional benefit in provoking body composition changes in post-menopausal women after either 8 or 18 months (Fjeldstad et al., 2009; Von Stengel et al., 2010a). Although participants assigned to exercise groups including WBV did display significant, favorable changes in body composition, the studies were not well controlled.

Negative Side Effects of WBV

Excessive vibration exposure may be potentially harmful. Certain occupations may subject individuals to dangerous levels of vibration. Occupations like off-road vehicle operators, tractor drivers, and helicopter pilots are exposed to chronic vibration in their professions. Possible negative effects of vibration include intervertebral disc displacement due to spinal column vibration, osteoarthritis, (Griffin, 1996; Lings & Leboeuf, 2000; Seidel, 1993) hearing loss, visual impairment, and vestibular damage (Bochnia, Morgenroth, Dziewszek, & Kassner, 2005; Griffin, 1996; Ishitake, Ando, Miyazaki, & Matoba, 1998). Severe consequences of vibration exposure are infrequent and usually only occur if exposure is of a high magnitude and long duration. Vibration exposure can be quantified using the estimated vibration dose value (eVDV) and is considered to be harmful if the value exceeds a level of 17 (International Organization for Standardization, 1997). The eVDV can be calculated using frequency, direction, magnitude and duration of vibration. This index is generally applied to occupational exposure to vibration and has not been applied to WBVT training. There does not appear to have been any reported incidences of severe vibration side effects as a result of vibration exercise. Mild symptoms such as minor skin irritation, headache, and itching ears seem to be the most commonly described effects, but are infrequent. The majority of individuals that have participated in vibration exercise have not experienced any negative side effects suggesting that vibration exercise can be considered low-risk. Severe cardiovascular disease, presence of tumors, and epilepsy should be preexisting conditions that would limit or negate the use of vibration exercise as a modality. Due to the novelty of WBV as a training method, little is known about the long-term use and potential effects. Certain populations, such as geriatric individuals, may be at increased risk for negative reactions because of the potential of a greater mismatch between the WBV intensity needed to bring about positive changes and the ability of this population to tolerate the intensity. On the other hand, the limited dynamic movement used with WBV exercise may be more appealing to individuals with mobility issues (Brooke-Wavell & Mansfield, 2009). Soiza (2009) recommends a vibration intensity of 3 mm displacement with a frequency of 30 Hz for older individuals. However, more research is needed in order to determine the protocol guidelines that provide sufficient benefit with minimal risk for all populations.

In summary, WBV exercise has the potential to positively impact a variety of physical performance parameters. Although there is conflicting evidence, the current literature convincingly supports the use of WBVT as an acute and chronic aid for increasing strength, power, and flexibility. At this time, the existing research does not show promising effects for the use of WBVT as a means for improving body composition. However, the number of studies performed investigating the effects of WBVT on body composition is limited. Furthermore, there is an inconsistency in WBVT protocol design, which must be addressed before any consistent findings for body composition can be obtained.

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APPENDIX A

Participant Eligibility Questionnaire

Participant Information

Research Study: The Efficacy of Whole Body Vibration as a Modality for Inducing Changes in Body Composition

Name:____________________________________ DOB:_____________

Address:____

Phone (h/w/c): ____________ Phone (h/w/c): ________________

Email:____

Please circle YES or NO in response to the following:

1. Are you a female between 50 and 69 years old? YES NO

2. Do you consider yourself overweight? YES NO

3. Did your last menstrual period occur more than 12 months ago? YES NO

1. Do you engage in physical activity more than 2 hours per week? YES NO
   If so, please indicate how often and type of Activity:____________________________________

   ____

2. Are you currently taking Hormone Replacement Therapy (HRT)? YES NO

6. Are you currently taking any medications? YES NO
   If so, please list:

   ____

7. Have you experienced any of the following? Check all that apply:

___ Acute thrombosis ___ Serious cardiovascular disease

___ Retinal Conditions ___ Recent metal plates/pins

___ Pacemakers/ICDs	___ Sensitive plantar surface
___ Joint implants	___ Severe diabetes
___ Acute hernia	___ Neuropathy
___ Epilepsy	___ Discopathy, spondylosis
___ Severe migraines	___ Recent infections
___ Tumors	___ Kidney, Bladder, Gall stones
___ Pulmonary embolism	___ Neoplastic spine disease
___ Recent surgery	___ Poor somatosensory receptor

Briefly explain any of the checked items:

____

____

____

8. Please list any other relevant illness, injury, or medical condition:

____

____

____

9. Are you able to make 3 exercise sessions per week for a period of 8 weeks? YES NO

10. Please list your availability below:

____

____

____

APPENDIX B

Medical Screening Form

Medical Screening Form

Name:____________________________________ DOB:____________

STUDY: *The efficacy of whole-body vibration training as a modality for inducing changes in body composition.*

Have you ever had any of the following? (Check all that apply):

- [ ] High blood pressure
- [ ] High cholesterol
- [ ] Heart disease
- [ ] Fatigue
- [ ] Heart murmur
- [ ] Epilepsy
- [ ] Asthma
- [ ] Heart surgery
- [ ] Dizziness/ Fainting
- [ ] Bleeding disorders
- [ ] Ulcers
- [ ] Respiratory disease
- [ ] Back injury
- [ ] Irregular heartbeat
- [ ] Kidney disease
- [ ] Rheumatic fever
- [ ] Arterial disease
- [ ] Liver disease
- [ ] Severe cough/wheezing
- [ ] Diabetes
- [ ] Shortness of breath
- [ ] Other ______________

Do you currently have any of the following? (Check all that apply):

- [ ] Acute thrombosis
- [ ] Severe diabetes
- [ ] Pacemaker or ICD
- [ ] Joint implants
- [ ] Recent infections
- [ ] Epilepsy
- [ ] Recently placed metal pins/plates
- [ ] Tumors
- [ ] Gallstones, kidney or bladder stones
- [ ] Sensitivity on the plantar surfaces of feet
- [ ] Serious cardiovascular disease
- [ ] Recent surgery
- [ ] Hernia, discopathy, spondylolysis
- [ ] Retinal conditions
- [ ] Severe migraines
- [ ] Pulmonary embolism
- [ ] Poor somatosensory receptors
- [ ] Neoplastic disease of the spine

Please list any other current medical problems:

____

____

Please list all medications you are currently taking:

____

____

Do you currently exercise?   [   ] Yes   [   ] No

If yes, how many hours per week? ________

Type of exercise:____

Do you smoke?   [   ] Yes   [   ] No

Caution: If accepted as a participant in this study, you may be asked to perform regular exercise sessions on a vibrating platform.

Do you foresee any reason why this may be a problem for you?   [   ] Yes   [   ] No

I certify that I have answered all questions accurately and honestly. I agree to notify the research staff of any changes in my health status during the course of the study.

Emergency Contact:____

Relationship:________________________ Phone:_______________

Signature of Participant: _________________________________

Printed Name: __________________________ Date:_____________

APPENDIX C

Informed Consent

Informed Consent

Research Study: The Efficacy of Whole Body Vibration as a Modality for Inducing changes in Body Composition

Investigators: Joseph Signorile, Ph.D. & Lauren Tapp, M.S.

Purpose

The purpose of this research study is to see if whole-body vibration training can help individuals lose body fat. We will compare three different types of exercise and how they affect body weight and body fat.

Description of Study

Upon acceptance into the research study, and within one week of the start of the exercise program, you will be expected to arrive at the lab for Day 1 screening and testing. These tests will include height and weight measurements, resting heart rate and resting blood pressure, as well as a health-screening questionnaire. You will be given instructions to follow throughout the study, At this time, you will also be scheduled for a DEXA scan appointment. After receiving instructions and given the chance to ask questions, you will take part in a treadmill exercise test that will tell us your level of aerobic fitness. During the treadmill test, you will be asked to wear a mask that will measure how much oxygen you are using. The exercise will get more challenging every few minutes until either we get the information we need, or you request to stop the test. Following the treadmill test, you will then perform a strength test using standard exercise machines. During this test, you will complete a few warm-up sets, and then you will lift as much weight as you can one time.

After your first visit, you will be randomly assigned to one of three exercise groups: treadmill walking, circuit training, or whole-body vibration. You will then be asked to come in to the UM Wellness Center 3 times per week for the next 8 weeks for the exercise sessions. Each exercise session will last approximately 30-60 minutes. All exercise sessions will include proper warm-up and cool-down periods, and will be supervised by trained and experienced staff members.

Benefits

You will be participating in this exercise study for a period of 8 weeks, in which you will be exercising on a regular basis. It is possible that you will lose body fat, and likely that you will improve your overall health status just by increasing your level of activity.

Risks and Discomforts

As with any exercise test, certain risks and discomforts may apply. The risks involved in exercise testing and during any of the exercise sessions may include abnormal blood pressure, fainting, disorder of heartbeat, and in the most extreme instances, heart attack, stroke, or death. Every effort will be made to minimize these risks by continuously monitoring you throughout exercise testing. It is your responsibility to inform us if you feel dizzy, light-headed or if you experience any other concerning symptoms during or after the treadmill test.

In addition, you may experience muscle aches or soreness due to the increased exercise activity. If assigned to the vibration training group, you may feel a tingling sensation or itching of the skin and/or ears during the vibration exercise. These are generally mild symptoms.

Following American College of Sports Medicine guidelines for exercise testing, the exercise tests and subsequent exercise sessions will be stopped if any of the following conditions happen: onset of chest pain; drop in systolic blood pressure with increasing exercise intensity; signs of poor circulation, including pallor (changes in skin color), cyanosis (blue skin), or cold and clammy skin; severe shortness of breath; vertigo or confusion; leg cramps; or intermittent claudicating (blood clotting that can cause intense leg pain), increased blood pressure (systolic blood pressure [SBP] > 260 mmHg; diastolic blood pressure [DBP] > 115 mmHg). First aid and an automated external defibrillator (AED), along with CPR and AED certified personnel, will be on hand to treat any problems that may arise.

Confidentiality

All information gathered from the study will remain confidential and kept in a locked drawer. Your individual information will not be disclosed outside of the testing personnel without your written permission. The results of this study may be published for scientific purposes, but your identity will not be revealed.

Withdrawal Without Prejudice

Participation in this study is purely voluntary. If you refuse to participate, you will receive no penalty. You are free to withdraw consent and discontinue participation in this project at any time without prejudice from this institution.

Costs and/or Payments to Subject for Participation in Research

Your participation in this study is strictly voluntary and you will not be paid to participate in this research project.

Informed Consent

Research Study: The Efficacy of Whole Body Vibration as a Modality for Inducing changes in Body Composition

Investigators: Joseph Signorile, Ph.D. & Lauren Tapp, M.S.

Agreement

This agreement states that you have received a copy of this informed consent. Your signature below indicates that you agree to participate in this study.

_________________________________ ________________
Signature of Participant Date

____
Subject name (printed)

_________________________________ ________________
Signature of Researcher Date

APPENDIX D

Workout Cards

WBV TRAINING LOG

SUBJECT:____ LBM:_____________________________

Session	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Date												
Completed												
Frequency	30	30	30	35	35	35	35	35	35	35	35	35
Sets/Reps	4/10	4/10	4/10	6/10	4/15	3/20	7/10	5/15	4/20	8/10	6/15	5/20
%Load	0	0	0	5	5	5	10	10	10	15	15	15
Load (lbs)												

Session	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**
Date												
Completed												
Frequency	40	40	40	40	40	40	40	40	40	40	40	40
Sets/Reps	9/10	7/15	6/20	10/10	8/15	7/20	11/10	9/15	8/20	12/10	10/15	9/20
%Load	20	20	20	20	25	25	25	25	30	30	30	30
Load (lbs)												

AEROBIC TRAINING LOG

SUBJECT:____ APMHR:____________________

Session	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Date												
Completed												
Time (min)	20	20	20	20	25	25	25	25	30	30	30	30
%HR	60-65	60-65	60-65	65-70	65-70	65-70	65-70	65-70	65-70	70-75	70-75	70-75
Actual HR												
Speed (mph)												
Grade (inc)												

Session	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**
Date												
Completed												
Time (min)	35	35	35	35	40	40	40	40	45	45	45	45
%HR	70-75	75-80	75-80	75-80	75-80	75-80	80-85	80-85	80-85	80-85	80-85	80-85
Actual HR												
Speed (mph)												
Grade (inc)												

CIRCUIT TRAINING LOG

SUBJECT: ________________________________

Session	1	2	3	4	5	6	7	8	9	10	11	12
Date												
Completed												
Sets/Reps	1RM	1/12	1/12	2/12	2/12	2/12	2/12	2/12	2/12	2/12	2/12	2/12
Load(%1RM)		50%	50%	50%	50%	50%	50%	50%	50%	55%	55%	55%
Rest (sec)	60	60	60	30	30	30	45	45	45	45	45	45
Exercises:												
Leg Press												
Chest Press												
Leg Extension												
Lat Pulldown												
Seated Leg Curl												
Shoulder Press												
Bicep Curl												
Tricep Extension												
Abdominals												

CIRCUIT TRAINING LOG

SUBJECT: ______________________________

Session	13	14	15	16	17	18	19	20	21	22	23	24
Date												
Completed												
Sets/Reps	3/12	3/12	3/12	3/12	3/12	3/12	3/12	3/12	3/12	3/12	3/12	3/12
Load (%1RM)	55%	55%	55%	55%	55%	55%	60%	60%	60%	60%	60%	60%
Rest (sec)	60	60	60	30	30	30	45	45	45	45	45	45
Exercises:												
Leg Press												
Chest Press												
Leg Extension												
Lat Pulldown												
Seated Leg Curl												
Shoulder Press												
Bicep Curl												
Tricep Extension												
Abdominals												

APPENDIX E

Data Collection Form

Participant Data Form

Research Study: The Efficacy of WBV as a Modality for Inducing Changes in Body Composition

Subject:_________________________ DOB:__________ Age:_____

Test Date:_____________________ Time:_____________________

Height:________________ Weight:_______________ BMI:______

Resting HR:__________ Resting BP:_________ BF%(DXA):_____

VO_2peak Test: Modified Bruce Protocol

Stage	Speed	Grade	HR		BP	RPE
1	1.7					
2	1.7	5				
3	1.7	10				
4	2.5	12				
5	3.4	14				
6	4.2	16				
7	5.0	18				
8	5.5	20				
9	6.0	22				

TPE:________________________ Peak VO_2:____________________

1-RM Strength Tests:

1-RM Chest Press:_____________ 1-RM Leg Press:___________

Settings:_____________________ Settings:_________________

APPENDIX F

Statistical Tables

Table F-1. Physical Characteristics of Subjects

	WBVT	AT	CT
Age, yrs	53.2 ± 2.1	55.2 ± 6.4	54.1 ± 5.3
Height, in	64.5 ± 2.4	63.1 ± 2.6	63.2 ± 2.7
Weight, lbs	193.0 ±52.1	198.0 ±18.0	173.8 ±18.2
Body Mass Index	32.6 ± 7.9	35.3 ± 5.6	30.6 ± 3.2

**Values are reported as mean ± standard deviation.*

Table F-2. Mean Body Composition Scores

	Pre	Post	Δ	%Change
Body Mass (lb)				
WBVT	193.00 ± 52.11	193.75 ± 51.26	0.75	---
AT	198.00 ± 17.97	198.17 ± 18.20	0.17	---
CT	173.79 ± 18.19	176.00 ± 16.21	2.21	---
Percent of Body Fat				
WBVT	46.47 ± 5.16	47.12 ± 4.57	0.65	---
AT	52.63 ± 5.62	52.13 ± 5.88	-0.5	---
CT	44.61 ± 5.49	44.37 ± 5.66	-0.24	---

Table F-2. Mean Body Composition Scores, continued

	Pre	Post	Δ	%Change
Lean Body Mass (lb)				
WBVT	101.6 ±20.26	100.77 ±19.07	-0.79	0.78
AT	93.2 ± 7.91	94.27 ± 8.38	1.07	1.15
CT	95.9 ±10.9	97.61 ±10.83	1.71	1.78

**Pre and Post Values are reported as mean ± standard deviation.*

Table F-3. Mean Aerobic Performance Scores

	Pre	Post	Δ	%Change
Peak Oxygen Uptake (ml/kg/min)				
WBVT	19.15 ±3.88	18.50 ±2.38	-0.65	3.39
AT	16.27 ±3.12	19.38 ±3.39	3.11	19.11
CT	16.41 ±6.10	19.24 ±5.99	2.83	17.25
Time to Peak Exhaustion (min)				
WBVT	12.32 ±2.62	12.71 ±2.20	0.39	3.17
AT	9.36 ±1.45	11.39 ±1.81	2.03	21.69
CT	11.94 ±2.49	13.21 ±2.25	1.27	10.64

**Pre and Post Values are reported as mean ± standard deviation.*

Table F-4. One-way ANOVA Subject Characteristics

Variable	df	SS	MS	F	P
Age (yrs)					
Between Groups	2	12.123	6.061	0.194	0.825
Within Groups	16	499.667	31.229		
Total	18	511.789			
Height (in)					
Between Groups	2	7.351	3.676	0.464	0.637
Within Groups	16	126.776	7.923		
Total	18	134.127			
Weight (lbs)					
Between Groups	2	2159.571	1079.786	1.006	0.388
Within Groups	16	17179.929	1073.746		
Total	18	19339.500			
Body Mass Index					
Between Groups	2	70.628	35.314	1.059	0.370
Within Groups	16	533.612	33.351		
Total	18	604.240			

Table F-5. 3 x 2 Repeated Measures ANOVA Summary

Variable	df	SS	MS	F	P
Percent Body Fat					
Between Groups	2	417.101	208.55	3.572	0.052
Between Times	1	0.009	0.009	0.021	0.886
Group*Time	2	2.207	1.104	2.572	0.108
Error	16	6.866	0.429		
Lean Body Mass					
Between Groups	2	336.624	168.312	0.454	0.643
Between Times	1	4.258	4.258	2.196	0.158
Group*Time	2	10.705	5.352	2.761	0.093
Error	16	31.020	1.939		
VO_2peak					
Between Groups	2	8.179	4.090	0.136	0.874
Between Times	1	29.442	29.442	2.828	0.112
Group*Time	2	26.907	13.453	1.292	0.302
Error	16	166.589	10.412		
Time to Peak Exhaustion					
Between Groups	2	38.879	19.439	2.605	0.105
Between Times	1	14.163	14.163	7.098	0.017*
Group*Time	2	4.083	2.042	1.023	0.382
Error	16	31.924	1.995		
1-RM UB					
Between Groups	2	4373.857	2186.928	5.018	0.020*
Between Times	1	0.134	0.134	0.005	0.946
Group*Time	2	388.330	194.165	6.927	0.007*
Error	16	448.512	28.032		
1-RM LB					
Between Groups	2	51669.862	25834.931	3.166	0.069
Between Times	1	11005.952	11005.952	23.498	0.000*
Group*Time	2	395.426	197.713	0.422	0.663
Error	16	7494.048	468.378		

**Indicates statistical significance (P<0.05)*
***Computed using mean differences*

Table F-6. One-way ANOVA Summary

Variable	df	SS	MS	F	P
Percent Body Fat					
Between Groups	2	4.414	2.207	2.572	0.108
Within Groups	16	13.732	0.858		
Total	18	18.146			
Lean Body Mass					
Between Groups	2	21.409	10.705	2.761	0.093
Within Groups	16	62.040	3.877		
Total	18	83.449			
VO_2peak					
Between Groups	2	53.814	26.907	1.292	0.302
Within Groups	16	333.178	20.824		
Total	18	386.992			
Time to Peak Exhaustion					
Between Groups	2	8.167	4.083	1.023	0.382
Within Groups	16	63.848	3.990		
Total	18	72.015			
1-RM UB					
Between Groups	2	776.660	388.330	6.927	0.007*
Within Groups	16	897.024	56.064		
Total	18	1673.684			
1-RM LB					
Between Groups	2	790.852	395.330	0.422	0.663
Within Groups	16	14988.095	936.756		
Total	18	15778.947			

**Indicates statistical significance (P<0.05)*
***Computed using change scores.*

APPENDIX G

Raw Data

Table G-1. Physical Characteristics of Subjects

Group	Subject	Age (yrs)	Height (in)	Weight (lbs)	BMI
WBVT					
	1	51	62	232	42.4
	2	56	63.5	140	24.6
	3	55	68.5	275	41.2
	4	54	66	150	24.2
	5	52	64	194	33.3
	6	51	63	167	29.6
AT					
	7	52	67	180	28.2
	8	52	61	204	38.5
	9	58	62	206	37.7
	10	52	63.5	173	30.2
	11	50	60	221	43.2
	12	67	63.5	204	33.9
CT					
	13	61	62.5	160.5	28.7
	14	51	67	196	30.7
	15	46	58.5	167	34.3
	16	62	62	161	29.4
	17	49	68	180	27.4
	18	60	62	199	35.8
	19	49	62	153	28.0

Table G-2. Body Composition and Lean Body Mass Scores

Group	Subject	Body Mass (lb) Pre	Post	Percent Body Fat Pre	Post	Lean Mass(lb) Pre	Post
WBVT							
	1	232	228	53.3	53.1	108.35	106.93
	2	140	142.5	39.4	41.1	84.84	83.93
	3	275	277	51.0	52.0	134.75	132.96
	4	150	152	44.9	45.3	82.65	83.15
	5	194	195	42.9	45.0	110.77	107.25
	6	167	168	47.3	46.2	88.01	90.38
AT							
	7	180	178	46.4	45.6	96.48	96.83
	8	204	207	58.6	58.4	84.46	86.11
	9	206	208	52.5	51.0	97.85	101.92
	10	173	174	49.6	49.9	87.19	87.17
	11	221	220	60.2	60.2	87.96	87.56
	12	204	202	48.5	47.7	105.06	105.65
CT							
	13	160.5	165	44.6	43.4	88.92	93.39
	14	196	193	39.9	38.6	117.79	118.50
	15	167	170	50.4	50.9	82.83	83.47
	16	161	170	40.7	40.9	95.47	100.47
	17	180	182	48.8	49.5	92.16	91.91
	18	199	199	50.7	49.8	98.11	99.90
	19	153	153	37.2	37.5	96.08	95.63

Table G-3. 1-RM Strength Scores (lbs)

Group	Subject	Chest Press Pre	Chest Press Post	Leg Press Pre	Leg Press Post
WBVT					
	1	90	70	400	410
	2	80	60	150	190
	3	70	70	210	310
	4	35	35	165	205
	5	85	80	250	270
	6	75	70	150	210
AT					
	7	60	60	135	135
	8	25	35	90	100
	9	60	60	220	300
	10	40	35	120	140
	11	45	50	130	165
	12	50	45	130	155
CT					
	13	60	75	170	190
	14	70	75	170	210
	15	80	85	155	240
	16	65	80	110	140
	17	40	50	170	210
	18	70	65	210	210
	19	90	95	250	250

Table G-4. Aerobic Test Scores

		VO_2peak (mL/kg/min)		Time to Peak Exhaustion (min)	
Group	Subject	Pre	Post	Pre	Post
WBVT					
	1	18.3	18.9	12.75	10.25
	2	15.8	19.6	9.92	12.00
	3	18.7	16.3	11.05	12.00
	4	26.8	15.3	15.25	16.17
	5	17.4	21.9	15.50	14.50
	6	17.9	19.0	9.50	11.33
AT					
	7	17.0	23.9	11.25	9.75
	8	13.2	18.1	7.58	10.00
	9	14.5	14.6	9.05	14.67
	10	20.4	17.8	10.08	11.33
	11	13.2	19.3	10.33	12.00
	12	19.3	20.1	7.87	10.58
CT					
	13	21.3	21.6	14.00	13.50
	14	20.4	25.4	12.00	14.75
	15	9.7	10.0	10.08	13.03
	16	23.7	21.6	13.03	14.13
	17	11.5	12.7	10.50	9.00
	18	9.1	18.1	8.50	12.00
	19	19.2	25.3	15.50	16.05